Head and Neck Surgery : Surgical Landmark and Dissection Guide

Norhafiza Mat Lazim
Zul Izhar Mohd Ismail
Baharudin Abdullah
Editors

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ISBN 978-981-19-3853-5 ISBN 978-981-19-3854-2 (eBook)
https://doi.org/10.1007/978-981-19-3854-2

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd. The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

I would like to dedicate this book, "Head and Neck Surgery: Surgical Landmarks and Dissection Guide," to my beloved family members; my loving husband, Associate Professor Dr. Zul Izhar Mohd Ismail; and my three beautiful children, Arieff Iskandar, Adry Zahrin, and Alyssa Yasmin, who have been my great motivation and aspiration throughout the journey of completing this valuable book.

The dedication also goes to my mother, Zainun Mat Jusoh, and my father, Mat Lazim Mat Yaakub, who had given their strong support, love, understanding, and perseverance throughout my career years. I am so much grateful and blessed to have my other siblings who have been around and supportive throughout the years.

In addition, the dedication also goes to my close colleagues at work especially my great mentor, Professor Dr. Baharudin Abdullah and young trainees in head and neck surgery, who have been my impetus in ensuring the completion of this book that can finally be published.

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Foreword

The head and neck is one of the most complex anatomical regions of the body and is of great interest to all surgeons regardless of their specialty. Being an area of the body intimately involved in communication, eating, breathing, feeling, and appearance, a lack of knowledge of the relevant surgical anatomy could lead to inadvertent harm during surgeries and be disastrous for both the patient and surgeon. Hence, a clear understanding of this multifaceted maze of vital structures is essential to perform safe and smooth surgery.

The editors are to be commended for taking on a mammoth task of compiling a reliable resource of surgical landmarks and techniques that can be used by surgeons, especially otolaryngologists and maxillofacial and plastic surgeons. All contributions have been compiled by leading surgeons and physicians that have shared their expertise and experience to provide a valuable reference for the community. The illustrative diagrams and relevant clinical images make this a ready reference of topics regularly encountered in the practice of head and neck surgeons. A thoughtfully balanced inclusion of different management philosophies, along with their latest updates, makes this book a much-needed addition to the literature.

In summary, this book brilliantly covers the clinical and surgical approaches to the pathology of the head and neck, including the oral, oropharyngeal, laryngeal, and hypopharyngeal lesion; thyroid and parathyroid; skull base tumors; and cervical lymphadenopathy. Each chapter presents an evidence-based, practical, and user-friendly approach to investigate and manage these patients. I expect this clear, concise, and comprehensive compilation to be very useful to trainees and practicing surgeons dealing with head and neck pathology.

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Foreword

With this textbook, Head and Neck Surgery: Surgical Landmarks and Dissection Guide, in front of you, Associate Professor Norhafiza Mat Lazim and team have made an excellent contribution to the need to acquire the necessary skills to perform surgery in this complex area.

With her exceptional motivation, Associate Professor Norhafiza Mat Lazim has visited many clinics abroad and has been a clinical fellow among others at the Department of Head and Neck Surgery of the Free University Hospital and at the Netherlands Cancer Institute in Amsterdam, where I met her for the first time. Dr. Norhafiza Mat Lazim has impressed me with her tireless motivation and eagerness to absorb all possible knowledge and to improve her surgical skills continuously, even when she had to stay abroad for 1 year without her young family.

During the last decades, head and neck surgery has grown into a dedicated specialism with clearly defined requirements for the surgeons involved. International societies like the International Federation of Head and Neck Oncologic Societies (IFHNOS) have set standards for theoretical knowledge and operative skills. An important part of the training in head and neck surgery is the fellowships abroad where young surgeons can familiarize themselves with treatment of head and neck cancer according to the international protocols and learn tips and tricks to improve the outcome after surgery. A crucial part of the treatment is the decision regarding which therapy will be optimal for a specific patient, especially in the case of major, mutilating surgery.

In order to achieve this, a multidisciplinary approach is critical, which warrants in-depth discussions within so-called tumor boards.

Since we, as doctors, all have acknowledged the Oath of Hippocrates, we always have to act in the best interest of our patients. This implies sometimes that we have to take the difficult decision not to treat, which is often even more difficult than to simply adhere to the protocols.

Treating head and neck cancer in a multidisciplinary team warrants from each member to be up to date with the current treatment protocols and aware of the most recent innovations within their respective specialties.

The head and neck surgeon should have proper knowledge of the anatomy and the most up-to-date surgical procedures and be familiar with the post-op care, rehabilitation, and management of complications. For this, dedicated literature and textbooks are indispensable.

My outspoken wish is that, thanks to the contribution of all the co-authors, this book will become a valuable tool to improve the outcome of our patients affected with head and neck cancer.

Ing Bing Tan
Head and Neck Surgery
Maastricht University Medical Center
The Netherlands Cancer Institute
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Gadjah Mada University
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Foreword

This book, edited and for a large part written by Norhafiza Mat Lazim, "Head and Neck Surgery: Surgical Landmarks and Dissection Guide," is a great addition to the surgical textbooks on head and neck surgery. Surgery in this area is performed by dedicated head and neck surgeons, otolaryngologists, maxillofacial surgeons, plastic surgeons, and general surgeons. The reason for all this attention is that it is a challenging field with complex anatomy. Because the head and neck area is a complex anatomical region, anatomical knowledge, with "tips and tricks" to perform the surgery, and knowledge on landmarks are crucial. In fact, each surgeon in this field should be able to approach regions from all different angles and have knowledge on 3D anatomy and correlation with imaging. Especially the impact of surgery on functional outcome is crucial in this field. This is not only the case for residents and junior staff, but also more experienced colleagues run into rare diseases and infrequent surgeries. Reading this book has also taught me new approaches and techniques.

The illustrations in the book are of high quality and clearly show the surgical anatomy, and the descriptions are clear and very practical.

Fiza told me that she found time to accomplish this work partly because of the Covid-related lockdowns that diminished routine work in the clinic. That might be one of the only.

In summary, this book gives a great overview on many aspects of head and neck surgery. It is practical and user friendly for surgeons to use.

I would like to congratulate Professor Norhafiza Mat Lazim, Professor Zul Izhar Mohd Ismail, and Professor Baharudin Abdullah for their tremendous work.

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Preface

This book "Head and Neck Surgery: Surgical Landmarks and Dissection Guide" is a great book, comprising each type of head and neck surgery that is commonly practiced at otorhinolaryngology—head and neck surgery departments and head and neck surgical oncology centers, globally. This book is intended for budding junior head and neck surgeons who have main passion and interest in head and neck surgery and wish to pursue their career in head and neck surgical oncology.

Head and neck surgery entails critical surgery to structures and organs that are vital for human daily functioning. Thus, this surgery deserves special attention and requires meticulous techniques and performance by a surgeon, for a safe conduct of every surgery. This ensures the best treatment outcomes for head and neck oncology patients postoperatively and preserves their quality of life. Each chapter of this book is accompanied by many intraoperative live surgery photos, and some of the figures are redrawn to emphasize on the anatomical detail of related structures that are vital to be addressed sufficiently during each type of surgery. My deepest appreciation goes to Mr. Muhamad Nor Firdaus Ab Rahman from the Department of Anatomy, who had been the main illustrator for this book, and the two esteemed co-editors, Associate Professor Dr. Zul Izhar Mohd Ismail and Professor Dr. Baharudin Abdullah, for their strong support.

My fellowship experience at Antoni van Leeuwenhoek-Netherlands Cancer Institute (NKIAVL), and Vrije University (VUMC), Amsterdam, Netherlands, as well as experience and exposure at Chris O'Brien Lifehouse, Sydney, Australia, have been my true aspiration and main focus for the production of this head and neck surgery book. Head and neck surgical oncology is my main passion and interest, and this book epitomizes the great adventure and experiences that I have gained and learnt from all my esteemed teachers, both locally and internationally.

I would like to take this opportunity to express my deepest gratitude to everyone, especially all the authors, who had contributed and given their strong commitment to ensure the completion of this book according to the timeline given. I hope this book will be a great addition to the current collection of head and neck surgery books in the world.

Kubang Kerian, Kelantan, Malaysia — Norhafiza Mat Lazim

Acknowledgment

This book, "Head and Neck Surgery: Surgical Landmarks and Dissection Guide," is a great addition to the current head and neck surgery literature collection for academia and scientific community. It is a highly useful reference book, especially for the young trainees and junior surgeons practicing in the head and neck surgery arena.

Preparation of this book has been a great experience for me myself. This has been accomplished with tremendous effort and contribution from various teams, including the editors, all esteemed authors (both local and international), and Springer Nature editorial team. My sincere appreciation goes to the two eminent editors of this book, Associate Professor Zul Izhar Mohd Ismail and Professor Baharudin Abdullah, who have reviewed the chapters and figures for the book.

I would also like to express my deepest gratitude and acknowledgment especially to the main illustrator for the chapters, Mr. Muhamad Nor Firdaus Ab Rahman, from the Anatomy Department, School of Medical Science, USM Health Campus, Kelantan, who has worked continuously and tirelessly in preparing the images and redrawn the figures used for this book. Without his strong commitment, completion of this book would not have been possible.

Last but not least, thanks go to the staffs and postgraduate students of ORLHNS, who have assisted in many ways during routine clinical activities at numerous venues, especially the head and neck surgery subspecialty clinic and the operation theatre. Thank you very much for your kind assistance.

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Contents

About the Editors

Norhafiza Mat Lazim is a Consultant at the Department of Otorhinolaryngology—Head and Neck Surgery, School of Medical Sciences, Universiti Sains Malaysia, Health Campus, Kubang Kerian, Kelantan, Malaysia. She obtained her MBBS from the University of Queensland, Australia, in 1999 and completed her Master of Medicine in Otorhinolaryngology—Head and Neck Surgery at the Universiti Sains Malaysia, USM, in 2012. Subsequently, she obtained her Clinical Fellowship in Head and Neck Surgical Oncology from Antoni van Leeuwenhoek-Netherlands Cancer Institute (NKIAVL), Amsterdam, Netherlands, in 2014 and from the VUMC, Free University Hospital, Amsterdam, in 2015. In addition, she had her clinical training at the Sydney Head and Neck Cancer Institute, Chris O'Brien Lifehouse, Australia, in 2019. Her main interest is in head and neck surgical oncology, and she has received several national and international grants on head and neck diseases and tumors. She has published multiple papers in peer-reviewed journals and several book chapters and books. Additionally, she is a reviewer for multiple international journals and also serves as an editorial board member to numerous international journals. She is a member of the American Head and Neck Society (AHNS), the European Head and Neck Society (EHNS), the Asian Society of Head and Neck Oncology (ASHNO), the American Thyroid Association (ATA), the British Association of Head and Neck Oncologists (BAHNO), the International Academy of Oral Oncology (IAOO), and the Australian Institute of Medical and Clinical Scientists (AIMS).

Zul Izhar Mohd Ismail is a Senior Lecturer in the Department of Anatomy, School of Medical Sciences, Universiti Sains Malaysia, Health Campus, Kubang Kerian, Kelantan, Malaysia. He received his MBBS degree from the University of Queensland, Brisbane, Australia, in 1999. He later obtained his Master of Philosophy (MPhil) degree in the field of Biomedical Science from the same university in 2005. He has been a lecturer of anatomy in USM since the year 2005, teaching anatomy to both undergraduate and postgraduate medical students. He had held several academic and administrative positions during the tenure of his service in USM. He is a member of the Malaysian Medical Association and lifetime member of the Malaysian Anatomical Society. He has written numerous publications in both local and international journals and presented his research findings in scientific conferences. As an anatomist, he has a particular interest in histomorphometry, neurotoxicology, radiological anatomy, clinical anatomy, and anatomy education.

Baharudin Abdullah is a Senior Consultant in the Department of Otorhinolaryngology-Head and Neck Surgery, School of Medical Sciences, Universiti Sains Malaysia, Health Campus, Kubang Kerian, Kelantan, Malaysia. He graduated with MBBS of Medicine and Surgery from Universiti Malaya (1994) and Master of Medicine (MMED) in Otorhinolaryngology—Head and Neck Surgery from Universiti Sains Malaysia (2002). He was an Honorary Visiting Scholar at Chinese University of Hong Kong, Asian Surgical Association Clinical Fellow at the University of Hong Kong, and Fellow in Rhinology and Endoscopic Sinus Surgery at the University of Graz, Austria. He is on the editorial board of reputable medical journals. He has published widely in allergy, rhinology, and head and neck surgery in several international and national journals and presented many scientific studies and papers, both at the national and international levels. He has contributed significantly to the successes of symposiums and workshops in Universiti Sains Malaysia (USM) and other symposiums, congresses, and workshops, both at national and international levels. He is the Past President of the Malaysian Society of Allergy and Immunology (MSAI).

1 Introduction to Head and Neck Surgery

Norhafiza Mat Lazim

1.1 Introduction

Head and neck surgery is crucial as it involves a complex head and neck region, which harbours multiple delicate anatomic structures. Many of the human vital functions such as breathing, speech, mastication, swallowing, hearing, and vision are carried out by the structures and organs that are located in the head and neck region (Fig. 1.1). Importantly, numerous major neurovascular structures, namely the cranial nerves, jugular vein, and carotid artery, are residing in this critical region in which any injury to these structures may lead to serious complications. For instance, cranial nerve palsy like facial nerve palsy will lead to facial asymmetry that can cause social embarrassment and is associated with drooling and incomplete closure of the eye that affect a patient's aesthetics. Jugular vein and carotid artery (Fig. 1.2) injury will lead to inevitable blood loss and risk of hypovolaemic shock. Hypoglossal nerve palsy will interfere with swallowing, speech, and so forth. All of these complications are avoidable if the practicing surgeons and the managing team have a sound anatomic knowledge of the head and neck regions, adequate clinical skills and practice, and a good teamwork during management of clinical cases.

To illustrate further, nasal cavity and paranasal sinuses (PNS) (Fig. 1.1) are critical anatomic regions in the facial and head region. They are responsible for multiple functions, for instance humidification of the inspired air, immune protection, mucociliary clearance, and facilitation of smell. An excellent knowledge of delicate vascular supply and innervation at the nasal cavity and PNS area will dictate safe surgical and endoscopic procedures necessary to treat related diseases and tumours in this region. Maxillary sinus is commonly affected by carcinoma, which sometimes necessitates maxillectomy. Different types of maxillectomy entail different segments of maxilla resection and lead to significant surgical and post-surgical sequelae. This again highlights the necessity of in-depth knowledge of anatomy of each subsite region of the head and neck region.

At the end of the other spectrum, oral cavity carcinoma such as tongue carcinoma has a different surgical management approach. The tongue has a rich lymphatic drainage to the neck nodes. This lymph node drainage area is also greatly different for a different part of the tongue. Tip of tongue drains to submental nodes, lateral tongue drains to ipsilateral jugular nodes, and base of tongue drains to both ipsilateral and contralateral deep cervical nodes. Thus, hemiglossectomy for tongue carcinoma (T1 and T2 lesion) should

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N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_1

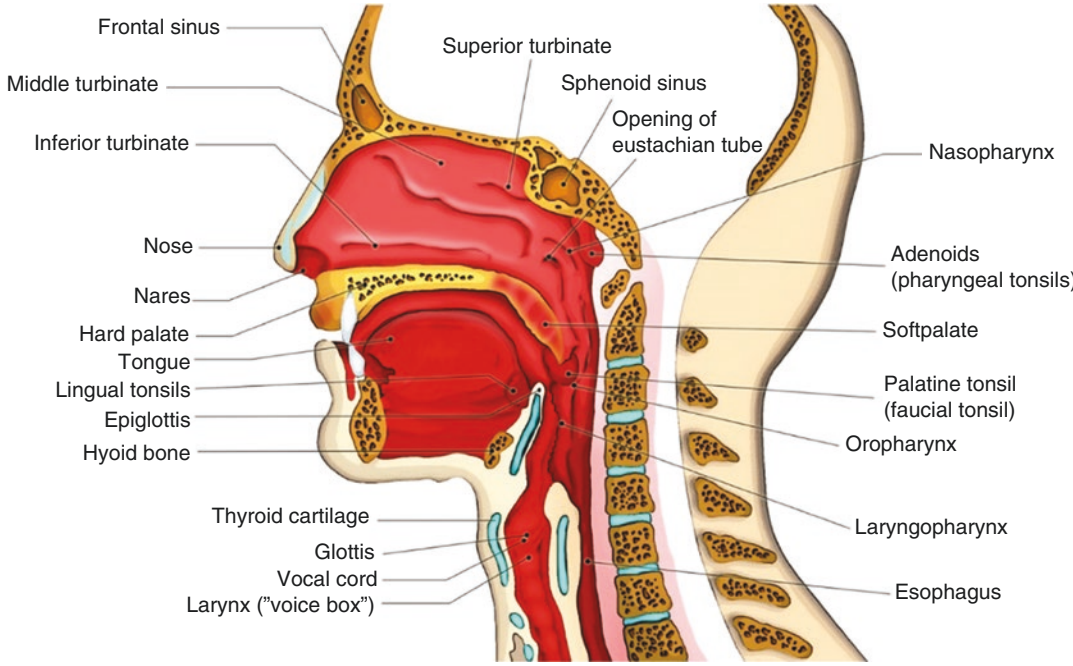

Fig. 1.1 Neck anatomy comprises vital soft-tissue structures and cartilaginous structures

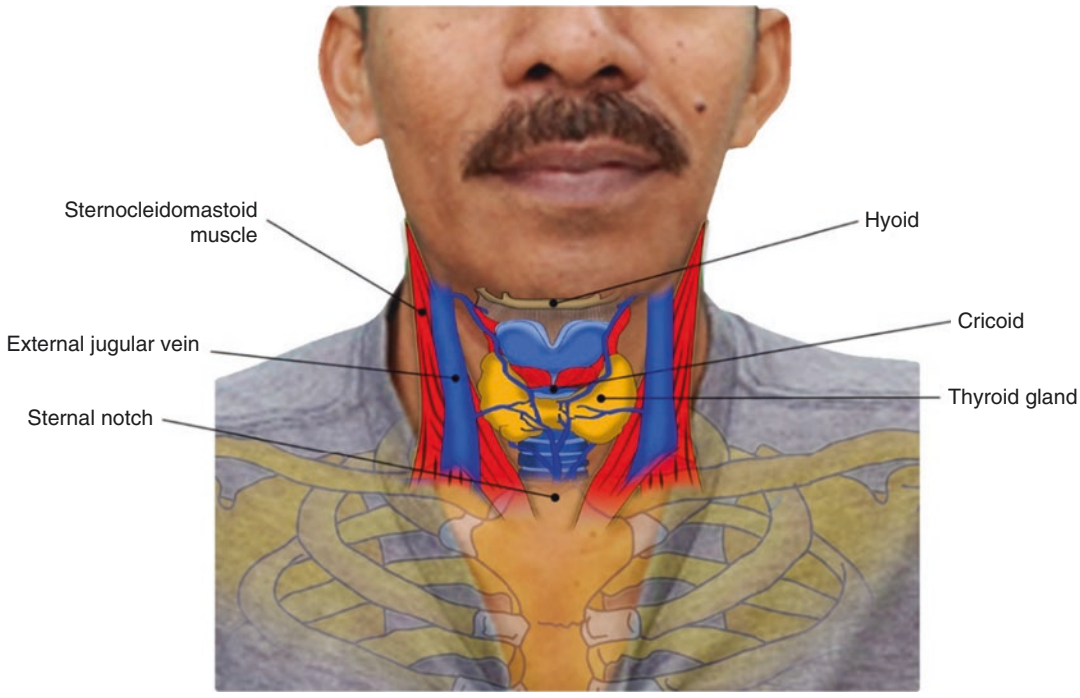

Fig. 1.2 Structures like sternocleidomastoid, jugular vein, hyoid bone, and cricoid cartilage are important landmarks at the neck

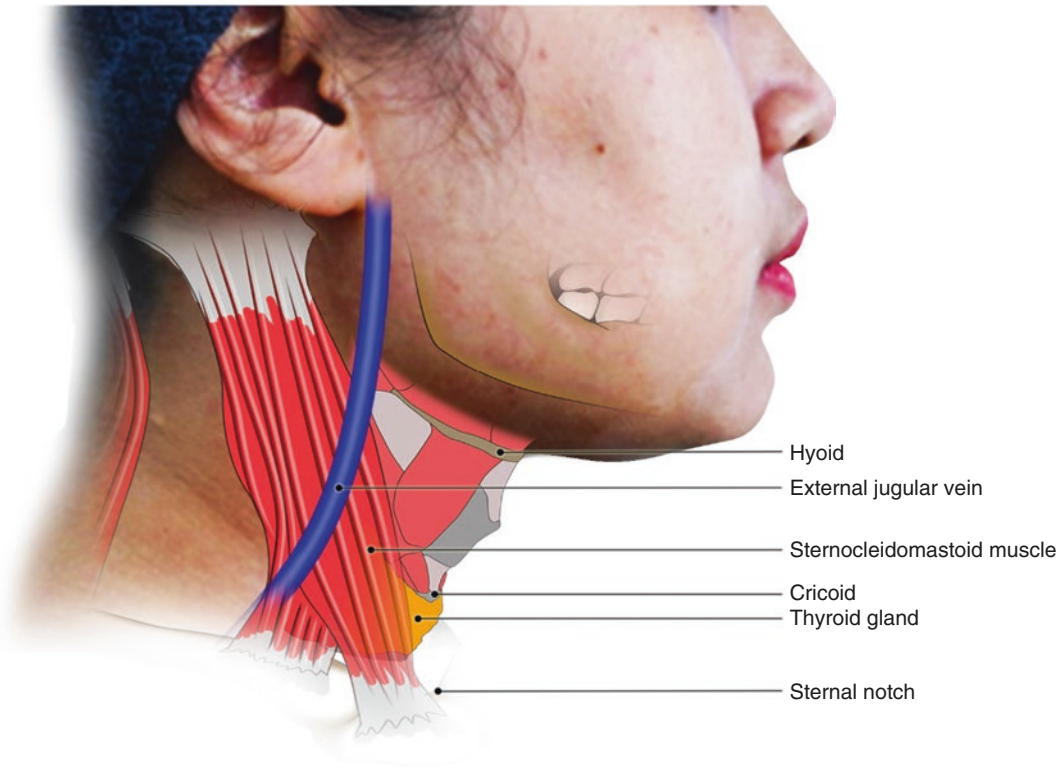

Fig. 1.3 The relationship of soft-tissue structures such as external jugular vein (EJV) to sternocleidomastoid muscle (SCM), or carotid sheath deep to SCM, is vital for deciding the surgical approach to the neck

always be accompanied by ipsilateral neck dissection of level I, II, III, and sometimes IV. If the tumour reaches the midline or the tumour originates from the tongue base, bilateral neck dissection should be performed. In neck dissection, relation of sternocleidomastoid muscle (Fig. 1.3) to vascular and adjacent structures is critical to be considered to facilitate a safe surgery.

1.2 Head and Neck Anatomy

Head and neck anatomy is a critical region as it encompasses highly vascularized areas with the involvement of multiple organs and structures required for vital human functioning. Such structures include oral cavity, nasal cavity and paranasal sinuses, pharynx, larynx and trachea, thyroid glands, salivary glands, cranial nerves, and eyes and orbits. The practicing surgeons, especially the junior trainees in the related field such as ORL, OMF, dental, and plastic reconstructive and oncologists, are required to have an optimal understanding of this critical head and neck region. This is crucial for the clinicians to accurately communicate findings and generate meaningful differential diagnoses, so that a better treatment plan can be incorporated.

The head and facial complex region is further subdivided into anterior or superior face, midfacial, and inferior facial regions. This complex structure of the midface presents a greater challenge to the clinician evaluating the outcomes of facial aesthetic. Numerous factors need to be considered when addressing the surgical approach for the head and neck region. The diversity and changes in the soft tissue of the midface region will alter the surgical techniques. The variable thickness of soft tissue and presence of multiple structures, such as the orbit, nose, and upper lip, each with variable anatomy, need to be considered when planning the surgical steps. The

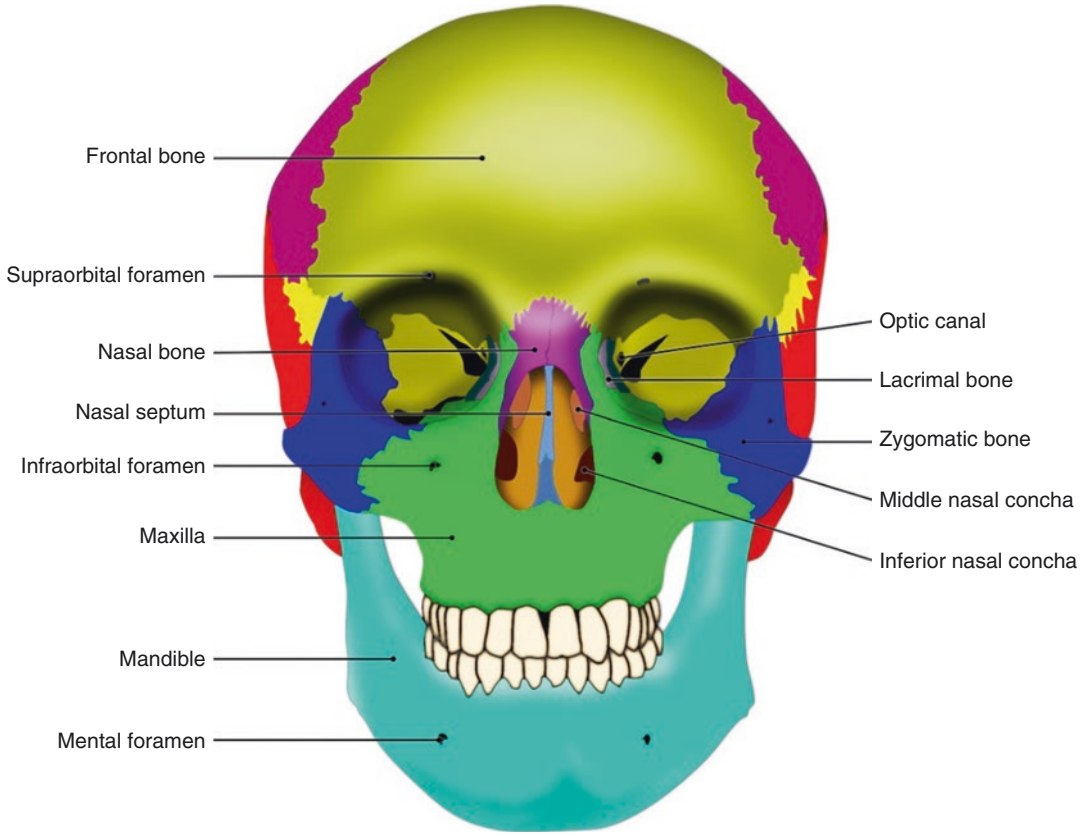

Fig. 1.4 The bony structures like maxilla, mandible, and temporal bones house many critical organs and tissues

effect of the musculature of facial structures may alter its dynamics and function [1].

The skull and the facial bones have their own critical features in humans (Fig. 1.4). Among these, the pillars of the maxilla, enlarged jaw, and robust orbits are the protective buttress of the face [2]. The paranasal sinuses are significant as they contain air that gives some weight support as the head houses muscular structures, which are heavy. Within the head and its structural regions, multiple vessels and nerves are vital as they supply these structures. Most of the surgical procedure involves or interrupts with the vascular supply; thus, surgeons need to be fully familiar with these vessels, its distribution, and their relation to the adjacent organ. In addition, dentofacial deformities, as well as malocclusion and consequent functional deficit, can cause disharmony of the facial form. Major and complex surgeries like total maxillectomy will cause significant impairment to the facial appearance. The treatment goals vary depending on the stage of the tumour and the wishes of each patient. In addition to achieving better oncological outcomes, the surgery should also aim to improve facial aesthetics. This can be achieved with multiple soft-tissue constructions. This is the cosmesis goal that clinicians need to consider when performing any surgery in the head and neck region [1].

The neck and its deeper structures are equally important in the head and neck surgical oncology arena. This begins with surface anatomy inspection for apparent surgical scar (Fig. 1.5). This will give clue to the possibility of difficult dissection due to the presence of scarring and fibrotic tissue. In order to perform neck dissection, the detailed knowledge of the deeper tissue planes, vasculatures, nerves, and lymphatic drainage is a prerequisite. Otherwise, the risk of

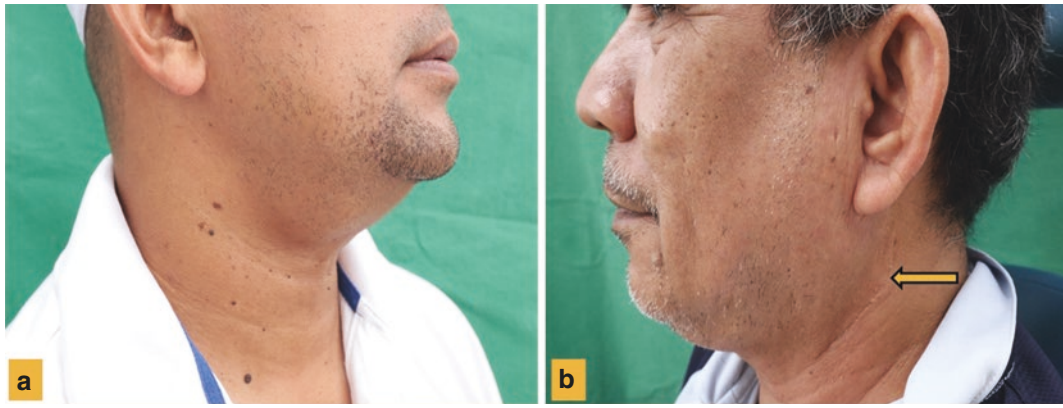

Fig. 1.5 Surface anatomy of head and neck structures and presence of surgical scars are important assessments during the outpatient clinic review: (**a**) The outline of SCM, lower border mandible, level Ia, Ib, II, III, IV, thyroid cartilage, cricoid cartilage sternal notch should be identified during inspection and palpation (**b**) A surgical scar, post modified Blair skin incision for parotidectomy (arrow)

bleeding, cranial nerve neuropathies, and chylous leaks can be very severe and life-threatening. Sternomastoid muscle is useful as a flap in selected head and neck malignancy surgery. This includes parotidectomy, temporal bone tumour dissection, and neck dissection. The segmental arterial supply of the sternomastoid makes it suitable for superiorly or inferiorly based flap. The spinal accessory nerves enter the sternomastoid at its superior third part and should be identified and preserved during harvesting the muscle for the rotational flap or during neck dissection. This illustrates how detailed anatomy of a structure is critical in ensuring a safe and effective surgery.

Importantly, the carotid sheath and last four cranial nerves are located deep in the neck. These structures will be encountered in the majority of head and neck cancer surgeries such as submandibulectomy, selective neck dissection, excision of vagal schwannomas, and thyroid surgery. Injury to these structures will result in significant morbidity to the patients. Occasionally, the internal jugular vein has many small branches that need to be identified during the dissection and clipped or ligated to avoid unnecessary bleeding during neck dissection. The carotid artery branches are sometimes used for donor vessels for flap reconstruction and should be properly identified and dissected.

1.3 Role of Imaging Complementing the Anatomical Details Necessary for a Surgical Mapping

In order to know the detailed anatomy and extent of the tumour, imaging has significant roles in delineating the extent of tumoural and pathology details in relation to adjacent structures' involvement. Even a simple neck X-ray (Fig. 1.6) can provide many critical information about the disease and for surgical mapping. The other conventional imaging modalities are ultrasound, CT scan, MRI, and PET scan. Other newly developed imaging tools have been used in select institutes and centres around the world, in order to enhance the disease and tumour detection and staging for a better management plan. This ensures an optimal treatment outcome for the majority of patients (Fig. 1.7).

Ultrasound is the mainstay of imaging modality in thyroid and salivary gland tumour, especially in small- to moderate-size tumours. In large and extensive tumours, CT scan is required in order to assess the extent of tumour and adjacent tumour involvement. For instance, in the suspected case of a submandibular malignancy, assessment of neck nodes and mandible involvement is important (Figs. 1.8 and 1.9).

This is critical for a decision whether to perform a submandibulectomy with or without neck dissection or marginal mandibulectomy. In case of nasopharyngeal carcinoma, CT scan allows assessment of the nasopharynx area and pterygoid muscle involvement (Fig. 1.10). In parotid gland and thyroid gland malignancy, CT scan gives additional information on margins of the tumour, neck node metastases, or airway patency (Fig. 1.11). A CT scan also allows accurate assessment of the parapharyngeal space mass or collection (Fig. 1.12). MRI, on the other hand, is used to assess the soft-tissue involvement, for instance in the oral cavity carcinoma, i.e. tongue carcinoma, where the inferior extension or depth of infiltration is one of the criteria for current TNM staging, the 8th edition.

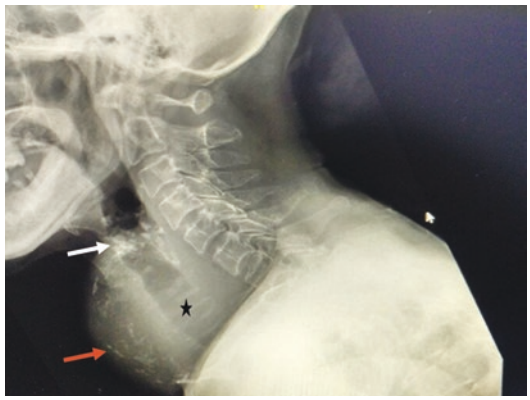

Fig. 1.6 Head and neck imaging such as a neck X-ray complementing the clinical examination findings. This is necessary for a complete assessment of the head and neck disease. This lateral neck X-ray shows a huge thyroid mass (red arrow) with evident calcification (white arrow) and the shadow of trachea (star)

Other types of imaging mode depend on the tissues and organs that need to be assessed (Table 1.1). For instance, the cone beam computed tomography is suggested as the 3D imaging modality for maxillofacial region imaging due to much reduced costs, lower radiation levels compared to multi-slice computed tomography, high bone and teeth resolution, and ability to obtain the entire set of traditional orthodontic images in just a single exposure [3].

The neck is a critical region that bridges the head with the rest of the body. It houses the cervical oesophagus, trachea, thyroid gland, and parathyroid glands. In addition, a dense network of

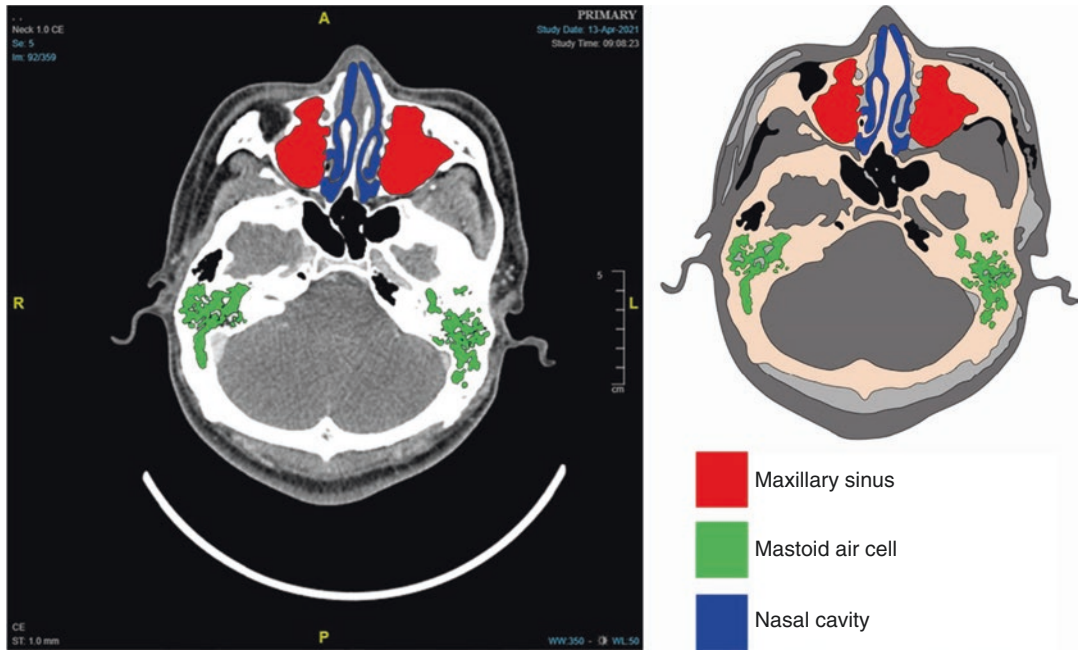

Fig. 1.7 The nasal cavity, sinuses, and temporal bones with mastoid air cell present a small part of the anatomy of the head and skull region but have tremendous implication in head and neck diseases and tumours management

lymphatic channels and nerves are located in the neck (Fig. 1.13). These lymphatics are critical as many of the head and neck diseases and tumours will spread through these lymphatic channels. The malignant tumour will eventually cause neck node enlargement due to this lymphatic spread. Importantly, different levels of neck nodes indicate different sites of primary tumours (Table 1.2). Other important structures include deep spaces of the neck such as parapharyngeal space, retropharyngeal space, and carotid space that are involved in the pathologies like tumour spread and abscess formation.

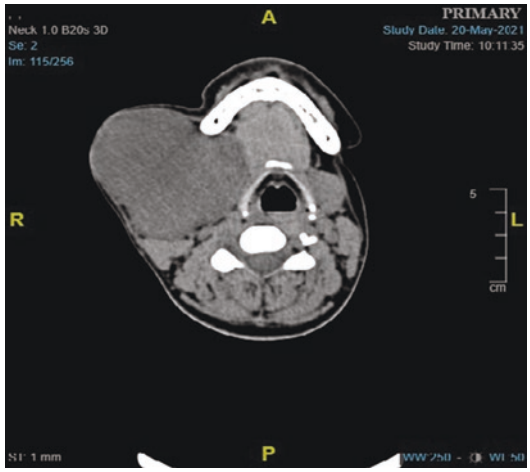

Fig. 1.8 Relationship of submandibular gland mass to adjacent structures like mandible, airway, and vertebra is critical when assessing the compression effect or infiltration by the tumour, benign or malignant

Conventionally, the neck is divided into two major triangles: anterior and posterior triangles. These are further divided into smaller additional triangles, which include submental, submandibular, and carotid triangles.

1. The anterior triangle is bounded inferiorly by the sternal notch and clavicle, laterally by the sternocleidomastoid, and medially by the trachea, thyroid, and cricoid cartilages.
2. The posterior triangle is bounded posteriorly by the anterior border of trapezius muscle, anteriorly by the posterior border of the sternocleidomastoid muscle, and inferiorly by the clavicle [4].

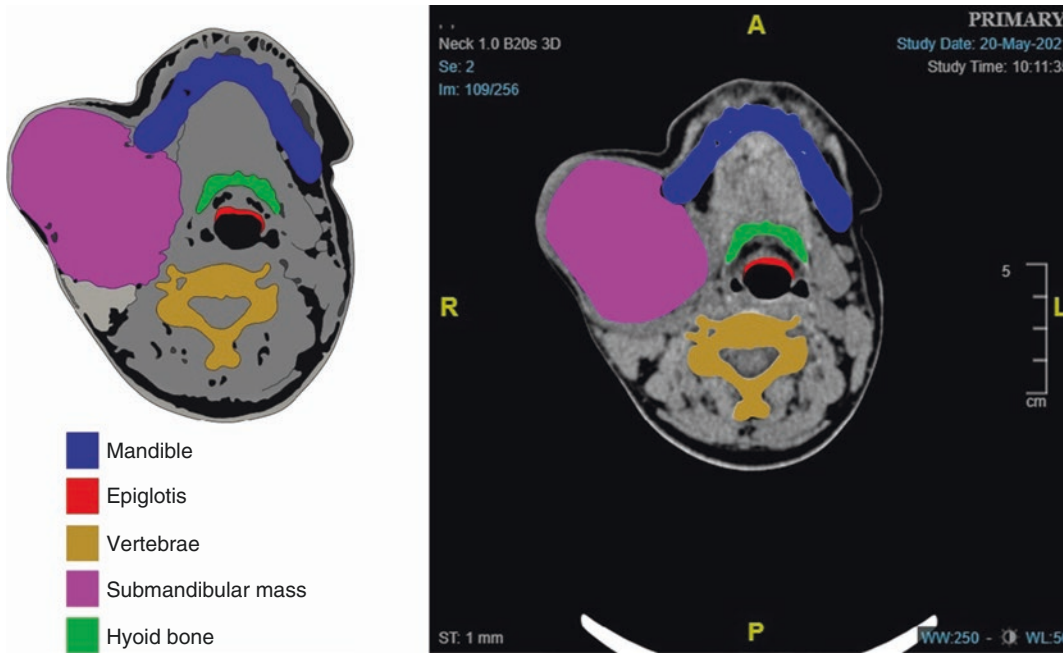

Fig. 1.9 Identification of vital structures in relation to the submandibular gland mass like mandible, epiglottis (and airway), and prevertebral area is critical when assessing the infiltration by the malignant tumour for designing a proper surgical approach

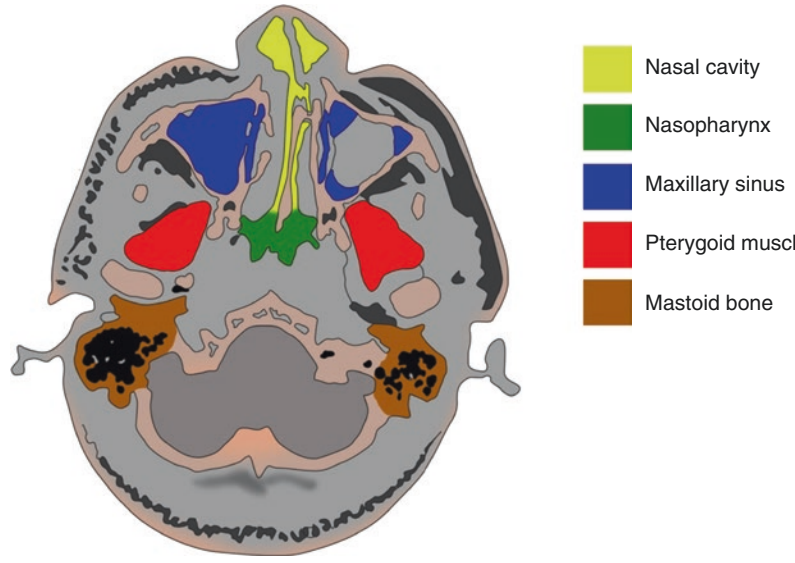

Fig. 1.10 Nasopharynx is a midline anatomic region and is surrounded by maxillary sinus and nasal cavity anteriorly, pterygoid muscle, pterygoid plates laterally, prevertebral space posteriorly, and skull base superiorly

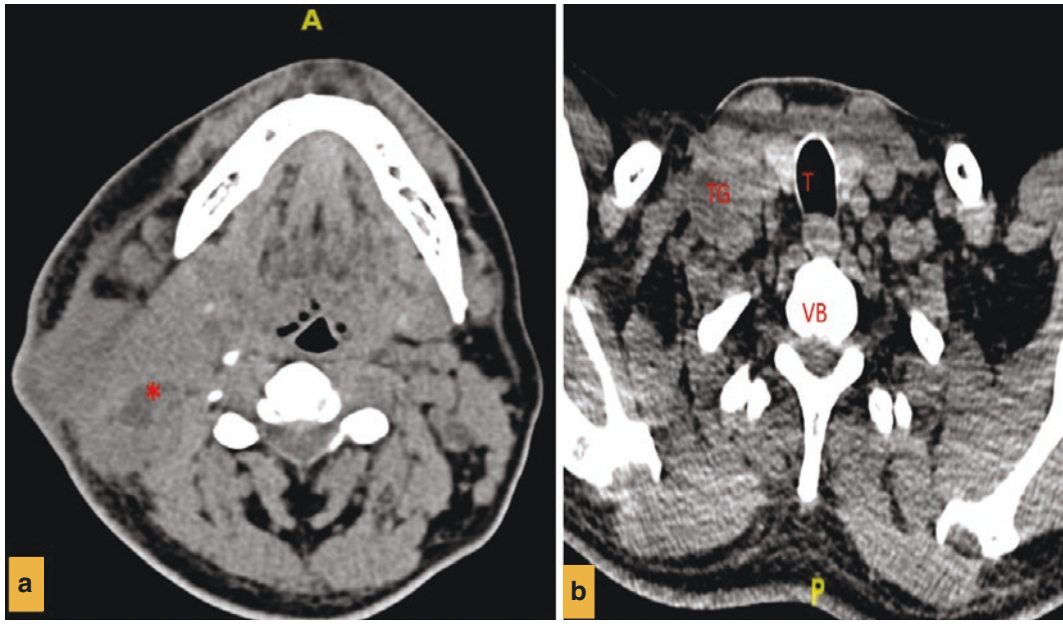

Fig. 1.11 CT scan of neck showing a heterogenous parotid tumour (asterisk), which could represent malignancy (**a**). Right thyroid gland (TG) is cystic and enlarged and can cause compression of the trachea (T) and airway (**b**). (**a**) Parotid gland mass with possibility of skin and subcutaneous infiltration. (**b**) Outline of normal structures; trachea (T), thyroid glands (TG), and vertebra (VB)

Apart from the lymphatic drainage, the arterial and venous supply of the neck is also crucial. These structures are commonly addressed in any surgery because of bleeding or as a part of vascular supply to the flap. The flap plays a significant role in head and neck reconstruction in the treatment of head and neck malignancy. The viability of flap depends on sufficient vascular supply.

The external carotid arteries have eight major branches. These branches supply critical organs and structures in the head, neck, and face region. The terminal branches of the external carotid

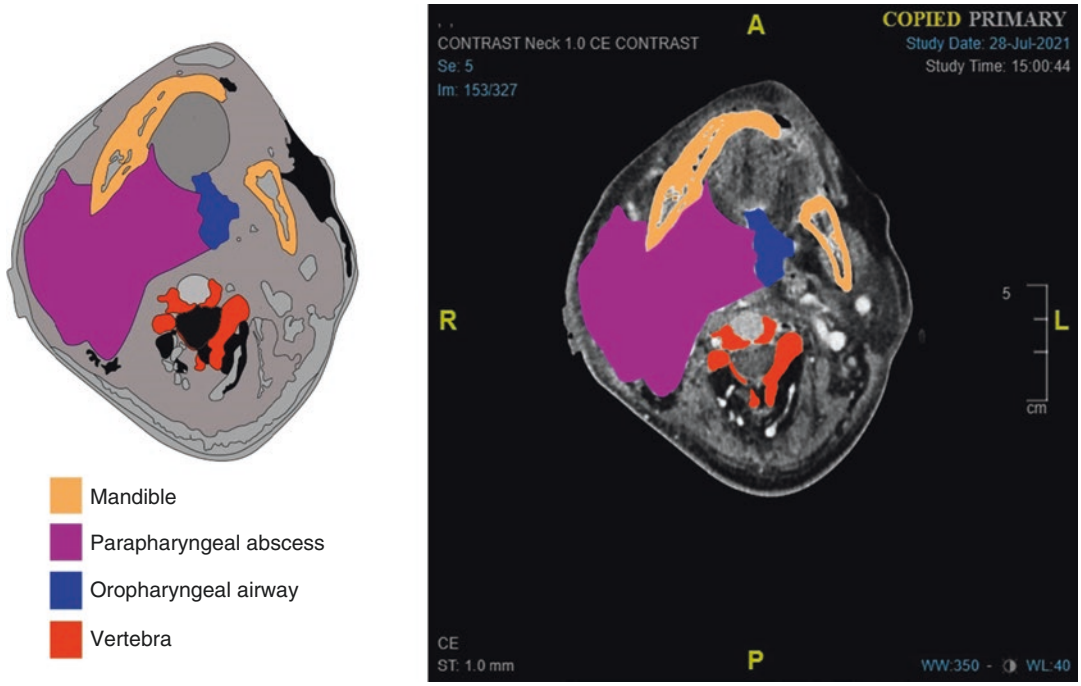

Fig. 1.12 Deep spaces of the neck can be complicated with abscess such as parapharyngeal abscess

Table 1.1 Imaging modalities and their indications in head and neck disease assessment

	Imaging modality	Application
1.	Ultrasound	• Assessment of thyroid mass: solid vs. cystic, vascularity, calcification, TIRADS classification • Assessment of salivary glands: parotid lobes, intraparotid nodes, capsular invasion
2.	Ultrasound Doppler	• Suspicion of vascular neck mass
3.	CT scan	• Assessment of malignant neck mass; adjacent tissue infiltration, mandible erosion, carotid sheath compression, airway obstructions, neck node metastases • Distant metastases
4.	MRI	• Soft-tissue tumour delineation • DOI of tongue tumour • Facial nerve infiltration
5.	PET scan	• Follow-up of head and neck cancer cases • Suspicious distant metastases • Suspicious local recurrence • TRO residual tumour
6	PET-CT scan fusion	• Better mapping of tumour size and location • Recurrent tumour

artery are the maxillary artery and superficial temporal artery. The maxillary artery is further divided into three parts with many small branches (Fig. 1.14). These branches of maxillary artery supply many structures in the head such as the muscles of mastication, teeth and the underlying gingivae, dura mater, calvaria, tympanic membrane, jaw, and external acoustic meatus of the ear. The superficial temporal artery supplies the scalp around the temporal region [5].

Apart from neck triangles, the level of neck nodes is equivocally important as many of the head and neck malignancies will require treatment of the neck. This treatment of the neck is critical in order to prevent recurrent tumour in the neck. Most of the times, treatment of the neck will be performed in the form of neck dissection, which should be performed in the most oncologically safe manner (Fig. 1.15).

The neck dissection surgery will require a thorough understanding of the anatomy of structures of head and neck along with their lymphatic drainage. Most of the lymphatic drainage will be to neck node levels I–IV. These neck node levels I–IV are further divided into a and b and contain

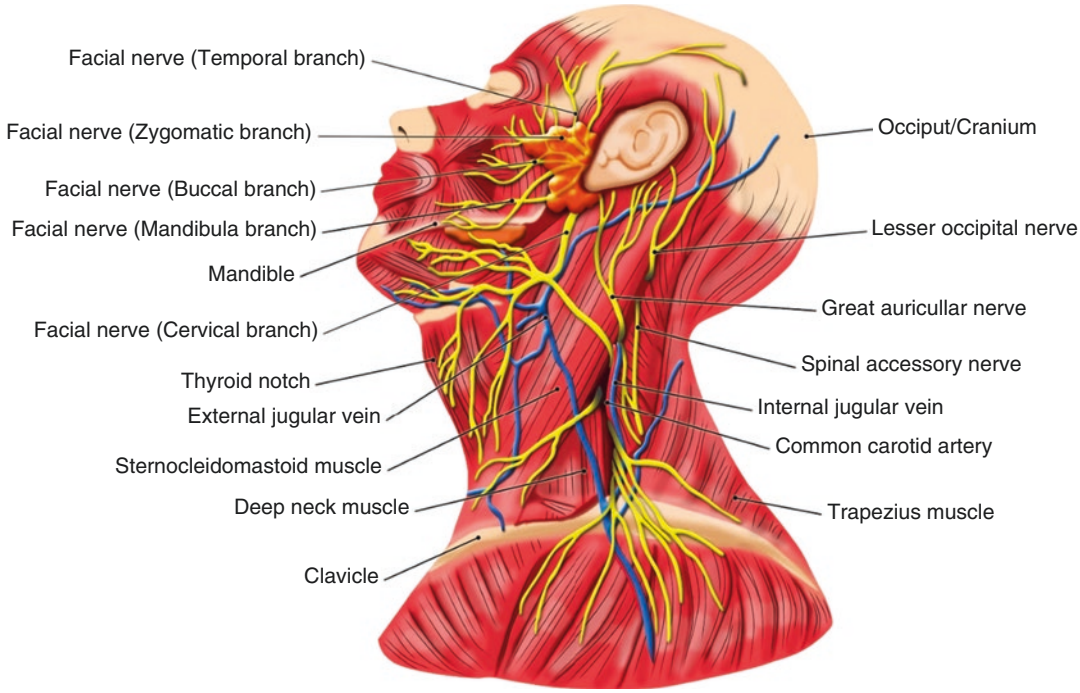

Fig. 1.13 Neck anatomy is a complex network of soft tissues like vessels, nerves, and muscles

Table 1.2 Neck node levels and their primary drainage area

	Neck node levels	Primary site drainage
1.	Level I Level Ia (submental) Level 1b (submandibular)	Anterior lips Tip of tongue Oral cavity Palate Buccal mucosa
2.	Level II	Oral cavity Larynx (supraglottic and subglottic) Pharynx
3.	Level III	Oral cavity Larynx (supraglottic and subglottic) Pharynx
4.	Level IV	Oral cavity Larynx (supraglottic and subglottic) Pharynx
5.	Level V	Thyroid glands Nasopharynx Laryngopharynx
6.	Level VI	Thyroid glands

multiple neurovascular structures together with the neck nodes (Fig. 1.16). The sound knowledge of detailed anatomy of this region will prevent complications of bleeding and nerve paralysis, which sometimes are difficult to manage. These include the boundaries of each neck node level and all their content (Table 1.3).

For instance, the oral cavity is mostly drained to levels I–III of the neck nodes. This entails the nodes at submental and submandibular triangle plus nodes that are located on the superior third of the IJV. The oral cavity has seven subsites, namely lip, alveolus, floor of mouth, buccal mucosa, tongue, palate, and retromolar trigone. Each of these subsites may have predilection of nodes to either level. Lip is commonly drained to levels I and II principally, while retromolar trigone may drain to levels III and IV.

Importantly, also in violated neck due to previous surgery or radiation, the normal lymphatic drainage is distorted, and the drainage may go to other neck node levels. The oral cavity is prone to 'skip metastases' to level IV neck nodes. Thus, in the majority of cases, selective supraomohyoid neck dissection levels I–III or anterolateral neck dissection levels I–IV should be performed for tongue carcinoma or other oral cavity carcinoma.

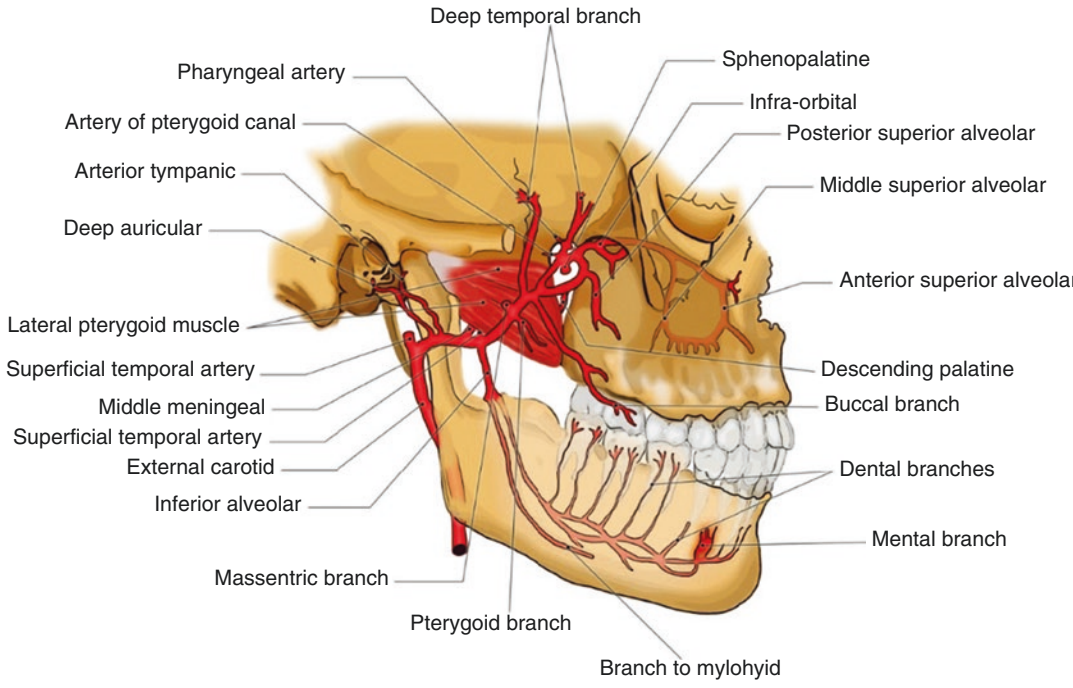

Fig. 1.14 The branches of external carotid artery include maxillary artery, which is further divided into three parts. The branches from these three parts supply important anatomic regions of the head and neck

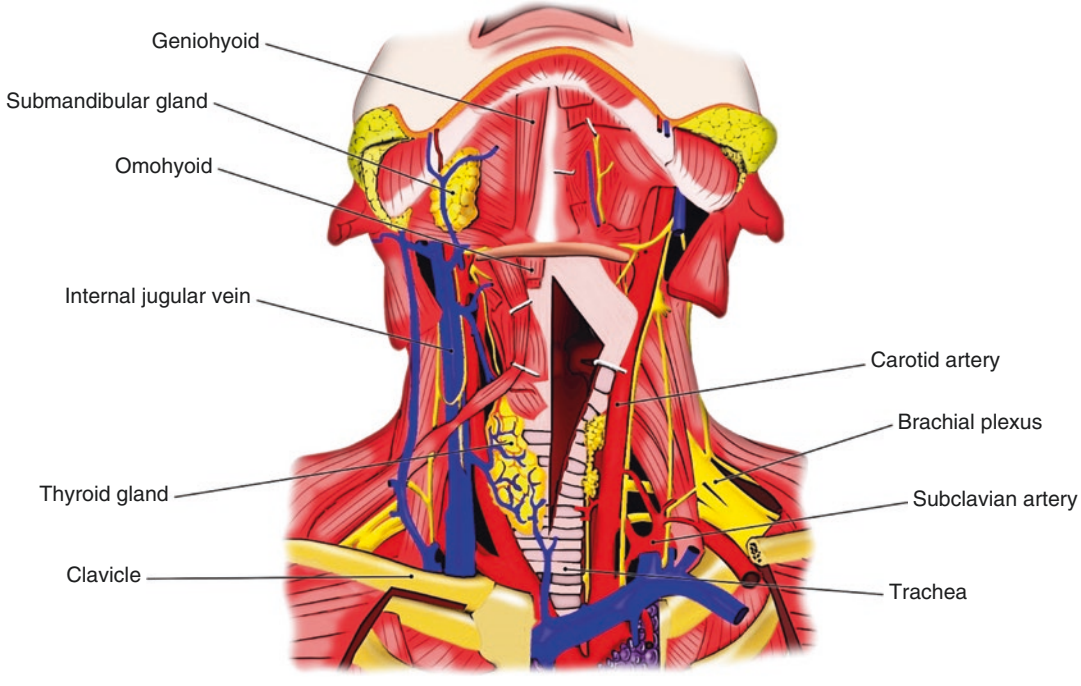

Fig. 1.15 Neck and its anatomy are critical for a safe surgery like neck dissection

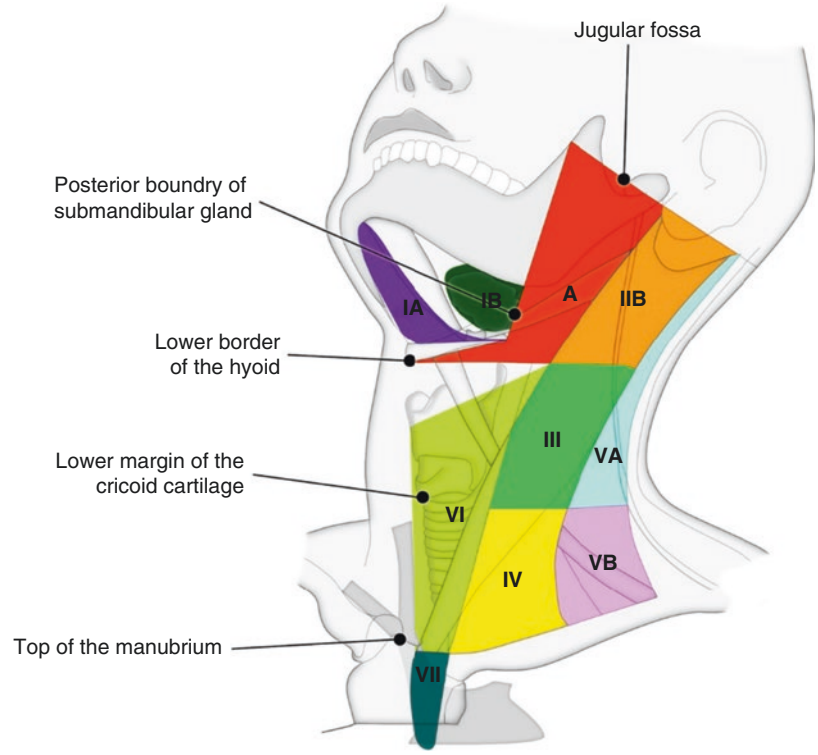

Fig. 1.16 Neck node levels (I–VI) and their detailed anatomy are critical for the conduct of a safe surgery like neck dissection

Table 1.3 Neck node levels and their boundaries and contents

	Level and triangles	Boundaries	Contents
1.	Level IA (submental triangle)	Between medial margins of anterior belly digastric	Submental nodes
	Level IB (submandibular triangle)	Mandible and symphysis menti Digastric muscle	Submandibular gland Submandibular nodes Lingual nerve, hypoglossal nerve
2.	Level IIA	IJV SCM	Upper jugular nodes
	Level IIB	Carotid artery Scalene muscle	
3.	Level III	Caudal edge of hyoid bone Caudal border of cricoid cartilage	Middle jugular nodes
4.	Level IV	From caudal border of cricoid to clavicle	Lower jugular nodes
5.	Level VA Level VB	Skull base to cricoid cartilage Cricoid cartilage till clavicle	Spinal accessory nerves Transverse cervical artery Brachial plexus
6.	Level VI	Hyoid Carotid artery Manubrium	Paratracheal nodes Pretracheal nodes

The lymph nodes in the retropharyngeal space are split into medial and lateral compartments. The medial compartment, at the level of the atlantoaxial junction, lies directly behind the nasopharynx. The lateral compartment lies between the longus capitis muscle and the carotid sheath, and slightly anterior to it. The retropharyngeal nodes are not palpable, and it is the deepest group of lymph nodes in the neck. The identification of retropharyngeal node disease can only be made by CT scan or MRI [6].

For differential diagnosis, prediction of disease spread, and surgical management, an accu-

rate comprehension of the arrangement and anatomic details of the cervical fascia and its associated compartments is crucial [7]. Ultrasound-guided fine needle aspiration cytology (FNAC) is the commonest procedure to investigate the neck mass. It is non-invasive and easy and has a high reliability in expert hands. As far as surgery is concerned, the decision on surgical margin is very important especially if the tumour is malignant [8]. An ample surgical margin will lessen the risk of recurrence. In case of benign parotid tumour for example, wider surgical margin is critical because of the pseudopods of the tumour, which if transected result in tumour spillage and can result in recurrence.

1.4 Anatomical Landmark of Head and Neck Region

Apart from surgical skill, the anatomical knowledge is also one of the basic tenets of surgery. Variations in anatomy are well known among physicians, radiologists, anatomists, and surgeons. This impacts their daily clinical routines such as decision-making of selected cases that were planned for surgery. Surgeons from different fields such as oral and maxillofacial surgery, otorhinolaryngology, vascular, plastic, orthopaedic, and general surgery frequently operate in the head and neck region [9]. They should be familiarized with the head and neck anatomy. Anatomical and surgical landmark is crucial in order to orientate the surgeon about the important structures that are being addressed during specific surgery. It provides tremendous information and useful guidance intraoperatively so that the surgery can be performed safely and effectively, without any sequelae and morbidities.

Sound knowledge of critical anatomical structures and its related relationship with the surrounding tissues and structures will give clues to the specific type of necessary resection of the tumours. Most of the tumours, especially advanced tumour, will show invasion and infiltration to the surrounding tissues. Some tissues can be resected without immediate complications; however, some of the other structures and tissues can cause significant complications if they are resected. This is apparent if resection involves scarification of major neurovascular structures.

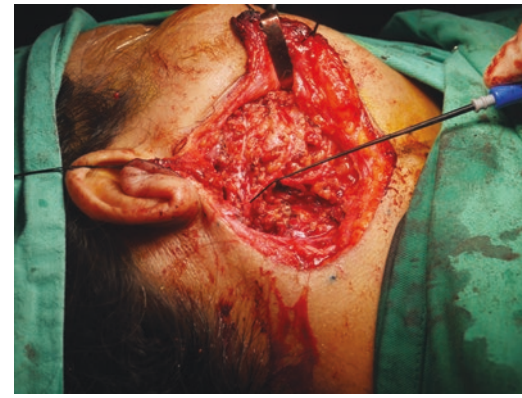

Fig. 1.17 Facial nerve trunk identification during the parotidectomy. It divides into two main branches within the substance of superficial lobes of the parotid gland. The superficial lobe of parotid gland has been removed in the photograph. The facial nerve stimulator with blue handle is used to locate the nerve and also assess its functionality

For instance, in the parotid gland surgery, the operation will be intricately involved with the identification and preservation of the facial nerves and its five important terminal branches (Fig. 1.17). The knowledge on the anatomical landmark to identify the facial nerve trunk is critical as it will assist the surgeon to quickly identify the nerves and save the operation time. The dissection can be performed continuously without interruption, and the surgeon will be able to avoid bleeding from injury to the vessels.

Generally speaking, the cervical region is regarded as similar to the stratified structure, which includes layers of skin, subcutaneous tissue, platysma, muscles and neurovascular structures. Nevertheless, the findings of anatomical and surgical studies have shown that subplatysmal structures, such as digastric structures, mylohyoid muscle, hyoid muscle, subplatysmal muscle fat, and bilateral salivary submandibular glands, influence the dissection techniques and outcomes of surgery [10].

1.4.1 Thyroid and Parathyroid Glands

Injury to the recurrent laryngeal nerve, superior laryngeal nerve, or glands of the parathyroid may have profound lifelong consequences for the

patient. A surgeon must have a thorough understanding of the anatomy of the thyroid and parathyroid glands and be able to apply this information to perform a safe and effective operation in order to minimize the morbidity of the operation [11]. A safe thyroidectomy starts with a correct design of skin incision (Fig. 1.18). Subsequently, a proper subplatysmal skin flap should be raised meticulously (Fig. 1.19). This is to avoid flap necrosis and to promote good healing of the wound later.

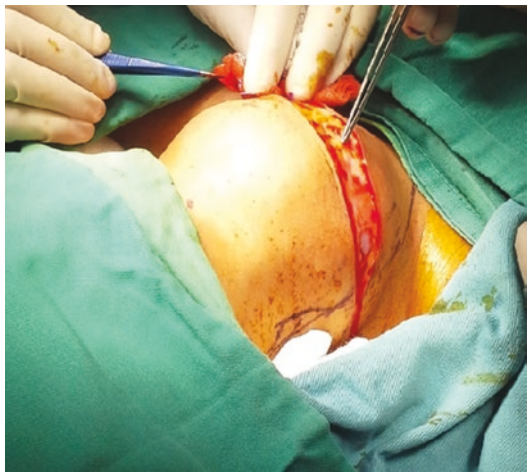

Fig. 1.18 The thyroid surgery is critical as skin incision has to be designed properly in order to have an excellent scar post-operatively

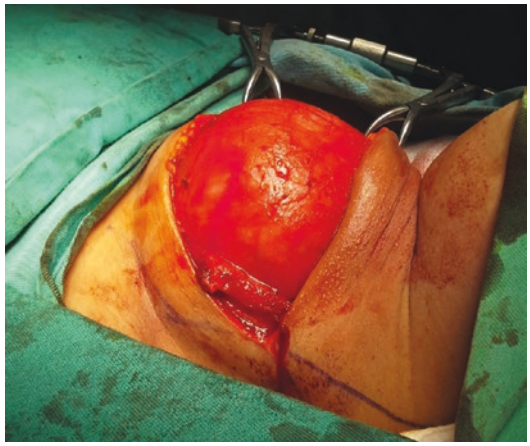

Fig. 1.19 The skin flap has to be raised in correct plane to facilitate easy and uncomplicated dissection. The subplatysmal flap is elevated before exposing the strap muscle and SCM

The preservation of RLN is critical in thyroidectomy (Fig. 1.20), as it controls the vocal cord mobility and influence the voice outcomes post-operatively. As the RLN rises, it develops an intimate relationship with the ITA in the TE groove. Several studies have attempted to define the relationship between the RLN and the ITA. The nerves can typically pass superficially or deeply, or between branches of the ITA. The ability of the surgeon to rely solely on the ITA as a landmark to identify the nerve is limited by this variable branching pattern (of the nerve and arterial system). The only constant is the ITA's intimate relationship with the RLN; most researchers recommend identifying the nerve before ligating the artery to avoid accidental nerve injury [12].

The Zuckerkandl tubercle is a poorly known and variable thyroid gland anatomical feature that is rare. It is the extension of the thyroid gland lobes laterally. This tubercle is regarded as a constant landmark for recurrent laryngeal nerve and also for the identification of superior parathyroid glands [13]. It occurs for embryological reasons, and during thyroid surgery, it can be a reliable anatomical landmark for identifying the recurrent laryngeal nerve. It should be included in the Nomina Anatomica as described by Zuckerkandl as the 'processus posterior glandulae thyroideae' [14].

Another critical structure that needs to be identified and preserved during thyroid surgery is the external laryngeal nerve (ELN). The ELN supplies the cricothyroid muscle, which tenses

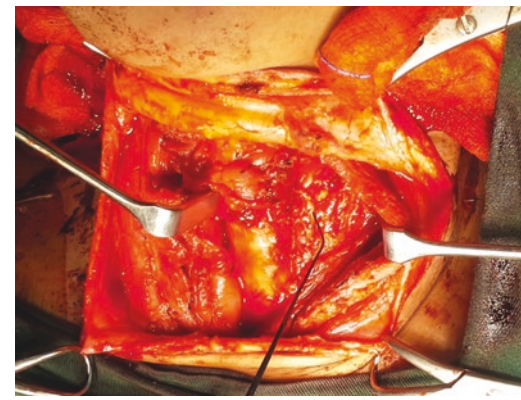

Fig. 1.20 The identification and preservation of RLN (under the black probe needle) are vital in thyroid surgery. This ensures normal voice post-operatively

the vocal cord and is useful in professional voice users such as singers and teachers. Thus, injury of the ELN during thyroid surgery causes significant morbidities. In particular, surgeons should be mindful that other types of surgery can also increase the morbidity to the ELN, including a variety of neck procedures such as parathyroidectomy, carotid endarterectomy, and anterior cervical spine procedures [15].

In the anatomical course of the ELN, there are large variations, making the intraoperative identification of the nerve difficult. This is compounded if surgical exposure of the thyroid gland area is limited. The nerve also sometimes can be very small and can only be visualized and assessed better using magnifying loupes or microscopes. Many authors consider the topographical relationship of the ELN to the superior thyroid artery and the upper pole of the thyroid gland to be the key point for identifying the nerve during neck surgery [15]. In fact, a classification system by Cernea provides information on the distance between external laryngeal nerve and upper pole thyroid (Fig. 1.21).

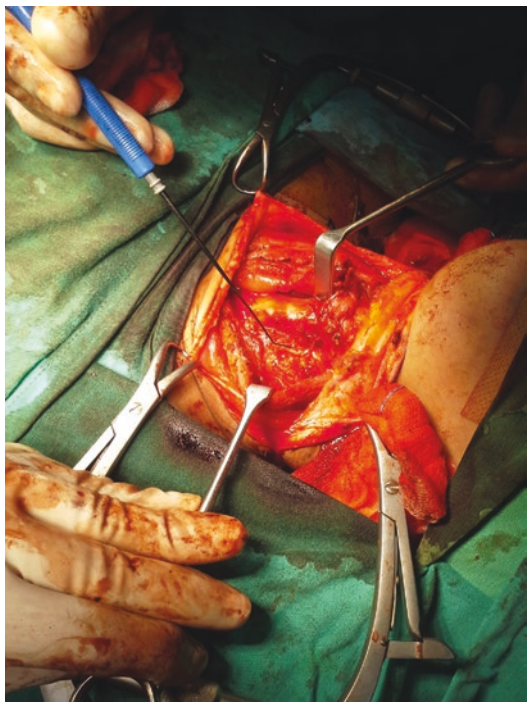

Fig. 1.21 The identification and preservation of RLN are aided by the usage of nerve stimulator. The nerve probe with a blunt-pointed end is used for stimulating the nerve

1.5 Surgical Landmarks of Selected Head and Neck Surgery

Surgical landmarks during the surgery can be a little bit different from the anatomical landmarks. It is well known that there is a variation of the anatomy of any given structures and organs within the human body. The anatomical landmarks are normally described based on the majority of the known anatomical details that are most of the time based on the cadaveric dissection specimen. However, there is variation in the organs and structures in the location, size, branching pattern, colour, and so forth. The variation especially is significant between the adult and paediatric patients.

These variations are mainly related to subcutaneous tissue, calibre of the nerve, number of branches and pattern of the branches of artery or vein, size and shape of the organs, location and consistency of organs, and so forth. All these variations need to be considered during the surgery. More experienced surgeons normally will be able to anticipate the anatomical details of the structures and organs and their variation, as they have been operating on many cases [16].

For instance, the facial nerve in a paediatric patient is located more superficially in contrast to an adult. Critically, the colour of facial nerve is very different to the colour of the facial nerve in an adult patient, which is usually white or pearly white. In paediatrics, the colour of the facial nerve is similar to the tissues, with more of tan or brownish in appearance. Thus, the use of intraoperative nerve stimulation is extremely helpful for the operating surgeon to locate the facial nerve in a paediatric patient. Injury to facial nerve can lead to major dreadful complications of the facial paralysis with facial asymmetry for life.

The SMAS layer is continuous with the platysma muscle inferiorly and the temporoparietal fascia and galea aponeurotica superiorly. In the face, the SMAS lies between the subcutaneous adipose tissue and the underlying parotidomasseteric fascia within which lies the facial nerves. The thickest SMAS is found in the lateral face overlying the parotid gland [17]. Sub-SMAS methods of

dissection may allow both the improvement of aesthetic change and enhanced longevity.

Surgeons depend on the use of anatomical landmarks for identifying various structures. Good landmarks are those which are easy to identify and easy to palpate and remain in a relatively constant position throughout the procedure, thus allowing for a safe and fast identification of anatomical structures. Bony structures are ideal than soft-tissue or cartilaginous landmarks because of their rigid and reliable anatomical location. For identification of the facial nerve during parotid surgery, a number of reference points have been used. These include the TP, stylomastoid foramen, TMS, PBDM, stylomastoid artery, retromandibular vein, transverse process of the atlas, styloid process, angle of the mandible, junction of the bony and cartilaginous EAM, and peripheral branches of the facial nerve. There seems to be little agreement over the most reliable and appropriate landmark [18].

The paired jugular veins and the carotid arteries form the major vasculature of the head and neck region. There is anatomical variation of these two structures between individuals. There is evidence to suggest that the right IJV is slightly larger and thicker in dimension compared with the left [9]. In almost any extensive surgery of the neck, proficient knowledge of the neck anatomy is essential to prevent accidental injury to these vessels and their branches, for instance, during a selective or modified neck dissection. Reasonable speed and safety are of fundamental importance in identifying and preserving important anatomical structures during any head and neck surgery. Importantly, for example, particular attention must be paid to the refined identification of the spinal accessory nerve (SAN) at level V during modified radical neck dissection [19].

1.5.1 Transverse Process of the First Cervical Vertebra

The useful surgical landmark at upper cervical region is the transverse process of the first cervical vertebra. This can be easily palpated anterior and inferior to mastoid process deep in the upper cervical region, level IIb. It has intimate relationship with IJV, SAN, and internal carotid artery [19]. The SAN is superficially located as it runs through the neck's posterior triangle or level V neck. In order to avoid injury to this nerve, the skin flap raised over this region must be kept relatively thin and the contraction of the trapezius should be constantly observed during the dissection. In this area, there are two significant anatomical landmarks that can be used to locate the SAN: firstly, Erb's point, and secondly, the distance between the trapezius muscle entering the nerve and the clavicle [20]. This is of importance because any inadvertent injury to the SAN during surgical procedures is a cause of significant morbidity with medicolegal repercussions. SAN injury may be avoided by safely identifying it in lymph node levels II and V. Numerous methods are proposed that utilize the SAN's relationship to structures such as the transverse process of C1, perforating veins draining the sternocleidomastoid (SCM), SCM branch of the occipital artery, and superior SCM tendon [21].

Additionally, hyoid bone is an important surgical landmark for neck procedures. The hyoid bone is located just beneath the mandible in the anterior midline. The anterolateral aspect of the hyoid bone may be present with a radiolucent gap or radiodense line [6]. When planning the operation of a neck lift, the surgeon has to make several decisions regarding whether to perform it in isolation or in combination with a facelift. It is critical to consider the use of an anterior (submental) or posterior (lateral) surgical approach and the subplatysmal layer. If the space of the subplatysmal is explored, the digastric muscle can be identified. Important neurovascular structures in the neck are located deep to the posterior belly of digastric muscle. Platysma muscle on its own is an important muscle. Midline plication, partial or complete horizontal transection, and most recent lateral skin displacement are platysma-modifying techniques [17].

1.5.2 Parapharyngeal and Retropharyngeal Space

Parapharyngeal space (PPS) is a deep space of the neck and harbours numerous critical structures, namely the deep lobe of parotid glands,

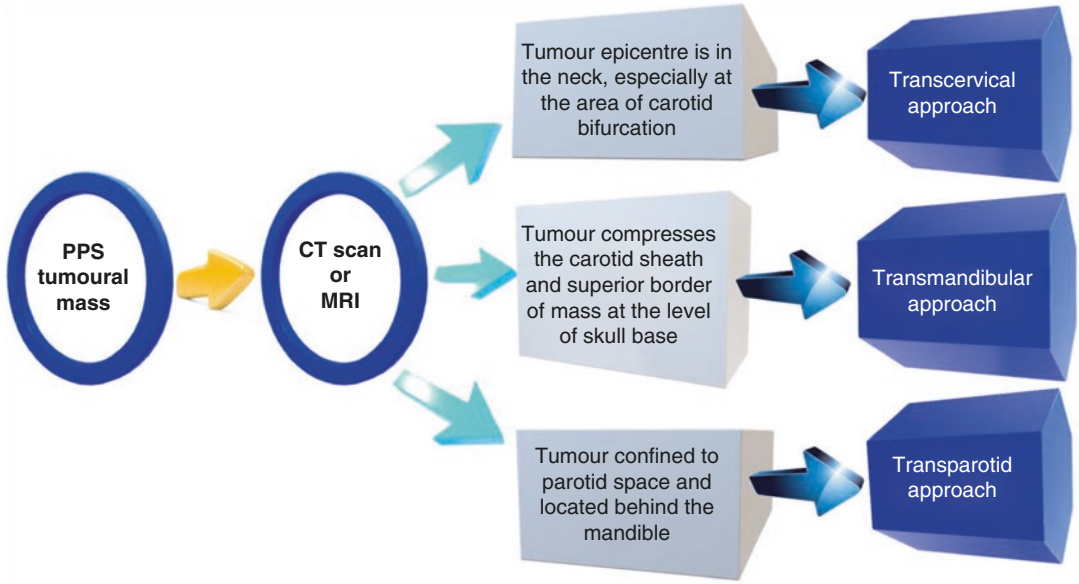

Fig. 1.22 Selection of surgical approach for a parapharyngeal space tumour depends on the tumour characteristic

cranial nerves, carotid sheath, and nodes. This deep space of the neck is significant as the surgical access to this region is technically challenging. In this region, the majority of pathology includes tumours of the salivary gland in the pre-styloid compartment and neurogenic tumours in the post-styloid of PPS. Pleomorphic adenoma is the most common salivary gland tumour, while schwannomas are the most prevalent neurogenic lesion in this area [22]. The other rare tumours include soft-tissue tumours, vascular tumours, and malignant tumours like acinic cell carcinoma of parotid glands. The retropharyngeal space (RPS) extends from the skull base to the upper mediastinum. Diseases are rare in this space but can lead to significant morbidity and mortality if not adequately managed.

In the assessment of the RPS and PPS, cross-sectional imaging plays an important role. Lesions arising within these spaces are difficult to evaluate on clinical examination due to their deep location within the neck [23]. Thus, imaging modality such as CT scan, MRI, or PET scan is very valuable in providing extra important findings and details characteristic of the mass that will help with the management of the patient. This can be highly crucial in deciding the details of surgical approaches for the mass extirpation, the pre-planned involvement of other expertise, and so forth.

The main surgical approach for addressing the PPS includes transoral, transmandibular, transparotid, and transcervical [24]. The choices of best approaches will depend on the location and size of the tumours (Fig. 1.22). Several PPS surgical approaches are available for use in addressing the pathology in this anatomic region. This includes the upper PPS, which can be exposed via a transnasal approach, though with limited working volume. The middle PPS can be exposed by transoral approaches, minimizing the neurovascular structures crossed. The entire PPS can be exposed only by transcervical and skull base approaches, crossing several neurovascular structures [25] (Fig. 1.23).

In order to improve treatment outcomes, the current trend in PPS tumour surgery is to develop minimally invasive approaches that enable tumour resection without the need for mandibulotomy or approaches to the lateral skull base. This can be achieved by considering a well-defined surgical route such as the transcervical, transnasal, or transvestibular, especially in a small and limited PPS tumour. Therefore, in view of the wide and heterogeneous choice of techniques that are available, careful surgical plan-

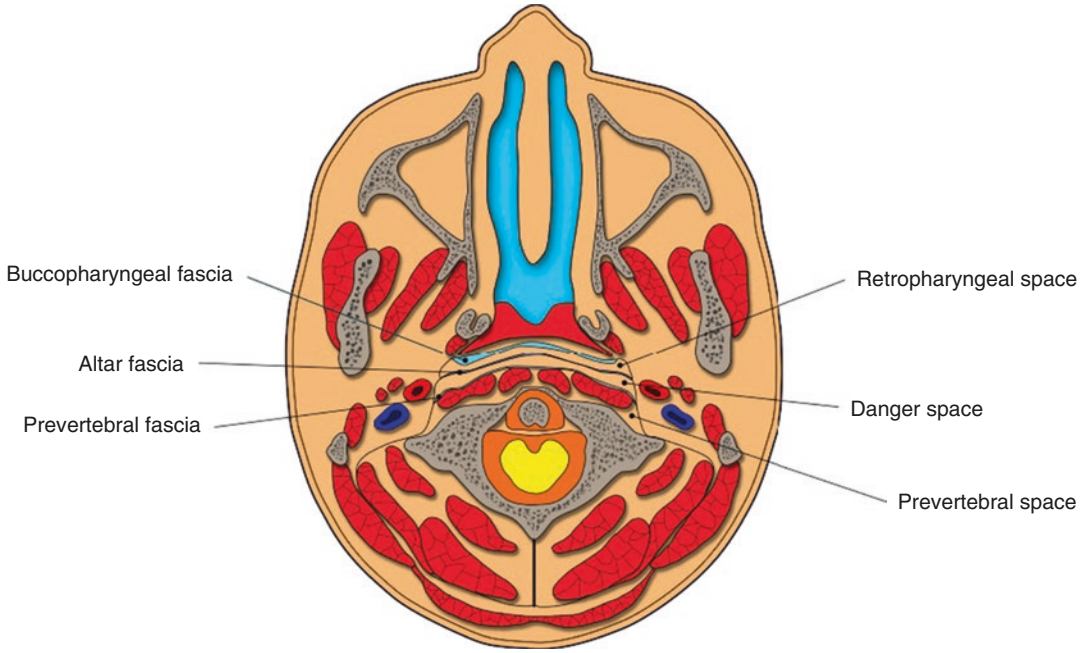

Fig. 1.23 Deep neck space of the head and neck region contains many structures and has many functional significances. Among these critical structures is this fascia layers and spaces, which is an easy route of spread of disease and tumour in this deep neck space, as it is a very thin layer. Importantly, communication exists between these deep neck spaces

ning is mandatory in order to tailor the surgical treatment according to the patient and tumour characteristics [26].

1.5.3 Sentinel Lymph Node Biopsy

Sentinel lymph node biopsy is an integral management component of oral cancers, and currently multiple studies are investigating its roles in other head and neck tumours like salivary gland tumour, thyroid tumour, and sinonasal carcinoma. The concept of sentinel lymph node biopsy is similar with super-selective neck dissection. This applies to a focal removal of at-risk or involved nodes only. Morbidity can be significantly reduced; hence, patient quality of life will be much improved. Some of the procedures have also been performed using a robotic system. At this juncture, as the robotic system has revolutionized most of the surgical approaches, the scars and aesthetic complication can be minimized, provided that the practising surgeon is well versed with the robotic system and its instrumentation.

Transoral robotic surgery has become significant in head and neck cancer treatment such as for oral, tongue base, and oropharyngeal cancers. For tongue base tumour, this approach is an efficient approach, as miniprobes and gadgets can be manipulated under direct visualization. The robotic endoscope will allow the control over the neurovascular structures in order to minimize complications. Transoral robotic surgery (TORS), which offers patients with newly diagnosed oropharyngeal carcinoma a novel option to the standard of care with RT and may provide better functional results, is now being used for the majority of early OPSCC patients in the United States [27].

1.6 Dissection Procedure

The plane of neck structures is vital in determining the bloodless, safe, and effective surgery. Most of the time, neck surgery will be initiated with the subplatysmal flap. Some vessels like EJV, which runs over the sternomastoid muscle,

can be easily seen once the flap is raised. Inadvertent injury to EJV and feeding veins can jeopardize the surgical bed and further compromises safer dissection or deeper structures like sternocleidomastoid muscle and the carotid sheath underneath. The sternocleidomastoid muscle is innervated by spinal accessory nerves, which run and enter the sternomastoid muscle at its superior one-third, and further anteriorly this SAN is closely related to IJV and carotid artery and its branches.

Following the IJV on a correct plane is essential, especially in case of neck dissection where the recurrent tumour can occur along this IJV. Multiple fascia layers envelope the IJV, where the lymphatic networks are located. Thus, dissection needs to include this layer together with the dissection specimen, so that the risk of recurrent neck tumour can be reduced. In some patients, the IJV can have multiple branches, which necessitate ligation with small clips. Otherwise, the dissection can freely continue through this plane.

1.6.1 Pearls and Pitfalls of Dissection Techniques

The pearls and pitfalls of dissection technique are depicted in the table as below:

Types of surgery	Pearls	Pitfalls
1. Oral cavity surgery	Need to get ample surgical margins due to overstretched tongue musculature during palpation and dissection Depth of invasion (DOI) is critical to be considered during glossectomy. DOI has been incorporated in the current eighth edition of TNM staging system In advanced tumour, floor of mouth needs to be resected together with glossectomy. FOM needs to be reconstructed with either SSG or STSG, in order to prevent tethering of neotongue to FOM during healing, which impairs speech and mastication	Total glossectomy mandates total laryngectomy, which further impacts the patient's functioning Choices of reconstruction post-resection are multiple and depend on the defect coverage characteristics
2. Oropharyngeal surgery	Combined mandible and oral surgery (commando) is required in T3 tumour and higher De-escalation treatment for HPV-positive patients has improved prognosis with this therapy Surgical tissue specimen should be assessed for HPV positivity/status, as it dictates the prognosis and treatment	Metastasis neck disease may present with cystic neck mass, mimicking brachial cyst Mandibulectomy is necessary in T3 tumour and higher Risk of osteoradionecrosis of mandible especially in patients with comorbidities
3. Nasal, paranasal sinus, and nasopharyngeal surgery	Maxillectomy is necessary in maxillary sinus carcinoma Robotic nasopharyngectomy Endoscopic nasopharyngectomy is indicated for a small recurrent tumour EBV status has been included in the current 8th edition of TNM staging system	Neck metastases in sinonasal malignancy imply distant metastases Retropharyngeal node involvement is challenging to address for NPC patients
4. Salivary gland surgery (a) Parotidectomy (b) Submandibulectomy	Facial nerve monitoring is a prerequisite during parotidectomy Marginal mandibular nerve needed to be identified during submandibulectomy Surgical loupes enhance the facial nerve dissection	Excessive stimulation with the nerve and traction causes temporary facial nerve paralysis Local anaesthesia interferes with the nerve identifications since the LA agent infiltrates the nerve and causes paresis

Types of surgery	Pearls	Pitfalls
5. Thyroid gland surgery	The identification of recurrent laryngeal nerve is aided with the uses of surgical loupes and nerve stimulator, to know the landmarks and meticulous dissection Parathyroid gland can be identified and reimplanted to reduce the morbidity of the surgery Use of ultrasonic device facilitates faster and bloodless surgery	External laryngeal nerve identification is challenging RLN palsy causes hoarseness, which impairs the functionality of professional voice users Central compartment neck dissection poses risks of RLN palsy and hypocalcaemia
6. Neck dissections	Knowing the anatomy and surgical landmarks of neck will facilitate easy dissection Use of ligaclips, surgical loupes, and ultrasonic device will save the operative time	Multiple complications arise from MRND and RND, which are difficult to manage such as frozen shoulder syndrome and chylous leak
7. Parapharyngeal spaces	Wide exposure and dissection of neck along the digastric to midline will facilitate access to parapharyngeal space without the need for mandibulotomy	Difficult access, which occasionally necessitates mandibulotomy for access

1.6.2 Dissection Guide

Multiple factors are a prerequisite for determining the success of dissection during any given specific surgeries. These factors include patient's factors, tumour factors, instrument factors, and staff's factors (Table 1.4).

The skill and experience of operative surgeons determine the success of a surgery. Meticulous dissection, adequate assistant, well-functioning instruments, and great teamwork with anaesthetists will ensure the success of any surgery.

Table 1.4 Determining factors for the success of a surgery

	Factors which influence the success of the dissection
Patient factors	Patient's consent Patient's financial status Patient's insight of the disease Patient's positioning Patient's blood parameter Patient's medication
Tumour factors	Complete evaluation of tumour Histology and grade of tumour Recurrent tumour
Instruments and facility factors	Adequate instruments Sharp instruments Spacious OT space Correct patient's positioning
Staffs and personnel factors	Proactive communication among surgeons, nurses, and paramedics

1.7 Optimal Setting for Head and Neck Cancer Surgery

The proper setting of instruments and monitor in the theatre is vital, as it facilitate a safe and effective surgery. For instance, the correct placement and usage of facial nerve stimulator in the operative theatre will ensure the success of a parotid gland surgery, as the facial nerve can be identified and preserved efficiently during the dissection. The useful anatomical landmarks for the facial nerve identification during the parotid surgery include the following:

1. Facial nerves run between the superficial lobe of parotid glands and the deep lobe of parotid glands. It gives off five peripheral branches within the substance of the parotid glands.
2. The facial nerve trunk lies 1 cm inferior to the tragal pointer and medial to the posterior belly of digastric muscle.
3. The facial nerve lies 4–5 mm to the tympanomastoid suture.

1.8 Availability of Necessary Instrument and Supportive Staffs

Instruments and facility play a significant role in determining the success of any surgeries. Knowledge details of the instruments that are available at the centre and correct handling of the

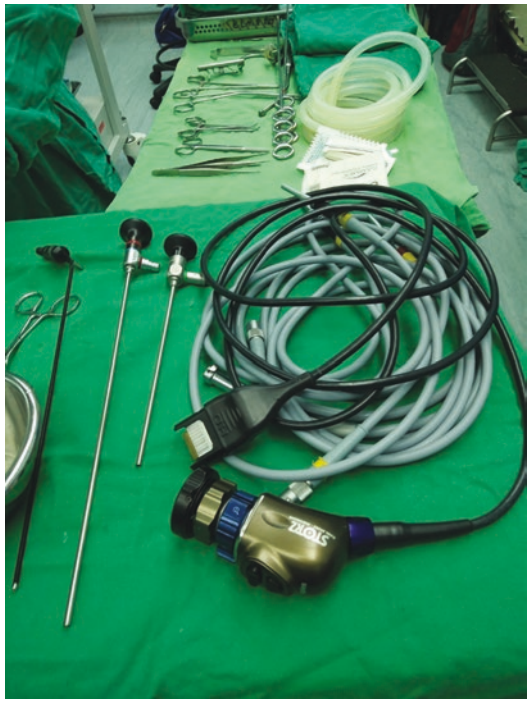

Fig. 1.24 Instruments for a surgical procedure should be prepared early. The OT nurses should be well informed if there is any extra equipment required for specific surgery

Fig. 1.25 The instruments and staffs should be well prepared. The monitor, OT patient table, and anaesthetic machine should be placed at an optimal position. This allows the surgery to proceed as planned without any unnecessary interruptions

equipment will ease the surgery and reduce the operation time (Figs. 1.24 and 1.25). This in turn will lessen at-risk complications including anaesthesia-related complications. The availability of committed supportive staffs is also essential in maximizing the success of a surgery

Fig. 1.26 Instruments like energy device and its monitor, a trolley, OT patient table, and anaesthetic machine should be placed at an ideal position. This facilitates efficient surgery with less unwanted complications

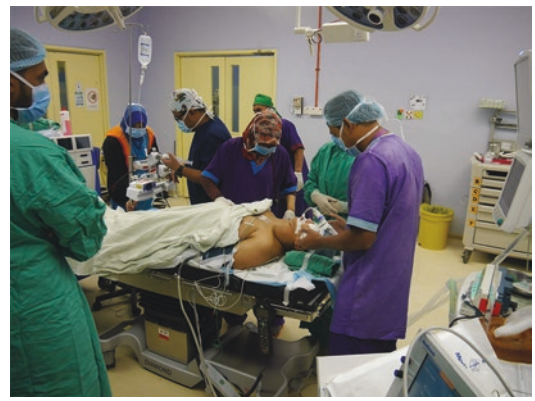

Fig. 1.27 The anaesthetist, scrubbing nurse, OT assistant, and medical officer should have a proactive role and communication. This ensures that the surgery will proceed with best outcomes

(Figs. 1.26 and 1.27). At this juncture, refinement and advancement in surgical techniques and instrumentations have led to the performance of multiple surgical procedures that are effective and optimal. Less time and minimal complications from the surgery translate into a safer procedure. This will improve the patient's treatment outcomes and overall quality of life. For instance, with the advancement of current imaging tools, surgical instrumentation, and minimal-access surgical procedures, the management of frontal sinus pathology has improved. Depending on the surgeon's expertise and experience, frontal sinus lesions can be treated in a variety of ways, ranging from totally endoscopic to fully open. This

will also depend on the detailed characteristics of the tumours. Smaller tumours are accessible via an endoscopic approach, and minimal morbidity is expected from experienced surgeons.

At present, many surgical instruments have evolved in order to be used conveniently by the practising surgeons. The cost of some of these instruments has also been reduced, as more choices of brands and types are available in the market. Newly developed technology gadgets, such as the ultrasonic devices, multi-angle endoscopes, 3D imprinting, digital nerve monitoring, and robotic systems, have escalated the management of head and neck diseases and tumour management [28]. For instance, 3D printing in reconstructive surgery has become critical in mapping the relevant structures that are involved during tumour resection, which need to be addressed during the surgical procedures. Three-dimensional printing offers a great appeal as customized materials can be invented and occasionally applied into the tissues with less reactions and morbidity [29]. For instance, three-dimensional printing offers an intuitive solution in otological, rhinological, or laryngological anatomy for preoperative design and surgical education [29]. This 3D printing is also routinely used in the OMF practice and surgery.

1.9 Conclusion

Head and neck surgery requires meticulous dissection so as to avoid complications and surgery-related morbidities. This is critical to ensure a complete resection especially of a malignant tumour in order to prevent future recurrences. Complications from unsafe surgery can be occasionally fatal and impair patient's quality of life. Importantly, recurrent diseases are more difficult to manage. It is a prerequisite for a surgeon to possess sound anatomical knowledge and be well versed with surgical landmarks in order to effectively perform a head and neck surgery. Additionally, knowledge of instruments, committed supportive staffs, and experience in handling complicated cases will ensure better surgical outcomes for patients.

References

1. Han MD, Momin MR, Munaretto AM, Hao S. Three-dimensional cephalometric analysis of the maxilla: analysis of new landmarks. Am J Orthod Dentofac Orthop. 2019;156(3):337–44. https://doi.org/10.1016/j.ajodo.2018.09.018.
2. Carrier DR, Morgan MH. Protective buttressing of the hominin face. Biol Rev Camb Philos Soc. 2015;90(1):330–46. https://doi.org/10.1111/brv.12112.
3. de Oliveira Lisboa C, Masterson D, da Motta AF, Motta AT. Reliability and reproducibility of three-dimensional cephalometric landmarks using CBCT: a systematic review. J Appl Oral Sci. 2015;23(2):112–9. https://doi.org/10.1590/1678-775720140336.
4. Roesch ZK, Tadi P. Anatomy, Head and Neck, Neck. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2021.
5. Nguyen J, Duong H. Anatomy, head and neck, anterior, common carotid arteries. In: StatPearls. Treasure Island, FL: StatPearls Publishing; 2020.
6. Branstetter BF 4th, Weissman JL. Normal anatomy of the neck with CT and MR imaging correlation. Radiol Clin N Am. 2000;38(5):925–ix. https://doi.org/10.1016/s0033-8389(05)70213-x.
7. Guidera AK, Dawes PJ, Fong A, Stringer MD. Head and neck fascia and compartments: no space for spaces. Head Neck. 2014;36(7):1058–68. https://doi.org/10.1002/hed.23442.
8. Atula T, Panigrahi J, Tarkkanen J, Mäkitie A, Aro K. Preoperative evaluation and surgical planning of submandibular gland tumors. Head Neck. 2017;39(6):1071–7. https://doi.org/10.1002/hed.24691.
9. Mumtaz S, Singh M. Surgical review of the anatomical variations of the internal jugular vein: an update for head and neck surgeons. Ann R Coll Surg Engl. 2019;101(1):2–6. https://doi.org/10.1308/rcsann.2018.0185.
10. Auersvald A, Auersvald LA. Management of the submandibular gland in neck lifts: indications, techniques, pearls, and pitfalls. Clin Plast Surg. 2018;45(4):507–25. https://doi.org/10.1016/j.cps.2018.06.001.
11. Mohebati A, Shaha AR. Anatomy of thyroid and parathyroid glands and neurovascular relations. Clin Anat. 2012;25(1):19–31. https://doi.org/10.1002/ca.21220.
12. Miller FR. Surgical anatomy of the thyroid and parathyroid glands. Otolaryngol Clin N Am. 2003;36(1):221–7, vii. https://doi.org/10.1016/s0030-6665(02)00132-9.
13. Costanzo M, Caruso LA, Veroux M, Messina DC, Marziani A, Cannizzaro MA. Il lobo di Zuckerkandl: faro del nervo laringeo ricorrente [The lobe of Zuckerkandl: an important sign of recurrent laryngeal nerve]. Ann Ital Chir. 2005;76(4):337–41.
14. Page C, Cuvelier P, Biet A, Boute P, Laude M, Strunski V. Thyroid tubercle of Zuckerkandl: anatomical and surgical experience from 79 thyroidectomies.

J Laryngol Otol. 2009;123(7):768–71. https://doi.org/10.1017/S0022215108004003.
15. Kochilas X, Bibas A, Xenellis J, Anagnostopoulou S. Surgical anatomy of the external branch of the superior laryngeal nerve and its clinical significance in head and neck surgery. Clin Anat. 2008;21(2):99–105. https://doi.org/10.1002/ca.20604.
16. O'Daniel TG. Understanding deep neck anatomy and its clinical relevance. Clin Plast Surg. 2018;45(4):447–54. https://doi.org/10.1016/j.cps.2018.06.011.
17. Charafeddine AH, Couto RA, Zins JE. Neck rejuvenation: anatomy and technique. Clin Plast Surg. 2019;46(4):573–86. https://doi.org/10.1016/j.cps.2019.06.004.
18. Kanotra S, Malhotra A, Raina S, Kotwal S. Landmarks for facial nerve identification in parotid surgery: a clinico anatomical study. Indian J Otol. 2020;26(1):15–9.
19. Popovski V, Benedetti A, Popovic-Monevska D, Grcev A, Stamatoski A, Zhivadinovik J. Spinal accessory nerve preservation in modified neck dissections: surgical and functional outcomes. Preservazione del nervo accessorio spinale nelle dissezioni del collo: outcomes chirurgici e funzionali. Acta Otorhinolaryngol Ital. 2017;37(5):368–74. https://doi.org/10.14639/0392-100X-844.
20. Aramrattana A, Sittitrai P, Harnsiriwattanagit K. Surgical anatomy of the spinal accessory nerve in the posterior triangle of the neck. Asian J Surg. 2005;28(3):171–3. https://doi.org/10.1016/S1015-9584(09)60336-5.
21. Eastwood MJ, George AP. A novel approach to identifying the spinal accessory nerve in surgical neck dissection. Otolaryngol Head Neck Surg. 2018;159(2):300–2. https://doi.org/10.1177/0194599818766057.
22. Luna-Ortiz K, Villa-Zepeda O, Carrillo JF, Molina-Frias E, Gómez-Pedraza A. Parapharyngeal space tumor: submandibular approach without mandibulotomy. J Maxillofac Oral Surg. 2018;17(4):616–24. https://doi.org/10.1007/s12663-018-1133-0.
23. Debnam JM, Guha-Thakurta N. Retropharyngeal and prevertebral spaces: anatomic imaging and diagnosis. Otolaryngol Clin N Am. 2012;45(6):1293–310. https://doi.org/10.1016/j.otc.2012.08.004.
24. Lien KH, Young CK, Chin SC, Liao CT, Huang SF. Parapharyngeal space tumors: a serial case study. J Int Med Res. 2019;47(8):4004–13. https://doi.org/10.1177/0300060519862659.
25. Ferrari M, Schreiber A, Mattavelli D, et al. Surgical anatomy of the parapharyngeal space: multiperspective, quantification-based study. Head Neck. 2019;41(3):642–56. https://doi.org/10.1002/hed.25378.
26. Paderno A, Piazza C, Nicolai P. Recent advances in surgical management of parapharyngeal space tumors. Curr Opin Otolaryngol Head Neck Surg. 2015;23(2):83–90. https://doi.org/10.1097/MOO.0000000000000134.
27. Lam JS, Scott GM, Palma DA, Fung K, Louie AV. Development of an online, patient-centred decision aid for patients with oropharyngeal cancer in the transoral robotic surgery era. Curr Oncol. 2017;24(5):318–23. https://doi.org/10.3747/co.24.3669.
28. Carniol ET, Vázquez A, Patel TD, Liu JK, Eloy JA. Utility of intraoperative flexible endoscopy in frontal sinus surgery. Allergy Rhinol (Providence). 2017;8(2):81–4. https://doi.org/10.2500/ar.2017.8.0205.
29. Crafts TD, Ellsperman SE, Wannemuehler TJ, Bellicchi TD, Shipchandler TZ, Mantravadi AV. Three-dimensional printing and its applications in otorhinolaryngology-head and neck surgery. Otolaryngol Head Neck Surg. 2017;156(6):999–1010. https://doi.org/10.1177/0194599816678372.

2 Principle of Head and Neck Surgery and the Importance of Anatomical Characteristics

Norhafiza Mat Lazim

2.1 Introduction

Head and neck surgery consists of surgical procedures, which involve many critical anatomic regions of the facial, head, and neck regions. These anatomic regions are responsible for most of the human vital functioning like breathing, olfaction, speech, mastication, swallowing, facial expression, hearing, and vision. In-depth knowledge of the surgical landmarks of specific surgery in combination with imaging findings will provide a crucial information for a surgical mapping. This ensures a safe surgery, where the inadvertent injury to critical structures can be minimized or avoided. Hence, surgery-related morbidities can be reduced to this subset of patients and their treatment outcomes and quality of life can be improved.

The head and neck region is the most exposed area of the human body. Importantly, this anatomic region is prone to infection, trauma, and tumour formation. These pathologies are very debilitating and can significantly interfere with humans' critical functions. The tumour, either benign or malignant, adversely affects patient prognosis and survival. Depending on the anatomic region of tumour formation, different sites involved present with different clinical manifestations. For instance, patients who had nasal polyps will present with a complaint of nasal blockage and rhinorrhoea, whereas patients with nasoangiofibroma will present with recurrent episodes of epistaxis that may necessitate ward admission. A nasopharyngeal carcinoma patient will present with neck node enlargement. Details of anatomic involvement by specific pathologies at these regions contribute to these different clinical presentations. This includes neural and vascular structure compression or erosion, pattern of the lymphatic drainage, and other adjacent structures' involvement.

Salivary gland's surgery can lead to significant morbidities in the patient. Thus, a meticulous examination and assessment of any parotid swelling are crucial. For instance, on inspection, parotid gland is visible just anterior to the tragus (Fig. 2.1). Anatomically, the parotid gland has delicate relationship with critical structures such as facial nerve, retromandibular vein, and maxillary artery. Surgery to parotid glands can be divided into two main types, the superficial parotidectomy and total parotidectomy. In superficial parotidectomy, the facial nerve needs to be identified and preserved during the dissection of the superficial lobe of the parotid glands (Fig. 2.2). The retromandibular vein needs to be ligated and secure, as it is located very close to the facial nerve. In a few instances, the retromandibular

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N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_2

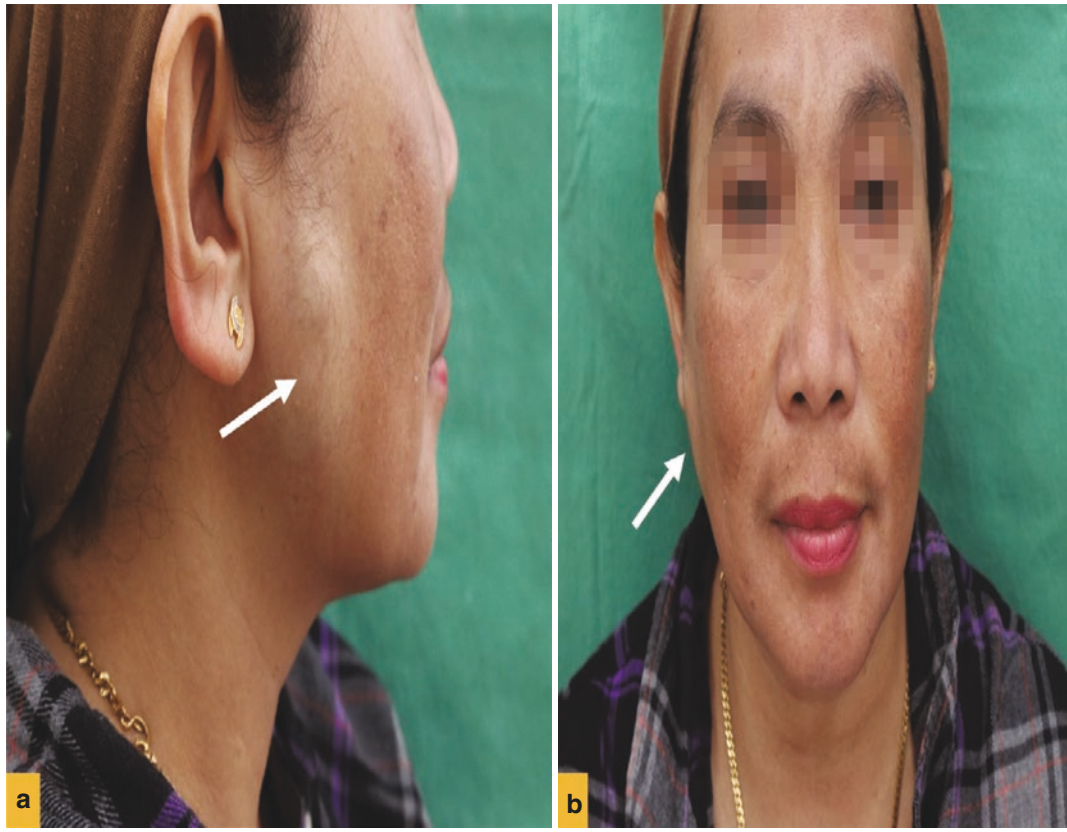

Fig. 2.1 Parotid gland enlargement (arrow) mostly located superficial to the facial nerve trunk and its branches. (**a**) Lateral view of neck inspection. (**b**) Anterior view of facial and neck inspection

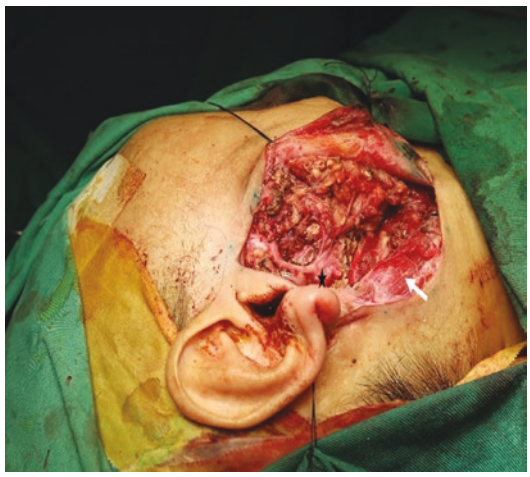

Fig. 2.2 Intraoperative figures showed facial nerve and its branches (star). Left sternocleidomastoid muscle is visualized laterally (arrow)

vein is located below or medial to the facial nerves. The maxillary artery (Fig. 2.3) can be palpated during dissection at the medial side of the superficial lobe so as to avoid inadvertent injury and unwanted bleeding. However, this rarely occurs.

Submandibular gland surgery is slightly different compared to parotid surgery as the submandibular area contains different neurovascular structures. Submandibular area is equal to level Ib neck node. It contains multiple critical structures including marginal mandibular nerves, facial artery and vein, lingual nerve, and hypoglossal nerve (Fig. 2.4). All of these neurovascular structures need to be identified and addressed accordingly in order to avoid the complications that may arise from the submandibular gland's surgery. These, for instance, can be uncontrolled

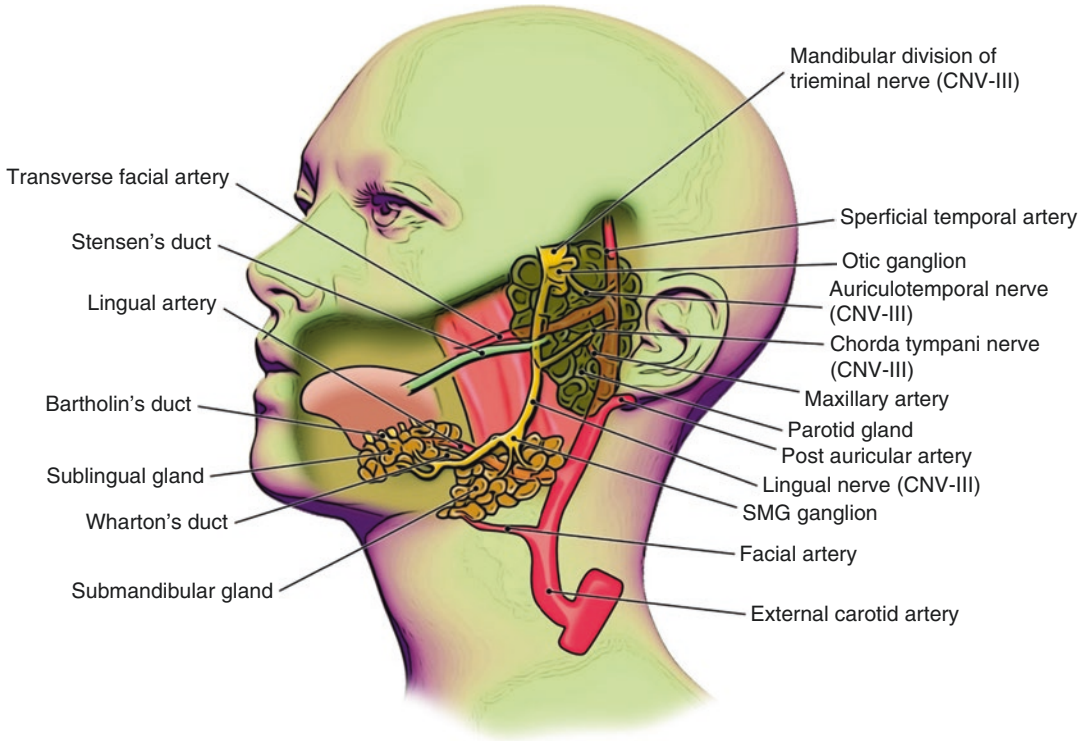

Fig. 2.3 Parotid glands and facial nerve and its branches and relation to adjacent critical structures such as carotid artery, maxillary artery, Stensen's duct, and submandibular gland

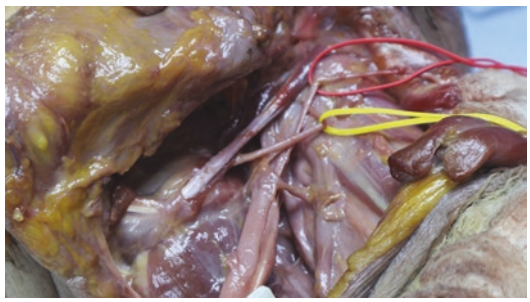

Fig. 2.4 Submandibular triangle or level Ib of neck harbours the submandibular gland, posterior belly of digastric muscle, hypoglossal nerve (yellow vessel loupe), and lingual nerve

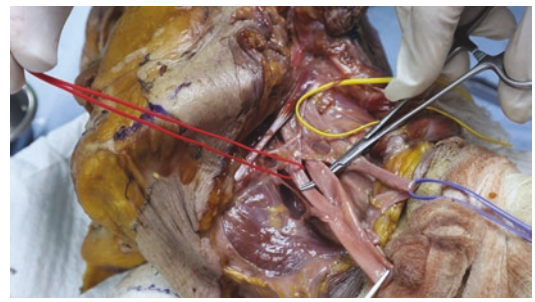

Fig. 2.5 Posterior belly of digastric muscle is visualized, external carotid (red vessel loupe), and IJV (blue vessel loupe)

bleeding from the injured facial artery and tongue deviation and atrophy due to hypoglossal nerve palsy. Further dissection at level Ib and II exposes the posterior belly of digastric muscle, carotid artery (internal and external carotid arteries), and internal jugular vein (Figs. 2.5 and 2.6).

During submandibulectomy, traction on the submandibular glands inferiorly pulls the submandibular duct and gives the appearance of lingual nerve as a 'V' shape. This is due to the duct which crosses the nerve from laterally to medially as it ascends forward (Fig. 2.7). Most com-

monly, the submandibulectomy is performed for pleomorphic adenoma of the submandibular gland's tumour (Fig. 2.8). It is a benign tumour and prone to recurrence if the capsule of the mass is breached during surgery. The hypoglossal nerve (Fig. 2.9) and lingual nerve are two most critical nerves to be identified and preserved during a submandibulectomy.

Fig. 2.6 Submandibular gland (arrow) is retracted inferior-laterally revealing the digastric tendon (white star). External jugular vein (black star) is visualized superficially to sternocleidomastoid muscle

Tongue carcinoma is another critical head and neck malignancy as the incidence is on the rise, especially in certain geographic locations such as India where the habit of betel nut chewing predominates. Clinical presentation varies with ulcerative growth, hypoglossal nerve palsy, or tongue muscle atrophy and fasciculation (Fig. 2.10). The management of tongue carcinoma is difficult as the majority of tumours are aggressive and tend to recur, especially in the neck. The anatomy of oral cavity (Fig. 2.11) is delicate as multiple structures within the oral cavity are involved with the process of mastication, taste, swallowing, and speech articulation. Clinical examination with palpation of the tumour mass (Fig. 2.12) and normal-looking adjacent tissues is critical to rule out infiltration by the tumour. Surgical treatment is the mainstay of the treatment of tongue malignancy. Depending on the location of the tumour, T stage, depth of infiltration (DOI), and histological grade, surgi-

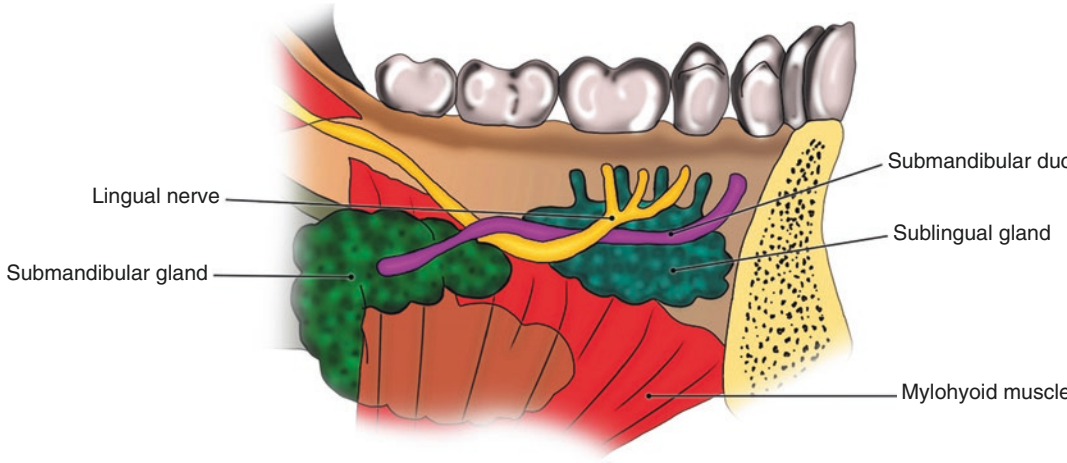

Fig. 2.7 Anatomical relationship of submandibular duct and lingual nerve observed during submandibulectomy. The submandibular duct crosses the lingual nerve from lateral to medial and from posterior to anterior direction. This is an important relationship as during the surgery the traction on the submandibular gland and its duct inferiorly will cause the lingual nerve to appear as 'V' shape. This facilitates identification and preservation of the lingual nerve

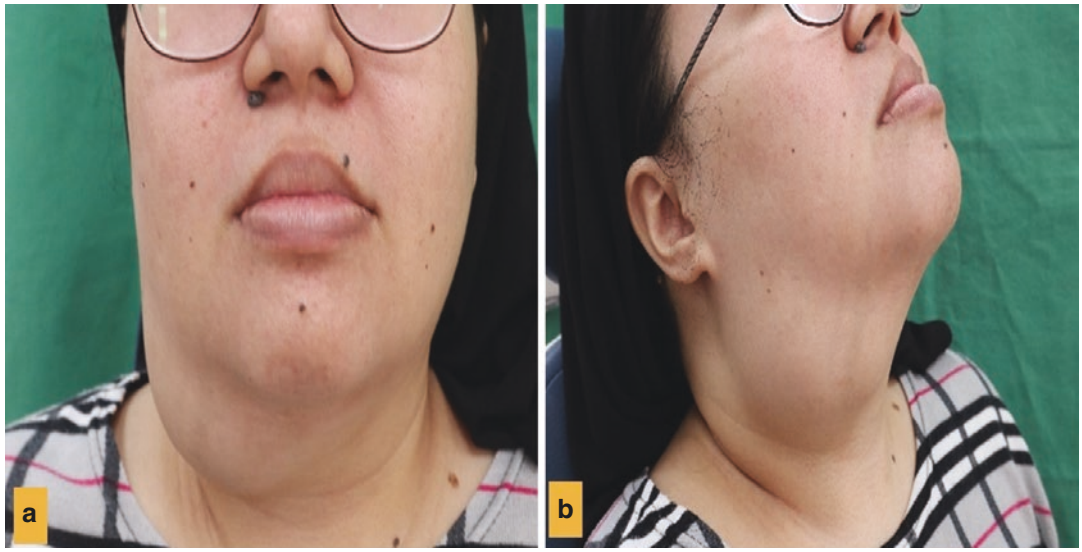

Fig. 2.8 The submandibular gland benign tumour and pleomorphic adenoma in a young patient. (**a**) Right submandibular pleomorphic adenoma in a young female patient. (**b**) The right submandibular mass occupies level Ib, II and III neck region

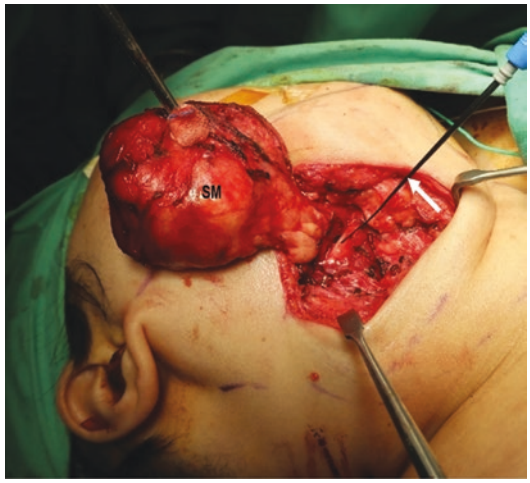

Fig. 2.9 Submandibular mass (SM) retracted superiorly exposing the hypoglossal nerve at the tip of the nerve stimulator probe (arrow)

cal types can be determined early with the incorporation of neck dissection due to high risk of micrometastatic tumour deposit in the neck. Surgery includes partial glossectomy, hemiglossectomy, subtotal glossectomy, and total glossectomy for the primary tumour of the tongue (Fig. 2.13), and supraomohyoid or anterolateral neck dissection for neck metastases. Occasionally, resection of floor of mouth and flap reconstruction, is necessary in higher stage tumours, where there is evidence of involvement in CT scan findings (Fig. 2.14).

There are a few types of mandibulectomy such as hemimandibulectomy, segmental mandibulectomy, and marginal mandibulectomy (Fig. 2.15). The indications of each type of mandibulectomy are different. This mainly depends on the location of the tumour, size, and grade of

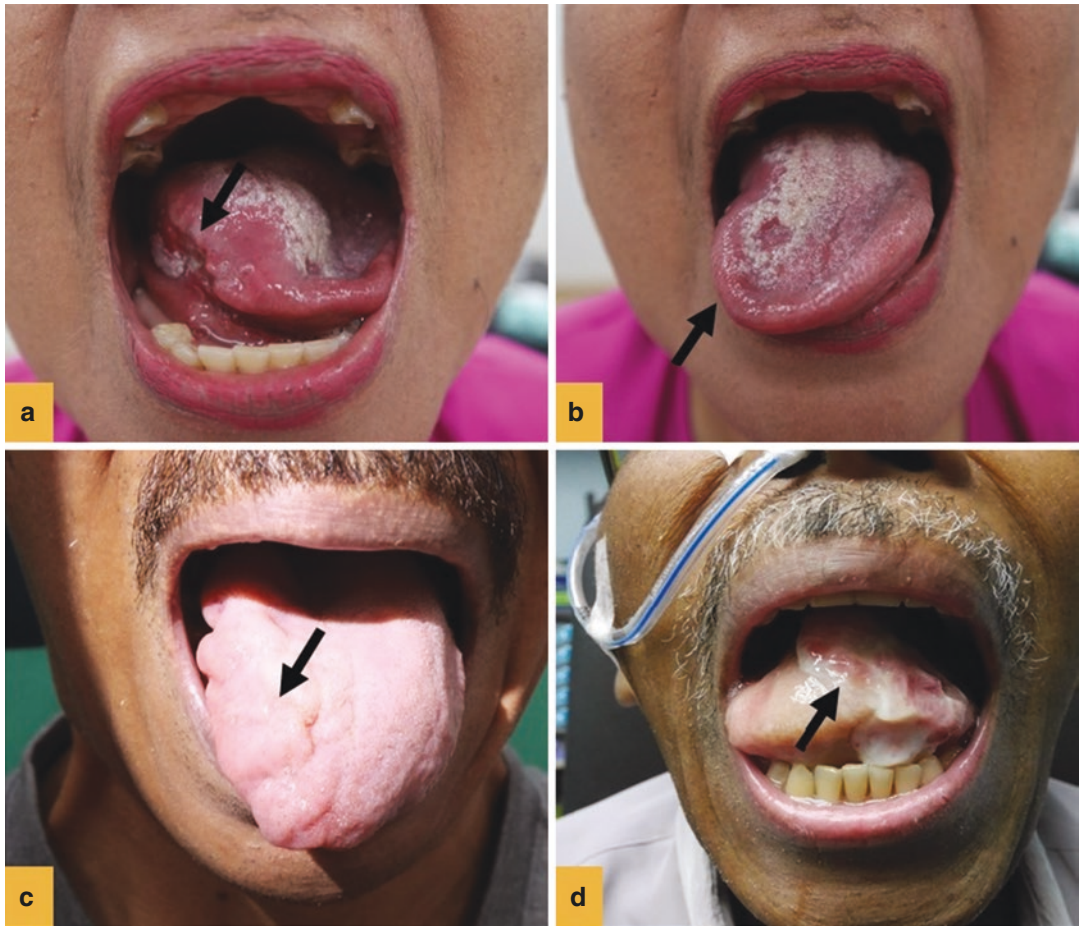

Fig. 2.10 Some examples of tongue carcinoma and its associated features. (**a**) Ulcerative mass at left lateral tongue. (**b**) Ipsilateral hypoglossal nerve palsy as evident with deviation of tip of tongue to the right. (**c**) Fasciculation and atrophy of right tongue due to right hypoglossal nerve palsy. (**d**) Tongue carcinoma of the left side with tip-of-tongue involvement

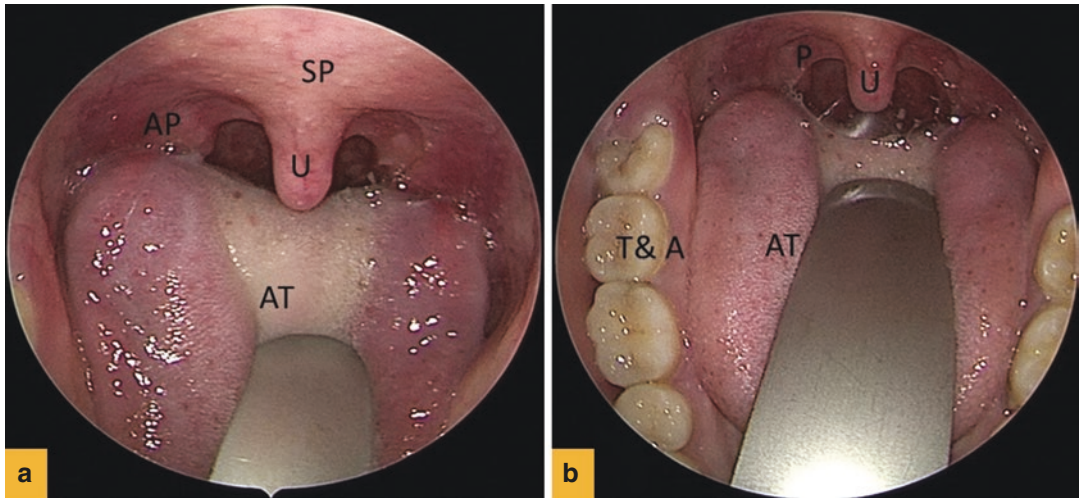

Fig. 2.11 (**a**, **b**) Normal anatomy of the oral cavity, anterior two-thirds of tongue (AT), soft palate (SP), uvula (U), anterior pillar (AP), teeth and alveolus (T&A), lip, floor of mouth, buccal mucosa, hard palate, and retromolar trigone

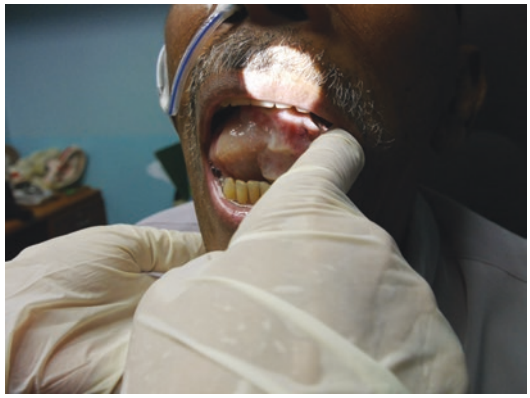

Fig. 2.12 Palpation of tongue mass and adjacent surrounding areas is important to rule out the involvement by malignancy

the tumour. If the tumour lies close to the mandible but on CT scan imaging there is no invasion of the mandibular cortex, then marginal mandibulectomy is recommended. If there is significant invasion of the mandibular cortex, then segmental mandibulectomy should be performed. Hemimandibulectomy is indicated when the tumour is extensive, and its location is direct on the mandible.

In selected cases, only a mandibulotomy (Fig. 2.16) is necessary as an approach to excise the tumour, for instance, the tongue carcinoma that has invaded the floor of mouth. In order to achieve free negative margins, mandibulotomy is an excellent approach.

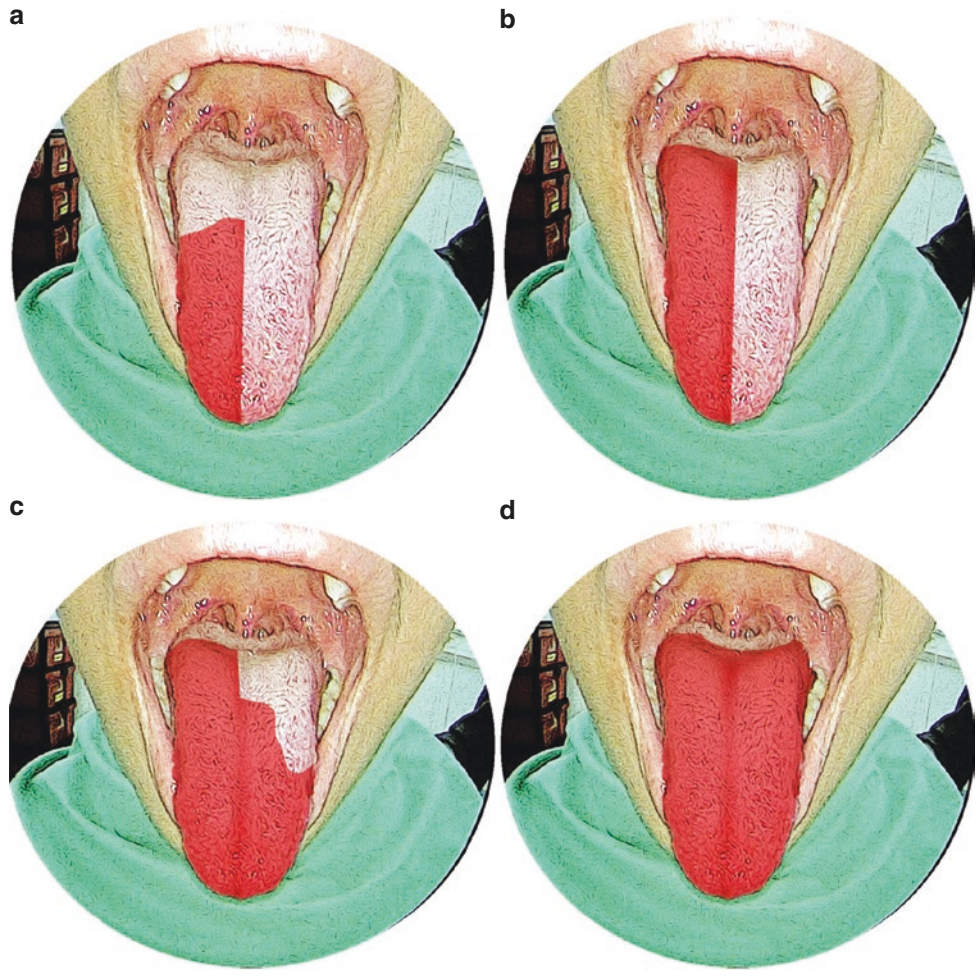

Fig. 2.13 Right partial glossectomy (**a**), right hemiglossectomy (**b**). A right subtotal glossectomy (**c**), total glossectomy (**d**)

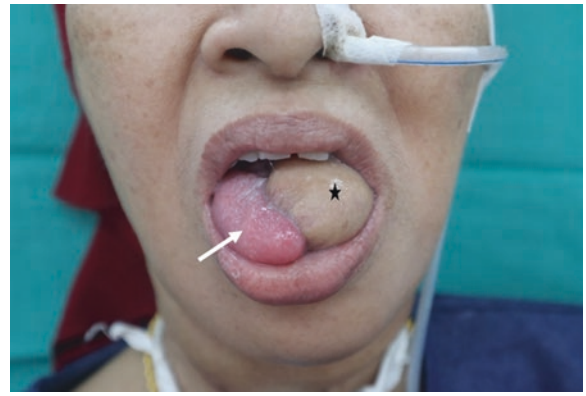

Fig. 2.14 Post-operative tongue surgery, hemiglossectomy with free flap reconstruction (star). Right side of tongue is maintained (arrow)

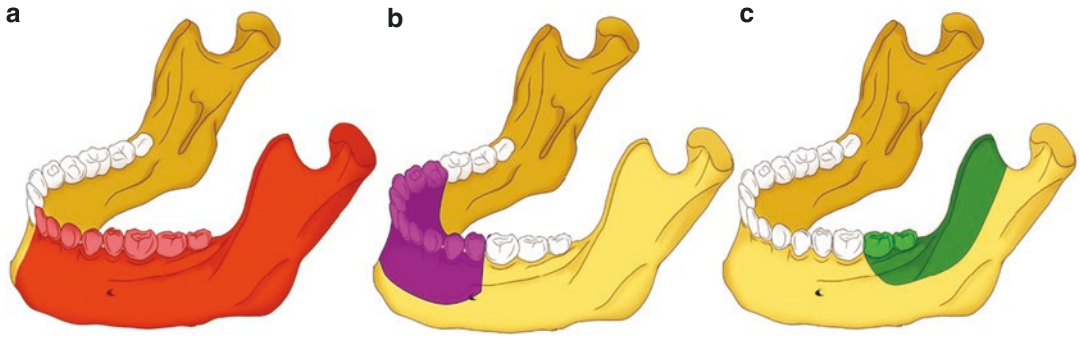

Fig. 2.15 Types of mandibulectomy. (**a**) Left hemimandibulectomy. (**b**) Marginal mandibulectomy (anterior). (**c**) Marginal mandibulectomy (left lateral)

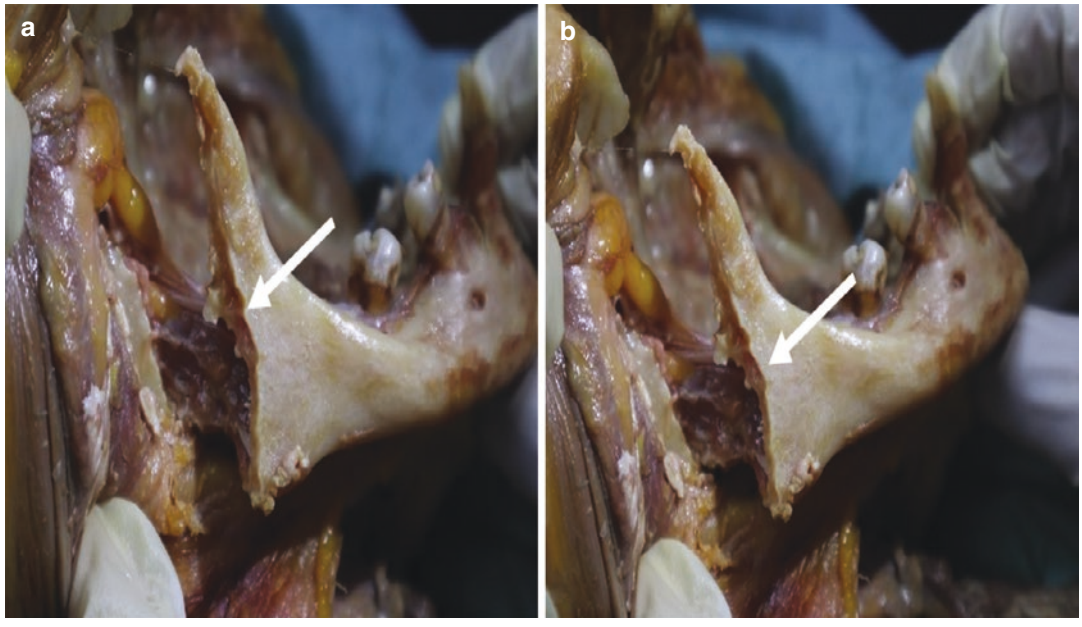

Fig. 2.16 (**a**, **b**) A lateral mandibulotomy is a cut on the mandible. This is an ideal approach for resection of the posterior or lateral tongue tumour, which is deeply invasive

2.2 Principle of Surgery for Head and Neck Cancer

It is highly critical for a surgeon to perform a safe surgery. A safe surgery encompasses a surgery that was conducted effectively without any serious complications or related morbidity. Any unwanted morbidities from a surgical procedure will impair patients' function and quality of life. In addition, it will also add significant cost and burden to the institution as the hospital stay will be prolonged and more human resource will involve in the management of the case. In order to perform the surgery safely, a surgeon should be well versed with the anatomical details of the organs involved. Additionally, the skills of the surgeon plus the availability of supporting staffs and instruments also influence the outcomes and conduct of any surgery.

A significant component of surgical planning involves evaluation of the tumour for resectability. Some tumours are resectable, whereas others are not. A number of tumour characteristics impart unacceptable functional consequences or a technical inability to clear the disease if surgery were to be attempted in extensive tumour [1]. The imaging tools like CT scan, MRI, and PET scan provide important findings such as primary tumour location, size of the tumour, neck node involvement, and involvement of adjacent critical structures. This is highly crucial for surgical mapping preoperatively and intraoperatively, to ensure that each type of surgery is able to address the adjacent structures that are affected by tumour, so that the procedure can be performed according to the principle of oncologic surgery with minimal related surgical morbidities.

Knowing the details of the involvement of the tumour will allow its en bloc resection. This allows for a complete evaluation of the tumour surfaces and more adequate assessment of the tumour margin by the pathologist. Even though negative surgical margin is the primary end point of the surgery, the function of residual unresected organs and aesthetic should be considered. This is important to avoid the unnecessary tissue resection. Although tumour transection can allow for a more complete assessment of tumour depth and extent by the surgeon intraoperatively, it should be optimized so that unnecessary resection of intact normal structures can be avoided [1]. This is important in terms of preservation of muscles and neurovascular structure, as some of them if sacrificed can result in detrimental consequences that may significantly compromise the patient's quality of life.

Given the anatomy of the head and neck, a surgeon often encounters cranial nerves during the course of surgical resection. The last four cranial nerves are located deep at the level II of the neck. Surgical procedures like neck dissection, submandibulectomy, and excision of vagal schwannomas or branchial cyst will expose these four cranial nerves, and hence they are at risk of injury. The carotid sheath is intimately related with these cranial nerves, and their injury can cause massive bleeding, most commonly from the IJV and its branches. The neural management is difficult in malignancy cases in contrast to benign cases, where the nerves should be identified and preserved. In an extensive malignant tumour, the nerve may or may not be preserved depending on the patient factors and tumour factors. The guidelines are somewhat ambiguous with respect to the management of nerves involved with gross disease. If gross invasion is present and the nerve can be resected without significant morbidity, it should be sacrificed with an adequate proximal and distal stump [1].

Mandibulectomy and mandibulotomy (Figs. 2.15 and 2.16) are critical operations in head and neck surgical oncology. This resection of mandible is necessary in the setting of oral carcinoma with mandibular cortex erosion, malignant parotid tumour located on the mandible, or submandibular carcinoma which is adherent to the mandible. The involved mandible needed to be removed during the resection of the primary tumour in order to reduce the risk of local recurrence. This is due to the presence of micrometastatic tumour deposit in the mandible that may spread the cancer cells to the adjacent structures.

The choices of mandibulectomy depend on the extent of tumour involvement and whether to obtain an adequate tumour-free margin. Additionally, the extent of mandibulectomy is determined by clinical, radiographic, and intraoperative findings. For instance, the guidelines state that marrow space involvement by the tumour is an indication for segmental mandibulectomy. This may be obvious, in some cases, based upon the clinical examination or preoperative imaging. However, determining the extent of resection can be somewhat more difficult in patients with tumours abutting the mandible/periosteum without obvious gross invasion [1]. In this case, the mandible can be debrided or shaved with bone debrider as in marginal mandibulectomy.

Marginal mandibulectomy deficiencies are caused by the removal of a single mandible cortex, whereas segmental mandibulectomy defects are caused by the removal of a whole segment of the mandible, both cortices and medullary space. Defects in the anterior arch, lateral portion of the body, or tibia can all be found after a segmental mandibulectomy [2]. When possible, osseocutaneous microvascular free flaps can be used to repair the ensuing mandibular flaws, avoiding the functional and aesthetic issues that come with a mandibular discontinuity defect.

2.3 Types of Head and Neck Surgery

2.3.1 Oral Cavity Surgery

Many pathologies can arise from the oral cavity. Oral cavity is subdivided into eight anatomic subsites:

(a) Lips
(b) Alveolus
(c) Teeth
(d) Buccal
(e) Tongue
(f) Floor of mouth
(g) Hard palate
(h) Retromolar trigone

There are myriads of pathology that can arise within the oral cavity, which can cause significant complications if not properly treated. Among the pathologies that can arise within the oral cavity include leukoplakia, erythroplakia, ranula, minor salivary gland tumour, and tongue carcinoma. All these lesions can impair the mastication, swallowing, and speech articulation especially if surgical resection involves a significant bulk of the tongue.

Leukoplakia is characterized by a white patch that cannot be rubbed off and is a risk factor for oral cavity carcinoma. It is commonly encountered in a smoker. In the majority of cases, it is a superficial lesion that can be easily excised. The treatment mainly involves transoral laser resection of the leukoplakia patch. Cautery can also be used to resect the mass safely, and at the same time bleeding can also be controlled via coagulation mode. The surgical resection of leukoplakia is both diagnostic and therapeutic.

For oral cancers (Fig. 2.17), a proper surgery is required and is more technically challenging especially in higher stage tumour. Surgery remains the foundation of management for tumours of the oral cavity. Tumour resection should be performed with allowable clinical clearance of 1 cm of adjacent mucosa structures (Fig. 2.18). In T2 tumour, hemiglossectomy may suffice, but for T3 and T4 tumours, either subtotal glossectomy or total glossectomy should be performed. The resection however is complicated as the tongue is a musculature organ and the estimated margin might be underestimated due to the traction used on the tongue pull during resection that overstretches the tongue. For all oral cavity tumours, elective neck treatment should be offered [3]. Additionally, if total glossectomy is to be performed, total laryngectomy also needs to be carried out in order to prevent chronic aspiration.

Tongue carcinoma is an aggressive tumour, and if early aggressive treatment is not implemented, the likelihood of locoregional failure is high. Several other histopathological factors, such as tumour thickness, extracapsular spread of nodal metastasis, and invasion patterns, have been shown to be of prognostic importance. Oral tongue SCC with a tumour thickness greater than

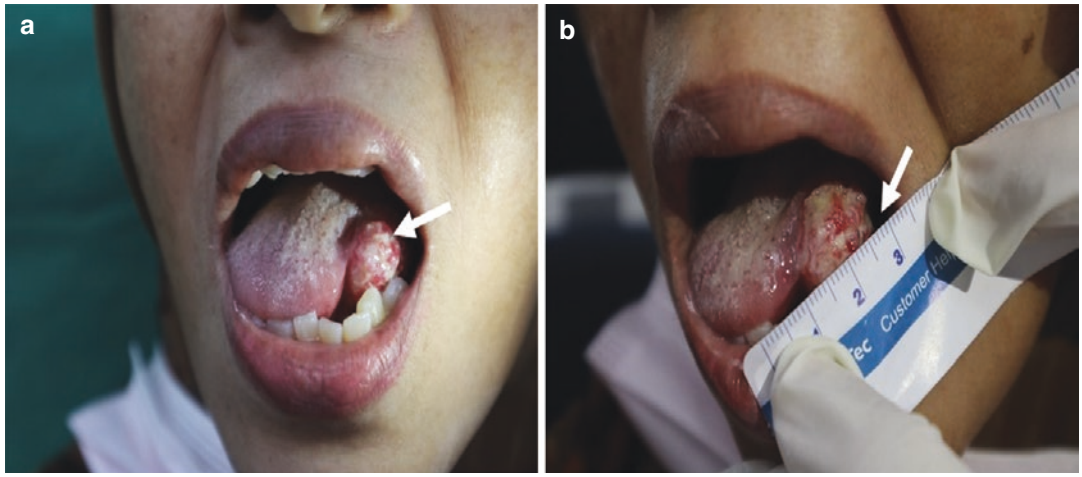

Fig. 2.17 An exophytic growth at left lateral tongue (**a**). This malignant mass needs to be measured for the purpose of staging (**b**)

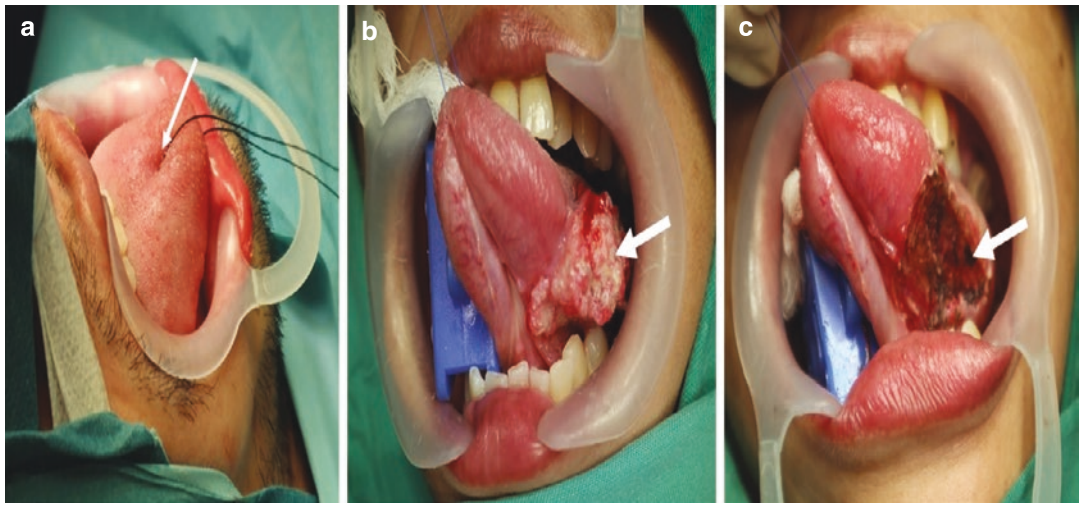

Fig. 2.18 Intraoperatively, tip of tongue is sutured for a retraction to facilitate mass resection (**a**). The malignant mass has spread inferiorly to dorsum tongue with the possibility of floor-of-mouth involvement (**b**). Post-excision biopsy of the mass (**c**)

4 mm is considered to represent a more than 20% risk of metastatic involvement of the cervical lymph node. The increased risk of local regional recurrence, distant metastases, and decreased survival is consistently associated with extracapsular spread in cervical lymph nodes [3]. This necessitates the optimum management of the neck. The lymphatic drainage of tongue and other subsites in the oral cavity thus needs to be comprehensively studied. The lateral tongue tumour should have ipsilateral neck dissection. If the tumour is located at the midline or base of tongue, the bilateral selective neck dissection should be performed.

Under the broad banner of surgery, a number of different options are available: conventional surgery, laser surgery, thermal surgery, and photodynamic therapy (PDT). The choices of the instruments mainly depend on the surgeon's preference and the availability. Curative surgery for

oral cavity cancer involves tumour resection with an appropriate safety margin and subsequent tissue reconstruction to maintain function. Selected instruments may compromise the surgical margins because of the interference with tissue architecture during dissection. Others like facial nerve monitoring if used excessively can lead to neuropraxia and nerve paralysis, which can be disabling during early post-operative recovery.

Although oncologic control remains the primary objective of oral cavity cancer treatment, the function of post-treatment for surviving patients has been recognized as an important secondary outcome over the past decades. Oral cavity defect reconstruction ranges from primary closure to advanced microvascular reconstruction, including multiple types of tissue. The ability to tailor transferred tissue to particular defects has been greatly improved by free flap reconstruction [4]. There are multiple flaps that are available for head and neck cancer reconstruction. Importantly, each of this flap carries its own advantages and disadvantages based on the anatomic profile variation. For instance, the radial forearm free flap can be harvested as flap with long pedicle vessels as the radial artery and veins can be raised according to the length required for reconstruction. Fibula free flap provides ample osteo component for reconstruction of, for example, the mandible.

Thus, great depth of knowledge of the forearm is a must so that the flap can be harvested without unnecessary complications. Meticulous surgical techniques will help with the success of the flap reconstruction. There have been other choices of better flap for oral cavity reconstruction post-tumour surgery as a result of the expansion of microvascular techniques and instrumentations [5]. The complications that may arise from flap reconstruction are critical as it may result in fistula formation, infection, leakage, etc. Thus, a watertight closure is paramount and a refined technique for repairing difficult-access areas like base of tongue and retromolar trigone is a must [6].

Due to the anatomical complexity and limited field of view of the oral cavity, oral and maxillofacial surgery (OMFS) still poses a significant challenge for surgeons. Computer-aided surgery has been widely used to minimize the risks and improve the accuracy of surgery, with the great development of computer technologies [7].

2.3.2 Pharyngeal Surgery

Most of the pharyngeal surgery commonly practised is for oropharyngeal cancer like tonsillar carcinoma (Fig. 2.19). For the hypopharyngeal cancer, most of the time the preferred treatment of choice is chemoradiation. The surgery of hypopharyngeal area is challenging as it has limited access. The adjacent structures like soft palate, tongue, epiglottis and vertebra posteriorly need to be considered during surgical approach to this region (Fig. 2.20). In addition, the surgery can also have significant sequelae on patient's function like swallowing.

For oropharyngeal cancer, the endoscopic assisted surgery can be performed for the primary tumour, together with neck dissection in indicated cases. Knowing the related surrounding structures adjacent to tonsil is very critical for a conduct of safe surgery. The carotid artery lies very close to the tonsil posterolaterally, about 1.0 cm deep. Vigorous resection and dissection may cause injury or rupture to the carotid artery with heavy bleeding.

Additionally, several other branches of arterial and venous supply are in close proximity to

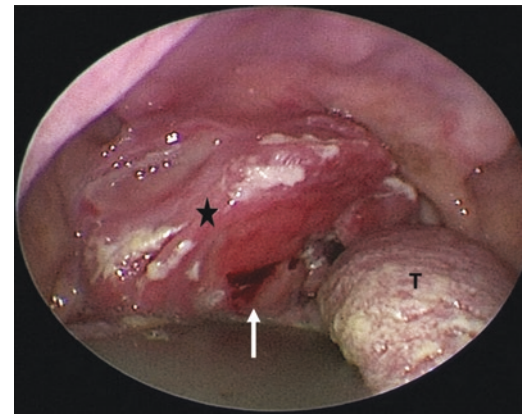

Fig. 2.19 An endoscopic examination of oral cavity and oropharynx showing a malignant mass (star) occupies the right soft palate and tonsillar region. There is minimal bleeding observed (arrow). The tongue (T) is on the left side of the view

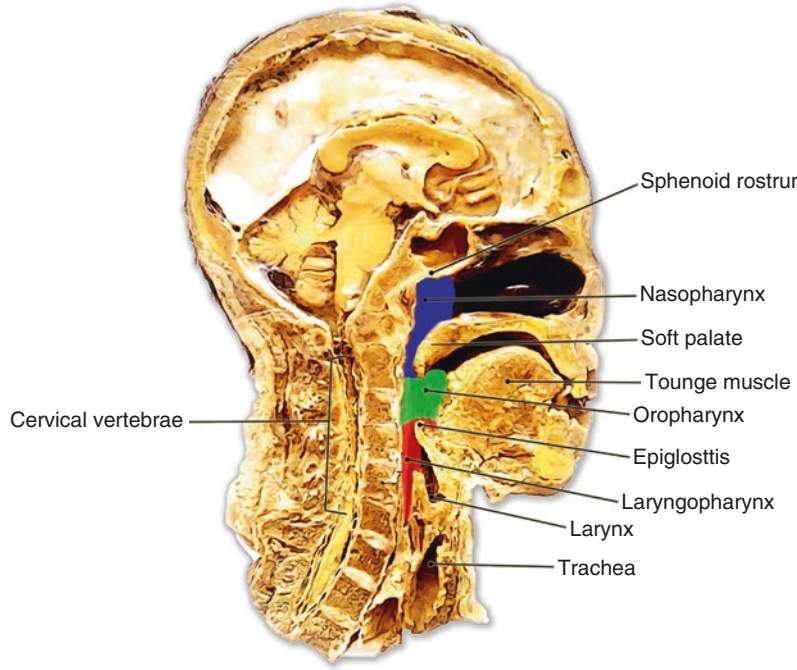

Fig. 2.20 The pharynx is divided into nasopharynx, oropharynx, and laryngopharynx. These three anatomic regions have significant relationship to anterior structures like nasal cavity, oral cavity, epiglottis, hyoid bone, and posterior structures such as the vertebrae

tonsil, which should be identified in order to prevent unnecessary bleeding intraoperatively. Imperatively, the vessel is highly useful for flap reconstruction needed in selected cases where a large of number of tissues and muscles have been resected.

Several nerves like glossopharyngeal nerves lie inferiorly to the inferior pole of the tonsil, and injury may also cause significant morbidity to patients like neuropathy and loss of functions.

The resection of the palatine tonsil deep into the pharyngobasilar fascia is a type 1 lateral oropharyngectomy (Fig. 2.21). It can include all or part of the palatoglossus arch to ensure a radical excision. The superior constrictor muscle is spared by this surgical procedure [8]. It is crucial to consider the patient's condition like presence of trismus or concomitant cervical vertebrae fractures or dislocation that may pose some difficulty for this approach. Patient's dentition may also result in unwanted complications associated with the surgery. Loosening of the tooth or presence of osteoradionecrosis may result in the increment of surgery-related morbidities.

Lateral oropharyngectomy type 2 is performed by removing the entire palatal tonsil, the muscle of the palatoglossus, the muscle of the palatopharynx, and the superior constrictor muscle (Fig. 2.22). The resection's deep limit is represented by the buccopharyngeal fascia, which covers the medial pterygoid muscle anteriorly and the parapharyngeal fat posteriorly. Assessment of adjacent structures' involvement by the tumour can be performed with MRI as it is an excellent imaging modality that delineates soft-tissue characteristics. The surgeon should be well versed with the anatomical details of pharyngeal area and highly trained in order to ensure success of the surgery.

Type 3 lateral oropharyngectomy is performed by removing the entire palatine tonsil, palatoglossus muscle, palatopharyngeal muscle, superior constrictor muscle, buccopharyngeal fascia, and parapharyngeal space fat content with extension to the pterygoid muscle. The muscles of the styloglossus and stylopharyngeus cross the dissection plane and should be fully or partially resected to ensure a safe margin from the tumour [8]. This procedure will result in more complication, especially if the patient is also a candidate for adjuvant radiation. The scarring and fibrosis from post-operative healing and induced by radiation will worsen dysphagia, impair neck movement and mastication, and so forth (Fig. 2.23).

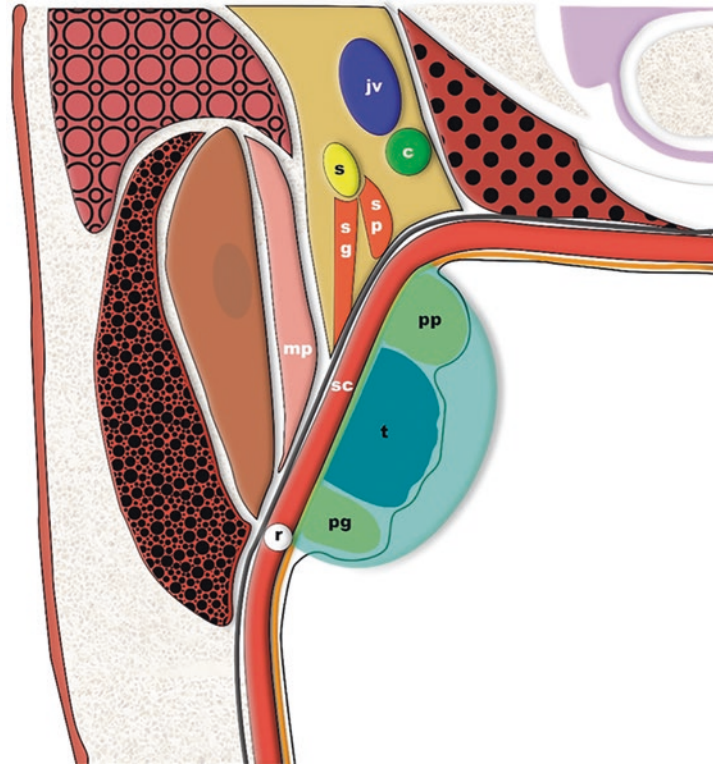

Fig. 2.21 Type 1 lateral oropharyngectomy

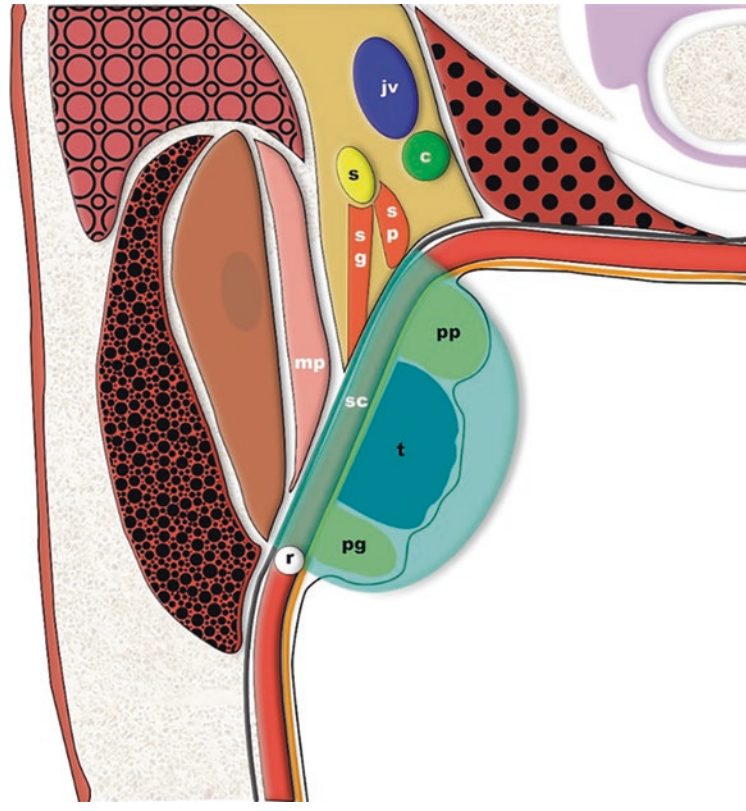

Fig. 2.22 Type 2 lateral oropharyngectomy

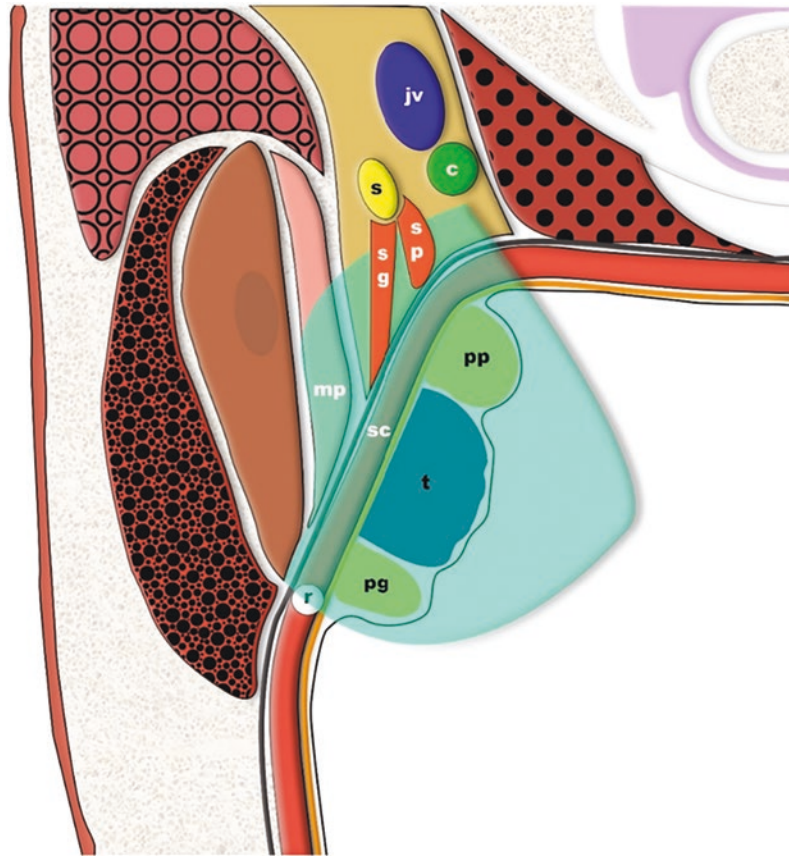

Fig. 2.23 Type 3 lateral oropharyngectomy

2.3.3 Transoral Robotic Surgery (TORS)

The application of TORS has been popularized due to the invention of a robotic system. It is a highly expensive system where a centre with good financial resource will be able to maintain and use these systems [9]. The da Vinci system is well known and has been increasingly used in the head and neck surgical oncology arena.

Minimally invasive approaches, such as transoral robotic surgery (TORS), avoid uninvolved tissue dissection and ensure safe resection without requiring an external incision of the lateral oropharyngeal wall, tongue base, and parapharyngeal tumours [10] (Figs. 2.24, 2.25, 2.26 and 2.27).

Complex transoral anatomy of the oropharynx and parapharyngeal spaces is one of the main challenges of using TORS. The inside-out anatomy of these spaces must be mastered by the robotic surgeon. Limited transoral robotic experience and poor anatomical understanding can cause significant morbidities [10]. Additionally, the issues of obstruction of the visual field and instrument collision are frequently encountered in the setting of TORS [9].

The lateral oropharyngeal wall, based on the styloid muscle diaphragm, was divided into three layers, from medial to lateral. The tonsillar vascularization and the lingual branch of the glossopharyngeal nerve are included in the first layer, medial to styloid muscles. The pharyngeal venous plexus, the glossopharyngeal nerve, and the lingual artery comprise the second layer, which is lateral to constrictor muscles. The third layer includes the parapharyngeal and submandibular

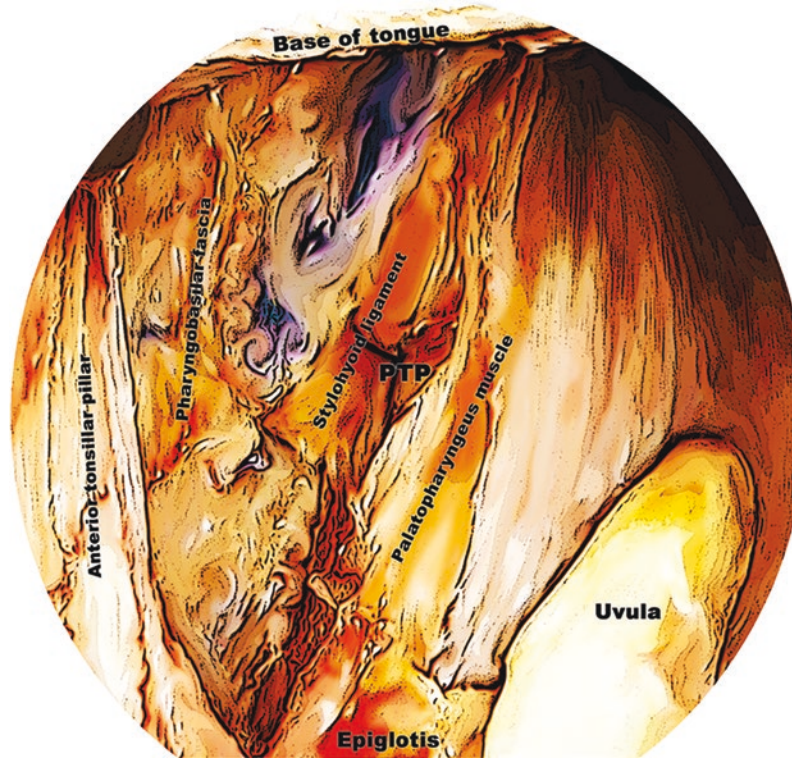

Fig. 2.24 The view of tonsillar fossa after tonsillectomy. *ATP* anterior tonsillar pillar, *BOT* base of tongue, *PTP* palatopharyngeal muscle, *U* uvula. Dotted line, palatopharyngeus muscle; dashed line, stylohyoid ligament; star, pharyngobasilar fascia

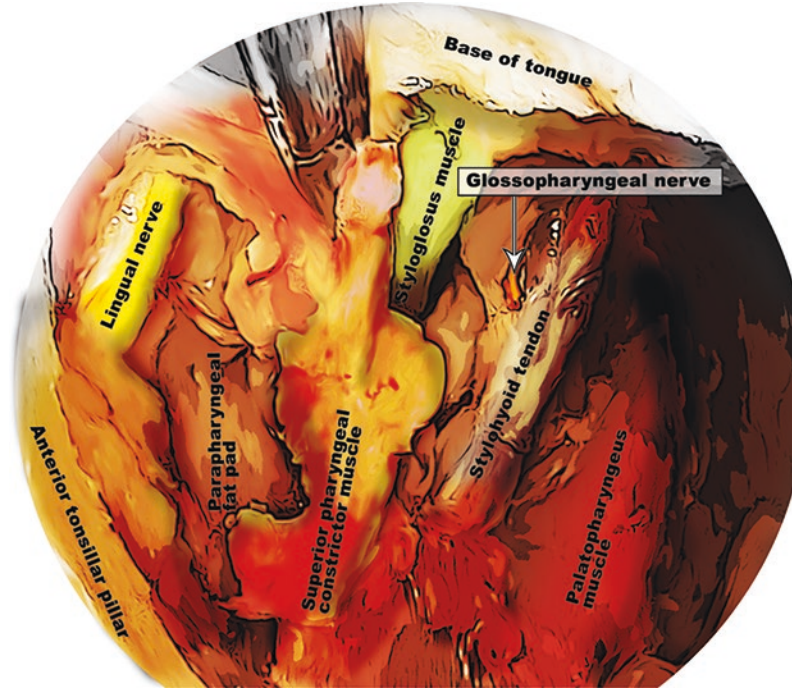

Fig. 2.25 The transoral view of the left parapharyngeal space and its content after resection of pharyngobasilar fascia. *IX* glossopharyngeal nerve, *PFP* parapharyngeal fat pad, *SGM* styloglossus muscle, *U* uvula

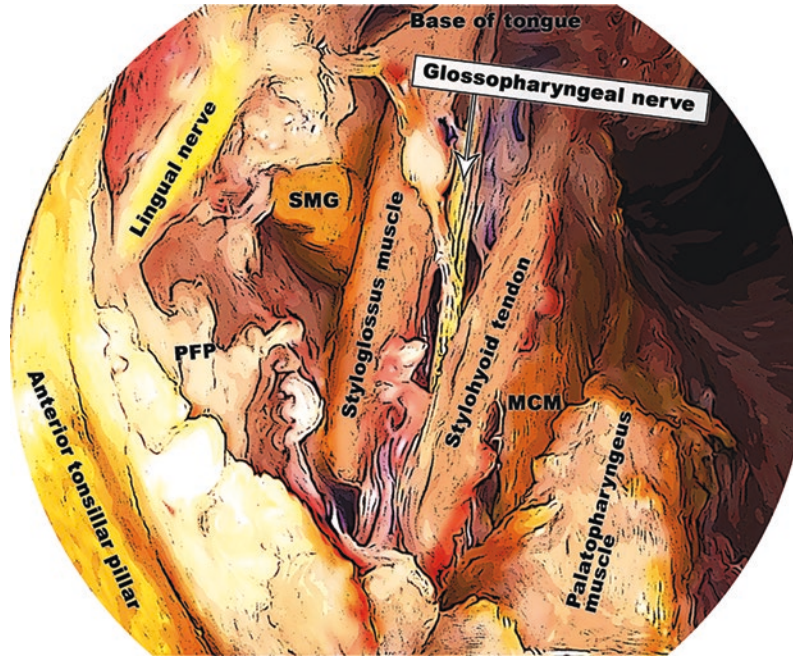

Fig. 2.26 The view of the deep parapharyngeal space after resection of the superior constrictor pharyngeus muscle and partial removal of the parapharyngeal fat pad. *IX* glossopharyngeal nerve, *MCM* median constrictor pharyngeus muscle, *PFP* parapharyngeal fat pad, *SMG* submandibular gland

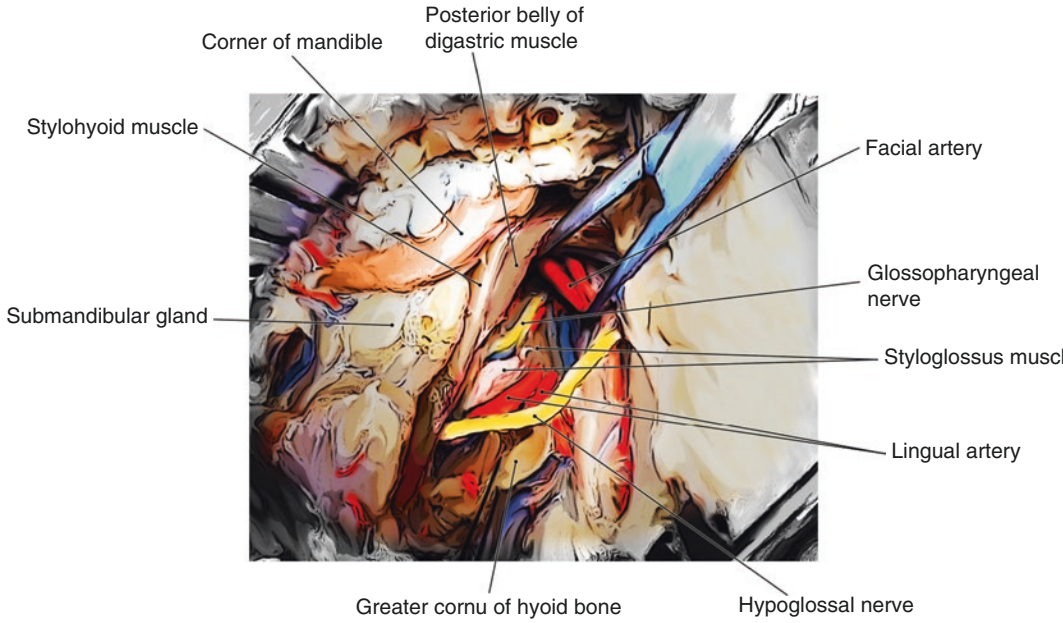

Fig. 2.27 Parapharyngeal structures at the level of tonsillar fossa from the lateral aspect of the neck. Stylohyoid muscle; posterior belly of digastric muscle; facial artery; submandibular gland

spaces, the carotid vessels, and the nerves of the lingual, vagus, glossopharyngeal, and hypoglossal, lateral to styloid diaphragm. The central and lateral parts containing the lingual artery and lingual branches of the glossopharyngeal nerve are divided into the base of the tongue [11].

Inside the tongue base, major neurovascular structures are placed laterally and deeply. Intrinsic and genioglossus muscle dissection is safe because on the lateral surface of the genioglossus muscle, covered by the hyoglossus muscle, the main trunk of the lingual artery lies. Lying on the external surface of the hyoglossus muscle, the hypoglossal nerve, with its concomitant vein, is more lateral [12]. Importantly, the location of the lingual artery was dramatically altered with tongue retraction in reference to the measured surface landmarks. The branches of the dorsal lingual artery were not found posterior to a horizontal line between the midway circumvallate papillate with retraction [13].

2.4 Laryngeal Surgery

Laryngeal surgery is always challenging as it is involved with airway manipulation. Airway manipulation in either way can result in serious airway obstruction and death, if not properly managed due to, for instance, significant airway oedema. Many instruments and endoscopes are required for a proper assessment of any airway pathologies (Figs. 2.28 and 2.29). A committed and strong cooperation with the anaesthetist is crucial for the conduct of a safe airway surgery. The requirement of endoscopes, intubation, and suction portal will narrow the access to control the airway efficiently. Thus, a surgeon needs to be well versed with the handling of endoscopes and other instruments to facilitate a safe and efficient surgery.

Laryngeal cartilages have intimate relationship with oesophagus, thyroid cartilage, carotid artery, IJV, and important nerves like recurrent laryngeal

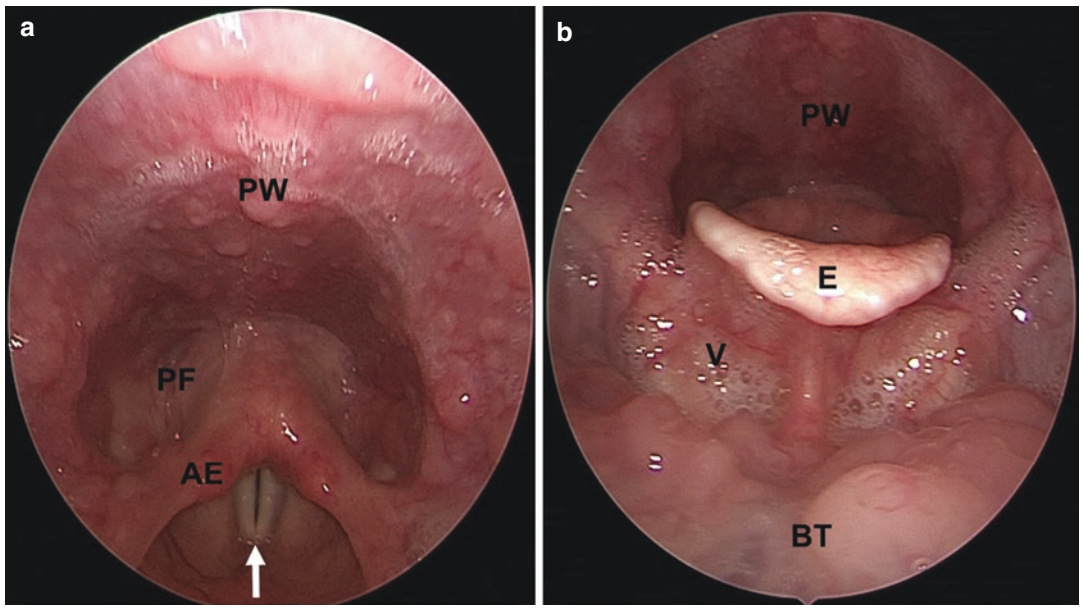

Fig. 2.28 (**a**, **b**) Endoscopic view of the larynx shows normal laryngeal structures like epiglottis (E) and aryepiglottic fold (AE). Other critical adjacent structures like valleculae (V), pyriform fossa (PF), posterior pharyngeal wall (PW), and base of tongue (BT) can also be assessed

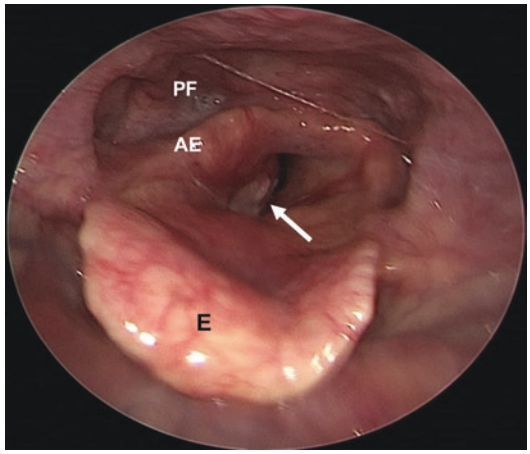

Fig. 2.29 An ulcerative white lesion (arrow) of the right vocal cord. This is proven to be a glottic carcinoma on the histopathological examination. The right vocal cord is fixed, which signifies a T3 tumour

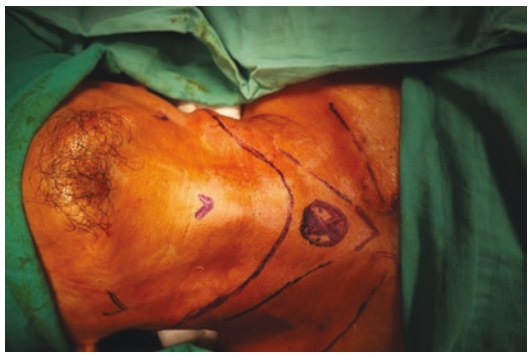

Fig. 2.30 Markings of landmarks are critical during the surgery. This is a case planned for a laryngectomy where the incision site, thyroid notch, and stoma site have been identified

nerve. All of these important structures have significant functions and, if injured during surgery, can result in detrimental sequelae that can impair the patient's quality of life post-operatively.

There are different types of laryngeal surgery that necessitate, for example, the surgical removal of the epiglottis alone or in combination with structures like thyroid cartilage. Thus, knowledge of the anatomy of these adjacent structures and neurovascular supply to each of these structures is vital. Total laryngectomy, on the other hand, will involve the resection of trachea, construction of pharynx, and neck dissection. The surface anatomy of the neck is critical for the identification of structures, for example, during designing a skin incision for a laryngectomy case (Fig. 2.30). This again will require great anatomy knowledge and details of these structures involved and their vascular supply, innervation, and lymphatic drainage.

2.5 Nasal Cavity and Nasopharyngeal Surgery

Nasal cavity can be the origin of many important pathologies such as polyposis, benign tumour such as inverted papilloma or juvenile nasoangiofibroma (JNA), and malignancy like squamous carcinoma and lymphoma (Figs. 2.31, 2.32, and 2.33). Nasopharynx is the origin of nasopharyngeal carcinoma, which is highly prevalent in geographic areas like Southeast Asia, South China, Hong Kong, Japan, and Korea [14]. The tumour originates from the fossa of Rossenmuller, a groove posterior to the eustachian tube opening at the nasopharynx region.

The anatomy of osteomeatal complex and sinuses is critical as endoscopic surgery is commonly performed in this narrow area with the application of many surgical instruments. Aggressive and higher stage tumour mandates surgical excision via an external approach like maxillectomy. Total maxillectomy has a significant impact on patient aesthetics and functions, which needs to be properly addressed by surgeons, so that the treatment outcomes are optimal and quality of life is maintained. Nasopharyngeal carcinoma patients has a tendency for neck nodes metastasis (Figs. 2.34 and 2.35). The majority of these nasopharyngeal carcinoma patients will be treated with chemoradiation.

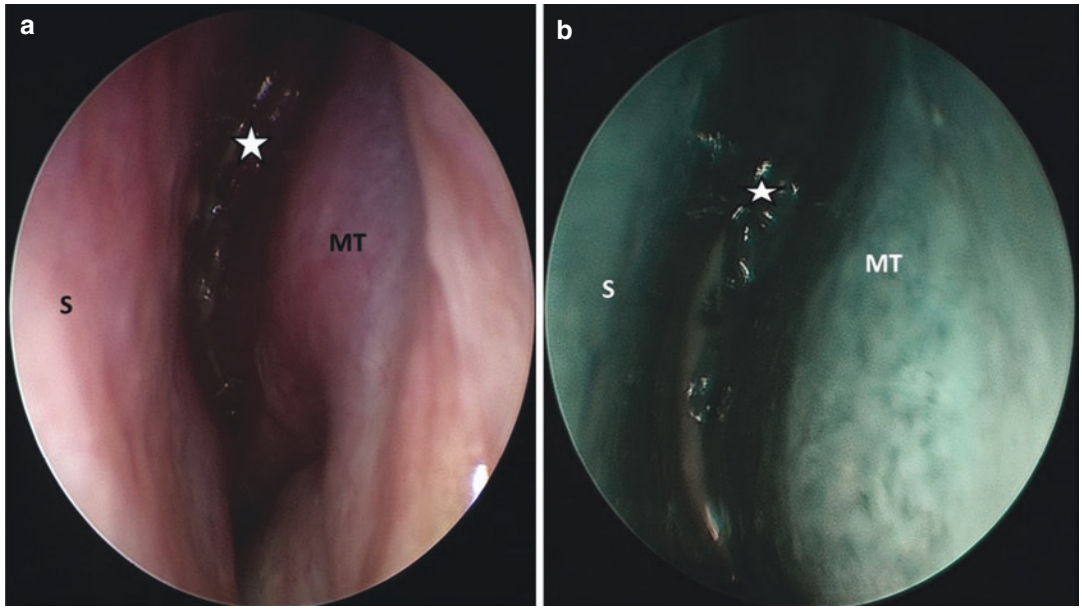

Fig. 2.31 (**a**, **b**) The nasal endoscopy of right nasal cavity showed a normal structure of middle turbinate (MT) and septum (S)

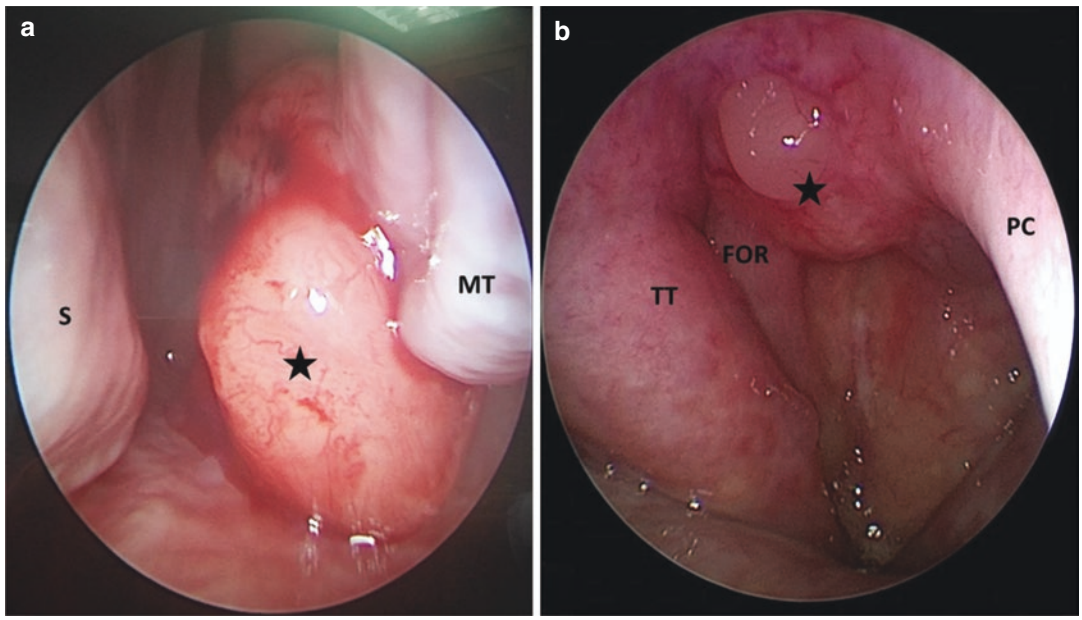

Fig. 2.32 (**a**, **b**) The nasal endoscopy showed tumoural mass arising from the right middle turbinate (MT). This tumoural mass is mildly vascularized and hyperaemic. There is mucosal mass at the left posterior pharyngeal wall (star) abutting the fossa of Rosenmuller (FOR), which is located posterior to the torus tubarius (TT). The end of septum is the region of posterior choanae (PC)

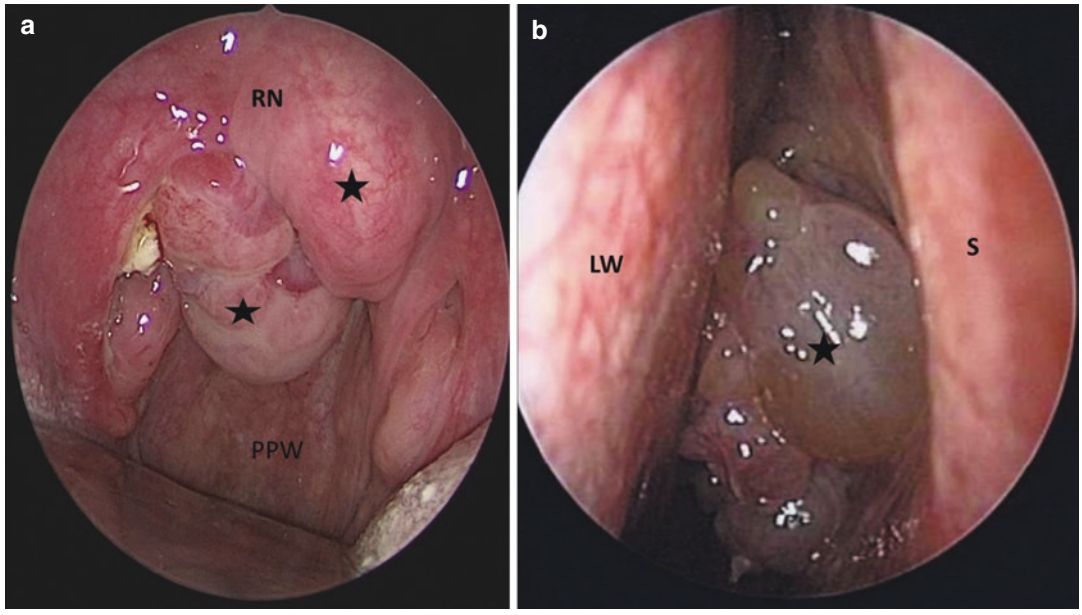

Fig. 2.33 (**a**, **b**) An endoscopic view showed an extensive mass (stars) arising from the posterior pharyngeal wall (PPW)

Fig. 2.34 The appearance of neck metastases (arrow) from the nasopharyngeal carcinoma in a young Chinese lady

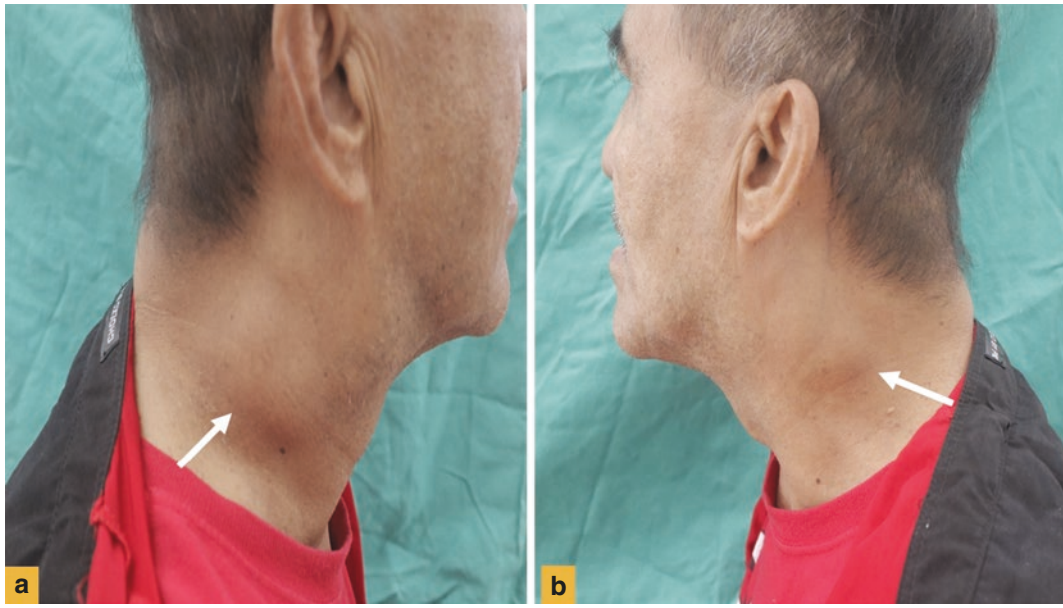

Fig. 2.35 (**a**, **b**) Multiple neck metastases are visualized on an elderly Malay male patient with nasopharyngeal carcinoma

2.6 Salivary Gland Surgery

Salivary glands comprise parotid glands, submandibular glands, and sublingual glands. Most of the surgery involves the parotid glands, i.e. parotidectomy, and the submandibular glands, i.e. submandibulectomy. Most of the pathology affecting the glands is pleomorphic adenoma.

Parotid glands are closely related to facial nerve, which runs between the superficial lobe and deep lobe of parotid glands. The identification and preservation of facial nerve are very important in parotidectomy so that facial asymmetry and persistent facial disfigurement can be avoided. This is especially true for the surgery of parotid, i.e. superficial parotidectomy for pleomorphic adenoma (Fig. 2.36). Thus, a complete facial nerve examination (Fig. 2.37) need to be performed preoperatively in every parotid cases going for parotidectomy.

The landmarks for identification of facial nerve in parotid surgery include

1. Tragal pointer
2. Posterior belly of digastric
3. Tympanomastoid suture

The peripheral branches of facial nerve need to be identified and preserved in all benign operated cases of parotid gland tumour. The injury and oedema induced during surgery can causes nerve paresis with the resultant functions like lid closure, blowing of cheek, and drinking fluids. Impairment of nerve functions will result in significant deterioration of patient's daily function and, hence, impair the quality of life of these patients. There are other

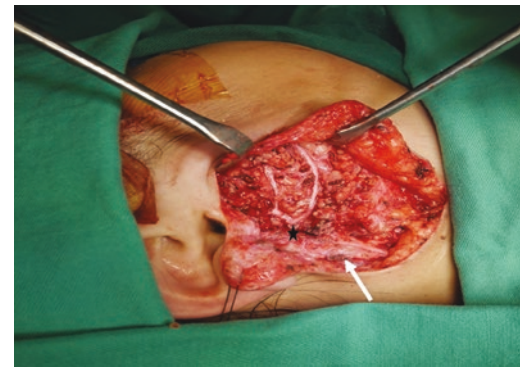

Fig. 2.36 In parotid gland surgery, the identification and preservation of the facial nerve trunk and its branches are crucial for good treatment outcomes and patient's quality of life

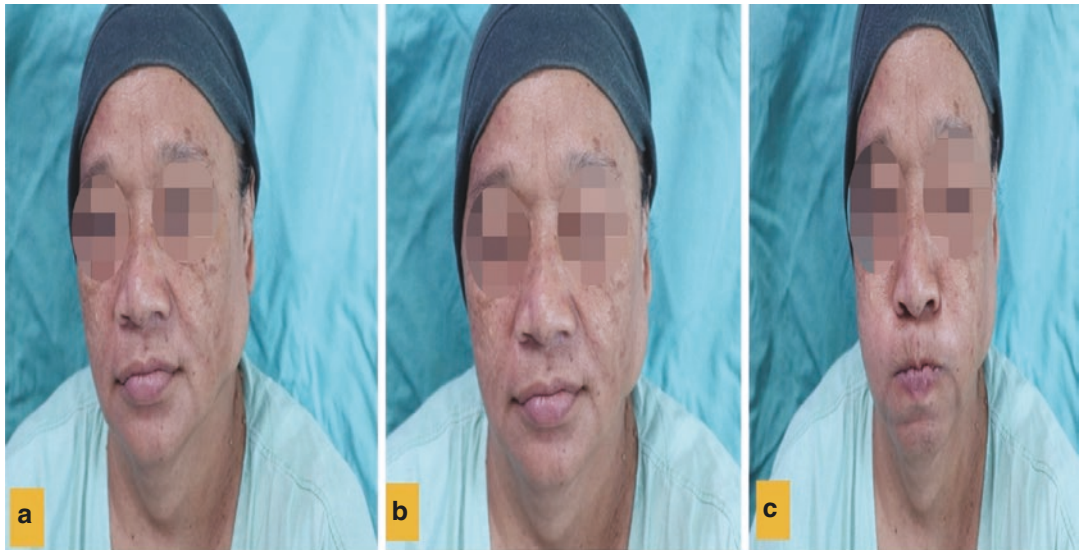

Fig. 2.37 Assessment of facial nerve and its function is critical before embarking on the parotidectomy. This includes the upper branch that supplies the orbicularis oculi and the buccal branch that supplies the buccinator muscle. (**a**) Preoperative facial nerve function should be assessed in all cases going for parotidectomy. (**b**) The upper temporozygomatic branch is intact. (**c**) Buccal branch is intact

critical complications from the parotid gland's surgery, e.g. Frey's syndrome and retromandibular depression.

Frey's syndrome is characterized by involuntary sweating, pain, and discomfort at the region of parotid bed due to the reinnervation of parasympathetic parotid glands to the sweat glands of the skin. The majority of patients do not report this symptom, unless more objective test like a Minor starch iodine test is carried out. Alternatively, the sternomastoid muscle lies inferolateral to parotid glands and can be used to prevent complications of Frey's syndrome. It can be harvested during the same surgery and rotates superoanteriorly to cover the surgical defect. By doing this, the flap will prevent reinnervation of the parasympathetic fibres. Additionally, this rotational flap will reduce the retromandibular depression that causes significant cosmesis embarrassment post-surgery (Fig. 2.38).

Submandibulectomy entails removal of the submandibular gland. In order to safely remove the submandibular glands, the adjacent structures also need to be addressed. The marginal mandibular nerve lies on the submandibular gland capsule. The facial artery and vein, which need to be ligated, lie deep to the glands. In addition, at the medial part of the glands, the hypoglossal nerve and the lingual nerve lie below the mylohyoid muscle and are at risk of injury. The submandibular mass can be malignant like lymphoma (Figs. 2.39 and 2.40) or benign pleomorphic adenoma (Fig. 2.41). The principle of surgery is similar, with a subplatysma flap elevation an dissection of the mass and preservation of neurovascular structures (Figs. 2.42, 2.43, and 2.44).

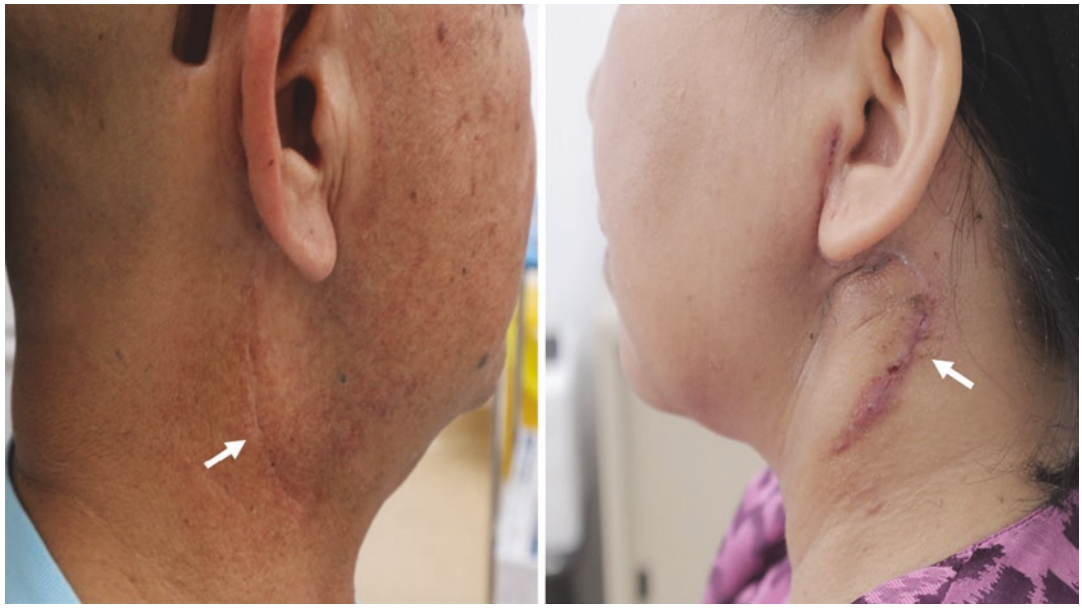

Fig. 2.38 Post-parotidectomy scar is visible at the neck region. Minimal retromandibular depression is also evident in both patients. These are some of the complications in patients who underwent parotid gland surgery

Fig. 2.39 There is an ulcerative mass overlying the anterior mandible and level Ib (arrow)

Fig. 2.40 The mass causes left marginal mandibular nerve paresis as evident by loss of depression of left lower lip. This signifies that it is a malignant mass

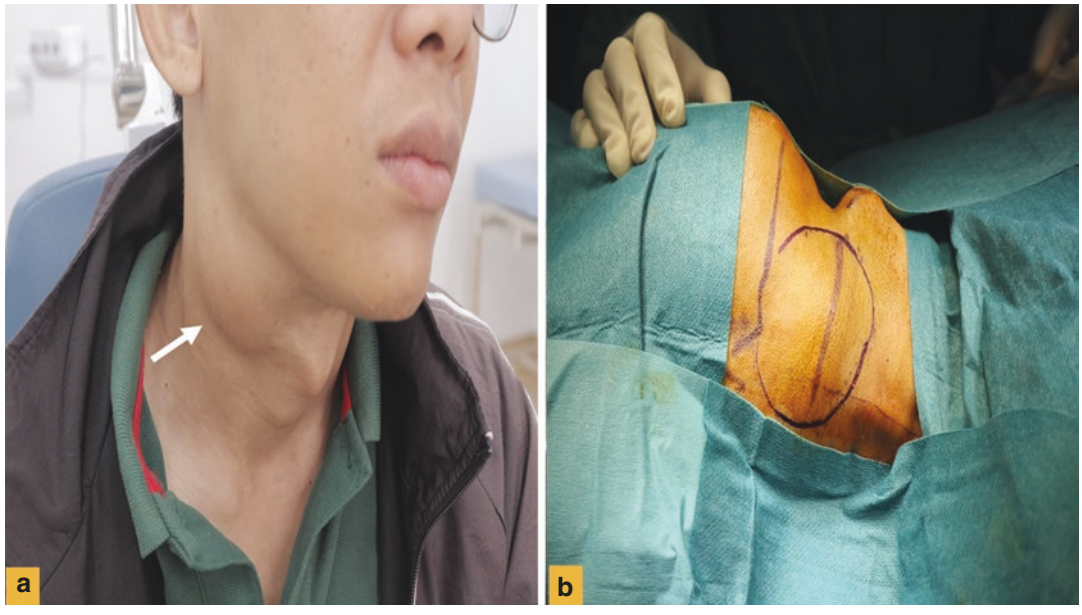

Fig. 2.41 This is a young male with a right submandibular gland's benign tumour, pleomorphic adenoma (**a**), which necessitates a submandibulectomy (**b**) for this patient

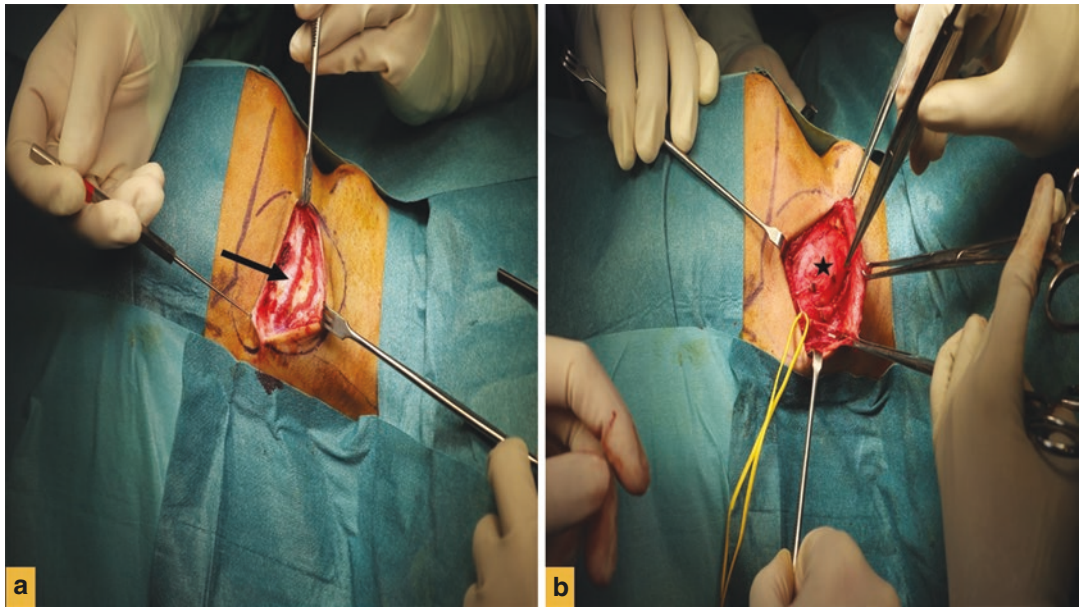

Fig. 2.42 During a submandibulectomy, a subplatysmal skin flap is raised. The platysma muscle is evident (arrow) as in (**a**). The submandibular mass (star) is visualized in (**b**)

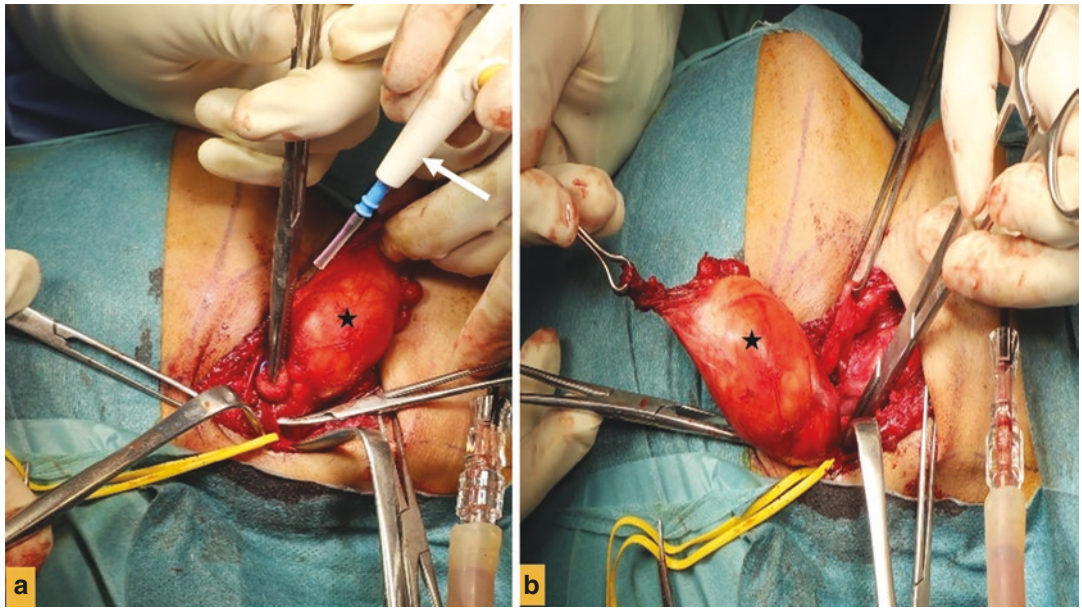

Fig. 2.43 The submandibular mass (star) is retracted and dissected (**a**, **b**)

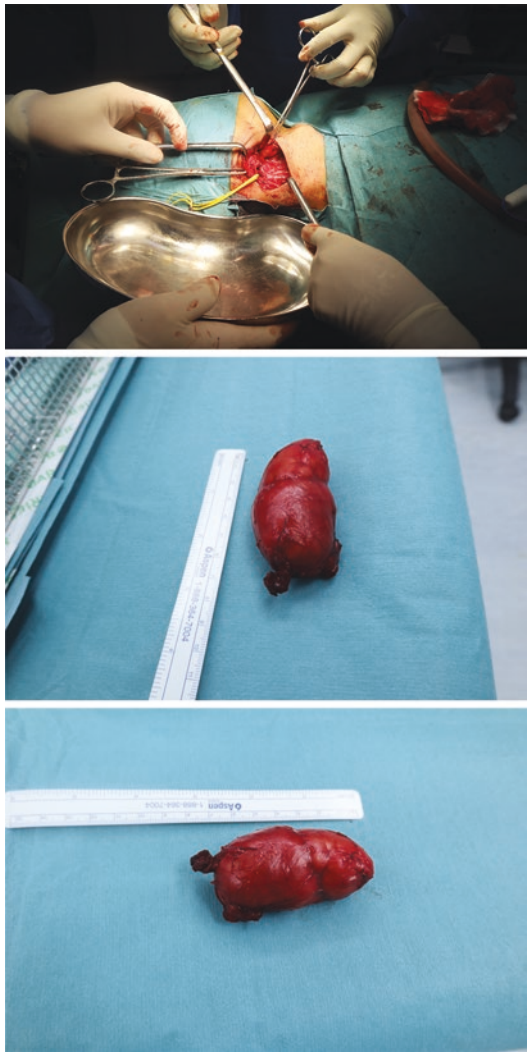

Fig. 2.44 The mass has been removed, and the surgical defect is visible as in the photograph

2.7 Thyroid Gland Surgery

Thyroid surgery can now be performed today with a mortality that varies little from the risk of general anaesthesia alone. Unfortunately, decades later, complications still do occur. To obtain excellent results, surgeons must have a thorough understanding of the anatomy of head and neck and pathophysiology of thyroid disorders. They should be well versed in the preoperative and post-operative care of patients; have a clear knowledge of the anatomy of the neck region; and use an unhurried, careful, and meticulous operative technique. Like in any head and neck surgery, surgeons operating by a clock have no place in thyroid surgery. A meticulous and organized approach is mandatory [15].

The importance of anatomical structures and its relationship in the thyroid gland surgery is for the identification and preservation of the recurrent laryngeal nerve and parathyroid glands. The Zuckerkandl tubercle (ZT) is a lateral projection from the lateral thyroid lobe that during thyroid surgery is a constant landmark for finding the recurrent laryngeal nerve. Located in the cricothyroid junction, it is the condensed thyroid parenchyma [16]. In most cases, the Zuckerkandl tuberculum was identified, with prevalence to the right. Its identification has made it possible to identify the recurrent laryngeal nerve immediately and safely, setting the time of the operation and, in particular, the possible injury to the recurrent nerves [17].

A classification system with 37% of the nerves crossing the superior thyroid pedicle within 1 cm of the superior thyroid pole was defined by Cernea et al. (type 2). More recently, 1057 SLNs studied at the time of thyroidectomy were analysed by Friedman et al. They suggested a classification system with three anatomical variations, including type 1 with the nerve running superficially to the lower constrictor muscle, type 2 with the nerve penetrating the lower part of the lower constrictor, and type 3 with the nerve penetrating the upper part of the lower constrictor muscle and remaining covered by the muscle on its course to the cricothyroid muscle [18].

Total thyroidectomy is performed with anelevation of sublatysma skin flap, lateralize/cut on the strap muscle, dissection of the mass with preservation of the recurrent laryngeal nerve, and exposure and preservation of trachea and cartilages (Figs. 2.45, 2.46, 2.47 and 2.48). The parathyroids must be identified from a surgical point of view and preserved with an intact blood supply. The plane of dissection along the thyroid capsule is used for medial-to-lateral dissection. In the usual locations, the parathyroids are identified. They are seen with a yellow tan to caramel colour as tiny bean-shaped structures. This medial-to-lateral dissection, while preserving the blood supply, allows identification and mobilization away from the thyroid [18]. Robotic thyroid

surgery is a relatively new technique that provides the patient with the aesthetic advantage of a surgery without a scar in the anterior cervical region. The use of this technique, however, forces the surgeon to view the anatomy from a different vantage point, concomitantly providing the surgeon with a challenge with respect to dissection and sound oncologic ablation [13].

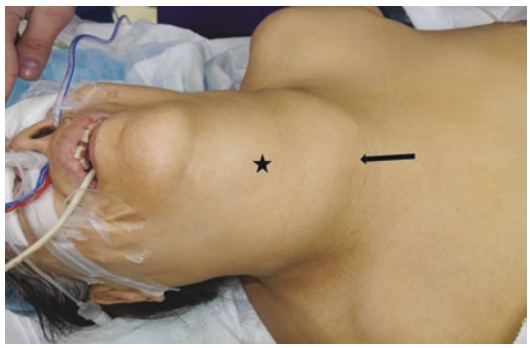

Fig. 2.45 A malignant thyroid tumour in a young lady planned for a total thyroidectomy

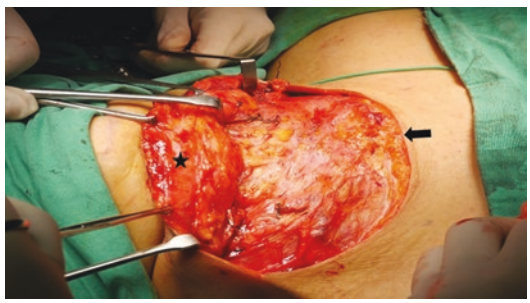

Fig. 2.46 A collar skin incision is performed, and the subplatysmal skin flap (star) is raised superiorly

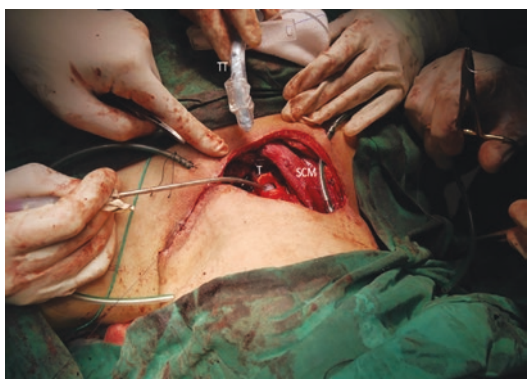

Fig. 2.47 After removal of the thyroid mass, the tracheostomy tube needs to be secured as preoperatively there is presence of vocal cord palsy. With manipulation during the surgery on the recurrent laryngeal nerve, there is risk of bilateral vocal cord paresis with an airway obstruction

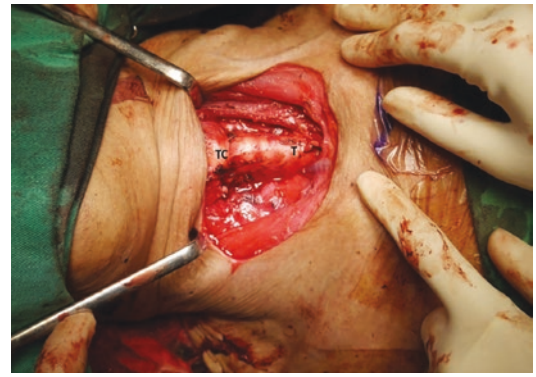

Fig. 2.48 Post-thyroidectomy, the tracheal ring (T) and thyroid cartilage (TC) are visualized

2.8 Neck Dissection

Neck dissection is a critical surgery in the head and neck surgical oncology arena. Most of the head and neck tumours will have neck involvement at certain stages of the tumour management. It is very important to have a thorough understanding of the anatomical structures of the neck and critical landmarks that can be used as a guide during clinical assessment, procedure, and surgical dissection.

Critically, the status of neck lymph nodes remains the single most important prognostic factor, in these cases. The management of neck metastases has evolved over the years. This has ultimately led to the conservative approaches of selective neck dissections depending on the primary site of the tumour, type of tumour, and characteristic features of the metastases themselves [19]. The neck is divided according to triangles and also the neck node levels. The classification of the triangle is crucial for the knowledge of details of structures and its neurovascular supply. The neck node level is important for a proper planning of types of surgical intervention. Particularly relevant is the lymphatic drainage to the neck node level, from the primary anatomic region. Different subsites of anatomic region will drain to different areas of the neck, which trans-

Fig. 2.49 A cadaveric dissection specimen showed critical structures in the neck including the omohyoid muscle, common carotid artery (CCA), internal jugular vein (IJV), spinal accessory nerve (SAN), and sternocleidomastoid muscle (SCM)

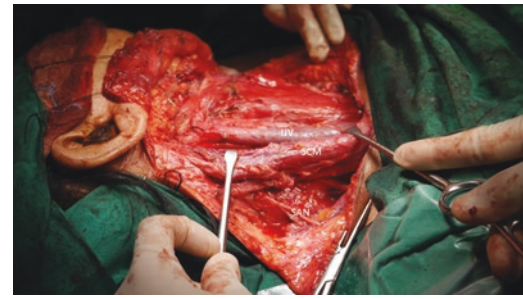

Fig. 2.50 Post left modified radical neck dissection with spinal accessory nerve (SAN), internal jugular vein (IJV), and sternocleidomastoid (SCM) is preserved

lates to the different areas of neck metastases. The better understanding of the lymphatic drainage of head and neck region by Rouviere et al. made it possible to predict the pattern of lymphatic drainage in a cancer involving a particular region, and neck dissections thus became more and more conservative and selective [15].

Neck dissection is classified based on which neck node level is removed during surgery. The surgical step is performed in a way that is in reference to a specific point or surgical landmarks. The correct landmarks are critical to ensure an optimum clearance of the tumour and its risk areas of micrometastatic deposits. For instance, the landmark in the posterior triangles is the Erb's point where the greater auricular nerve exits at the posterior border of sternocleidomastoid muscle. The spinal accessory nerve enters the posterior triangles approximately 2.0 cm above the Erb's point [20]. This landmark is used during neck dissection in order to identify and preserve the SAN (Fig. 2.49).

Salvage neck dissection is necessary in selected cases of recurrent tumour. This poses surgical difficulty as the normal anatomical pattern has been disturbed due to the fibrosis post-surgery or due to chemoradiation. In order to limit significant morbidity from a comprehensive neck dissection that is commonly employed for recurrent tumour, some cases can be addressed safely with selective neck dissection. This is especially true if recurrent neck metastases are single, small in size, and located at one level only. Although a comprehensive neck dissection like modified radical neck dissection (Fig. 2.50) has been the standard treatment for individuals with recurrent or persistent neck disease following chemoradiation, there is growing evidence that most patients can be effectively treated with a selective neck dissection [21].

2.9 Ear and Temporal Bone Surgery

Temporal bone surgery and middle-ear surgery are challenging due to close relationship with the facial nerve. Facial nerve runs in the middle ear at the medial wall before passing through to the stylomastoid foramen and entering the parotid gland. The mastoid segment of the nerve runs in a line starting from fossa incudis where short process of incus lies to the anterior end of the digastric ridge. Because the facial nerve follows a fairly predictable path within the temporal bone, unintentional injuries are uncommon in skilled hands [22].

A refined surgical technique is thus necessary for a safe surgery and minimizing the complications to the middle ear and adjacent structures (Figs. 2.51, 2.52 and 2.53).

2.9.1 Paediatric Surgery

Paediatric head and neck surgery is technically demanding due to multiple critical factors that need a careful consideration. Generally, paediat-

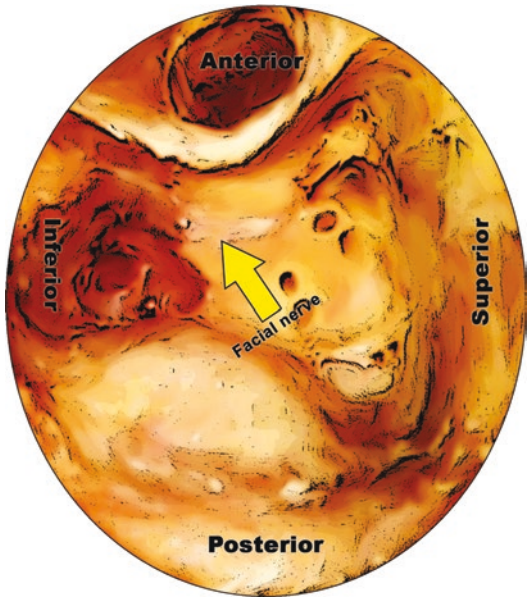

Fig. 2.51 During mastoidectomy, identification of facial nerve (arrow) as it runs in the temporal bone is critical. This avoids inadvertent injury to the facial nerve during dissection

ric head and neck anatomy is significantly different to the adult anatomy. The laryngeal cartilages have different sizes, location, angulation, and other characteristics. The epiglottis and trachea are different in shape and size, which influences the detailed techniques of the surgery. The nerves such as facial nerve are also located more superficially in the neck in contrast to the adult facial nerve. The colour of facial nerve in a child is not as white as in an adult. This makes identification of the nerve difficult during the parotid gland's surgery. All these factors need to be considered by surgeons when managing paediatric head and neck tumour pathology in order to ensure an efficient and safe surgery.

Many innovative techniques have paved the way for the development of paediatric head and neck surgery as a specialty, including endoscopic diagnosis and minimally invasive treatment of piriform sinus fistula, ultrasound-guided intervention of vascular malformation, and oesophageal repair and reconstructive surgery [23]. The

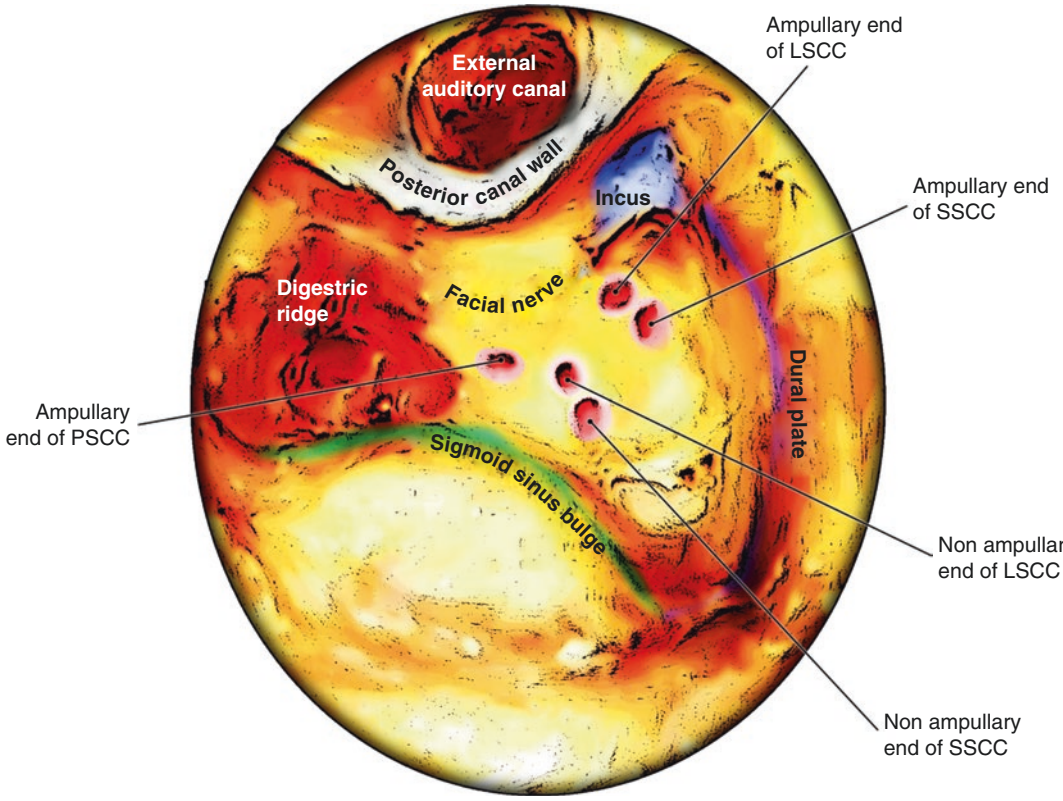

Fig. 2.52 The critical surgical landmarks during the mastoidectomy include the semicircular canal, sigmoid sinus, digastric ridge, incus, and posterior canal wall

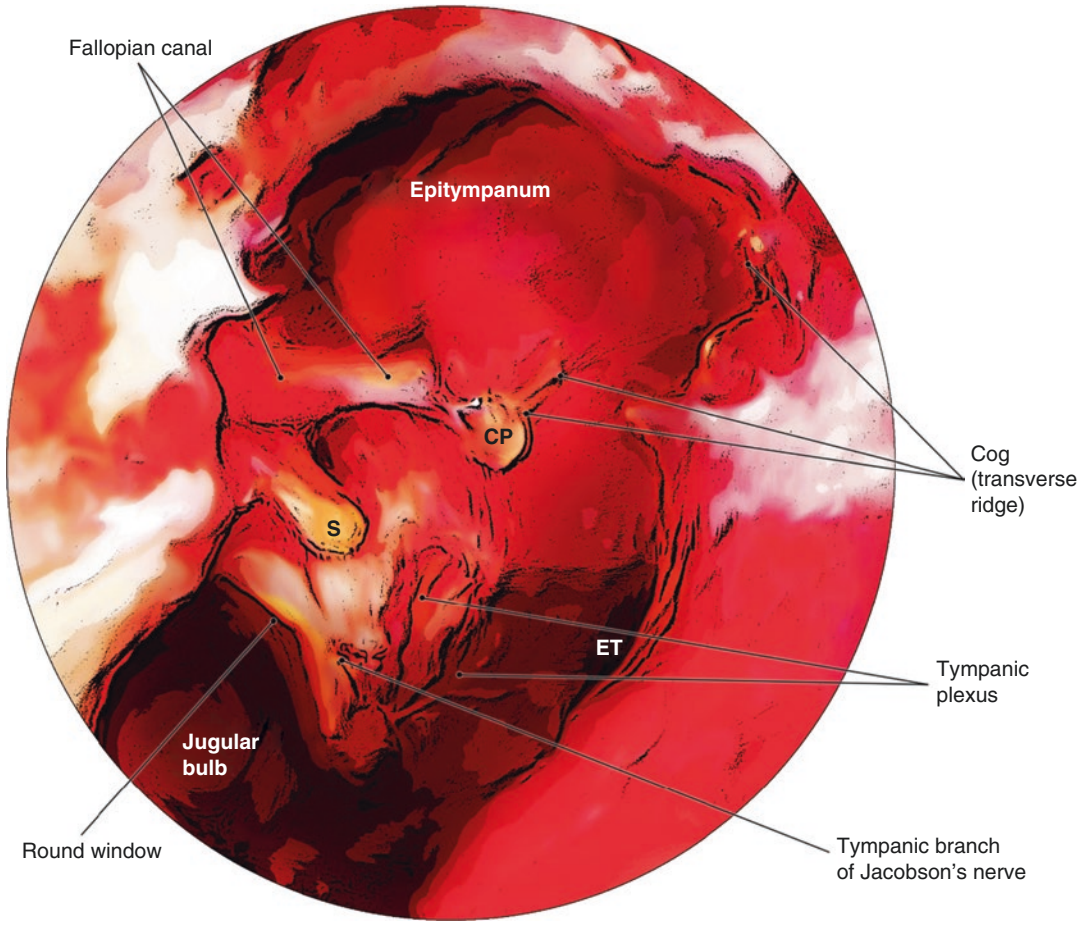

Fig. 2.53 The knowledge of anatomical details of structures in the middle ear and adjacent structures is crucial for the conduct of a safe surgery

multidisciplinary team approach to the management of head and neck diseases in children has also been advocated in an attempt to maximize patient benefits with minimum costs.

2.10 Anatomical Versus Surgical Landmarks

Anatomical knowledge of the head and neck region is crucial in ensuring the performance of good surgery. Surgical landmarks play a vital part during dissection and extirpation of specific structures and organs. In some tumour cases, the adjacent structures should be preserved, whereas in case of malignant tumour, the adjacent structures that are affected by the tumour should be sacrificed [24]. This is important to achieve better oncological outcomes in the management of malignant tumour.

2.11 Techniques of Dissection

Dissection is a critical part for ensuring a safe surgery without causing any complications. This requires a complete set of required instruments as well as proper setting of the OT facilities, staffs,

and attending assistants. The available instruments should be in the best form and functioning well, in order to reduce operative time. The skills of dissection can be enhanced with multiple methods, and more procedures are performed. Attendance in head and neck surgery hands-on workshop will be able to facilitate the skills and knowledge of junior head and neck surgeons.

Imperatively, the skill of the operating surgeon together with the thorough knowledge of the cases with reference to critical structures that need to be addressed during surgery is fundamental for ensuring optimal treatment outcomes. For young junior surgeons, a repeated practice such as during cadaveric dissection programme will help to enhance the surgical skills and improve the anatomical knowledge of that specific surgery. Training session in a high-volume centre with the availability of expertise further improves the dissection skill. A refined skill is necessary especially if head and neck surgeons also practise flap reconstruction for head and neck oncology cases.

2.12 Pearls and Pitfalls of Head and Neck Surgery

There are many approaches and surgical techniques that are available for a specific type of surgery. To choose which one is the best will depend on several criteria. This includes the expertise of the practising surgeon, the availability of instruments necessary for the procedures, the assistant nurse, and the committed cooperation from another related team, e.g. anaesthetist, medical, cardiothoracic, and plastic reconstructive.

Other crucial points that need to be considered include the clinician's knowledge of the cases, the patient's perception of his or her illness and the necessary treatments, a proactive resident, and trainees in the programme. The communication that exists among the managing team is essential in ensuring the success of the managed cases.

It is understood without saying that a thorough knowledge of the anatomical and surgical landmarks in combination with a refined surgical skill is a prerequisite for a safe and successful surgery.

2.13 Conclusion

Being well versed with the head and neck anatomy and surgical landmarks allows a surgeon to perform the surgery effectively. The experience of surgeons, availability of instruments, and a dedicated multidisciplinary team and staffs are pivotal in determining the success of any surgery. Patient's quality of life can be improved if the morbidities from the surgery can be minimized. This requires a diligent surgeon, effective communications, a refined treatment plan, as well as supportive family members.

References

1. Miller MC, Goldenberg D. Do you know your guidelines? Principles of surgery for head and neck cancer: a review of the National Comprehensive Cancer Network guidelines. Head Neck. 2017;39:791–6. wileyonlinelibrary.com. https://doi.org/10.1002/hed.24654.
2. Petrovic I, Ahmed ZU, Huryn JM, et al. Oral rehabilitation for patients with marginal and segmental mandibulectomy: a retrospective review of 111 mandibular resection prostheses. J Prosthet Dent. 2019;122(1):82–7. https://doi.org/10.1016/j.prosdent.2018.09.020.
3. Kerawala C, Roques T, Jeannon JP, Bisase B. Oral cavity and lip cancer: United Kingdom National Multidisciplinary Guidelines. J Laryngol Otol. 2016;130(S2):S83–9. https://doi.org/10.1017/S0022215116000499.
4. Pipkorn P, Rosenquist K, Zenga J. Functional considerations in oral cavity reconstruction. Curr Opin Otolaryngol Head Neck Surg. 2018;26(5):326–33. https://doi.org/10.1097/MOO.0000000000000474.
5. Patel UA, Hartig GK, Hanasono MM, Lin DT, Richmon JD. Locoregional flaps for Oral cavity reconstruction: a review of modern options. Otolaryngol Head Neck Surg. 2017;157(2):201–9. https://doi.org/10.1177/0194599817700582.
6. Crosetti E, Caracciolo A, Arrigoni G, Delmastro E, Succo G. Barbed suture in oral cavity reconstruction: preliminary results. Acta Otorhinolaryngol Ital. 2019;39(5):308–15. https://doi.org/10.14639/0392-100X-2130.
7. Chen X, Xu L, Sun Y, Politis C. A review of computer-aided oral and maxillofacial surgery: planning, simulation and navigation. Expert Rev Med Devices. 2016;13(11):1043–51. https://doi.org/10.1080/17434440.2016.1243054.
8. De Virgilio A, Kim SH, Magnuson JS, et al. Anatomical-based classification for transoral lateral

oropharyngectomy. Oral Oncol. 2019;99:104450. https://doi.org/10.1016/j.oraloncology.2019.104450.
9. Crosetti E, Arrigoni G, Manca A, Caracciolo A, Bertotto I, Succo G. 3D Exoscopic surgery (3Des) for transoral oropharyngectomy. Front Oncol. 2020;10:16. Published 2020 Jan 31. https://doi.org/10.3389/fonc.2020.00016.
10. Gun R, Durmus K, Kucur C, Carrau RL, Ozer E. Transoral surgical anatomy and clinical considerations of lateral oropharyngeal wall, parapharyngeal space, and tongue base. Otolaryngol Head Neck Surg. 2016;154(3):480–5. https://doi.org/10.1177/0194599815625911.
11. Mirapeix RM, Tobed Secall M, Pollán Guisasola C, et al. Anatomic landmarks in transoral oropharyngeal surgery. J Craniofac Surg. 2019;30(2):e101–6. https://doi.org/10.1097/SCS.0000000000004935.
12. Dallan I, Seccia V, Faggioni L, et al. Anatomical landmarks for transoral robotic tongue base surgery: comparison between endoscopic, external and radiological perspectives. Surg Radiol Anat. 2013;35(1):3–10. https://doi.org/10.1007/s00276-012-0983-2.
13. Cohen DS, Low GM, Melkane AE, et al. Establishing a danger zone: an anatomic study of the lingual artery in base of tongue surgery. Laryngoscope. 2017;127(1):110–5. https://doi.org/10.1002/lary.26048.
14. Mat Lazim N, Baharudin B. Risk factors and etiopathogenesis of nasopharyngeal carcinoma. In: Abdullah B, Balasubramanian A, Lazim NM, editors. An evidence-based approach to the management of nasopharyngeal cancer. Amsterdam: Academic Press; 2020. p. 11–30. ISBN: 9780128144039. https://doi.org/10.1016/B978-0-12-814403-9.00002-1.
15. Chintamani D. Editorial: "ten commandments" of safe and optimum thyroid surgery. Indian J Surg. 2010;72(6):421–6. https://doi.org/10.1007/s12262-010-0217-y.
16. Irkorucu O. Zuckerkandl tubercle in thyroid surgery: is it a reality or a myth? Ann Med Surg (Lond). 2016;7:92–6. Published 2016 Apr 6. https://doi.org/10.1016/j.amsu.2016.03.030.
17. Costanzo M, Caruso LA, Veroux M, Messina DC, Marziani A, Cannizzaro MA. Il lobo di Zuckerkandl: faro del nervo laringeo ricorrente [The lobe of Zuckerkandl: an important sign of recurrent laryngeal nerve]. Ann Ital Chir. 2005;76(4):337–41.
18. Miller FR. Surgical anatomy of the thyroid and parathyroid glands. Otolaryngol Clin N Am. 2003;36(1):221–227, vii. https://doi.org/10.1016/s0030-6665(02)00132-9.
19. Subramanian S, Chiesa F, Lyubaev V, Aidarbekova A, Brzhezovskiy V. The evolution of surgery in the management of neck metastases. Acta Otorhinolaryngol Ital. 2007;27(2):309–16.
20. Chintamani. Ten commandments of safe and optimum neck dissections for cancer. Indian J Surg. 2015;77(2):85–91. https://doi.org/10.1007/s12262-015-1277-9.
21. Coskun HH, Medina JE, Robbins KT, et al. Current philosophy in the surgical management of neck metastases for head and neck squamous cell carcinoma. Head Neck. 2015;37(6):915–26. https://doi.org/10.1002/hed.23689.
22. Kalaiarasi R, Kiran AS, Vijayakumar C, Venkataramanan R, Manusrut M, Prabhu R. Anatomical features of intratemporal course of facial nerve and its variations. Cureus. 2018;10(8):e3085. Published 2018 Aug 2. https://doi.org/10.7759/cureus.3085.
23. Ni X, Zhang J. Pediatric otolaryngology–head and neck surgery in China: present situation and future prospects. Pediatr Invest. 2019;3:137–40.
24. Swift AC. Principles and practice of head and neck oncology. J R Soc Med. 2003;96(11):566–7.

3 Significance of Anatomical Versus Surgical Landmarks in Head and Neck Surgery

Norhafiza Mat Lazim, Zul Izhar Mohd Ismail, Muhamad Nor Firdaus Ab Rahman, and Baharudin Abdullah

3.1 Introduction

Head and neck surgery entails multiple procedures involved with important structures of the head and neck region. The organs for breathing, hearing, taste, vision, and swallowing all reside in the head region. In the neck, there are multiple neural and vascular structures that are at significant risk during surgery. This includes the lower four cranial nerves, carotid artery, internal jugular vein, larynx, oesophagus, thyroid glands, and so forth. In order to perform an effective and safe surgery while minimizing the morbidity, an operating surgeon should have a sound anatomical knowledge as well as refined surgical skills. In addition, the availability of instruments and proactive communications with staffs would facilitate an efficient surgery (Fig. 3.1). Inadvertent injury to aforementioned critical structures could lead to serious and fatal complications. The availability of imaging tools like CT scan (Fig. 3.2) and other diagnostic optical endoscopy allows surgical mapping that would minimize surgery-related morbidity.

A variety of methods are available to enhance the anatomical knowledge of young trainee and junior surgeons practising in head and neck surgery. These range across cadaveric dissection, simulation training, head and neck online courses, and many more. An efficient way to consolidate anatomical knowledge and to link this awareness for better understanding of head and neck surgery is the new interdisciplinary hands-on course [1]. The 3D simulation cadaveric dissection is probably the best way, as the head and neck's detailed anatomical structures could be mapped on virtual reconstructive models. This will facilitate greater understanding of relevant surgical landmarks during the dissection process.

The neck region is a compartmental area with superficial and deep layers of fasciae dividing the region into many small spaces. All of these spaces have clinical and surgical importance. The deep space of the neck is crucial as multiple pathologies such as infection, tumour spread, neck node metastasis, and spread of disease could occur inside these spaces (Table 3.1). For example, the poststyloid compartment of the parapharyngeal space is well known for the occurrence of pleomorphic adenoma of the deep lobe of parotid glands and paragangliomas that originate from the last four cranial nerves or those that arise from sympathetic fibre that overlies the carotid wall. Surgical access to parapharyngeal space is

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N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_3

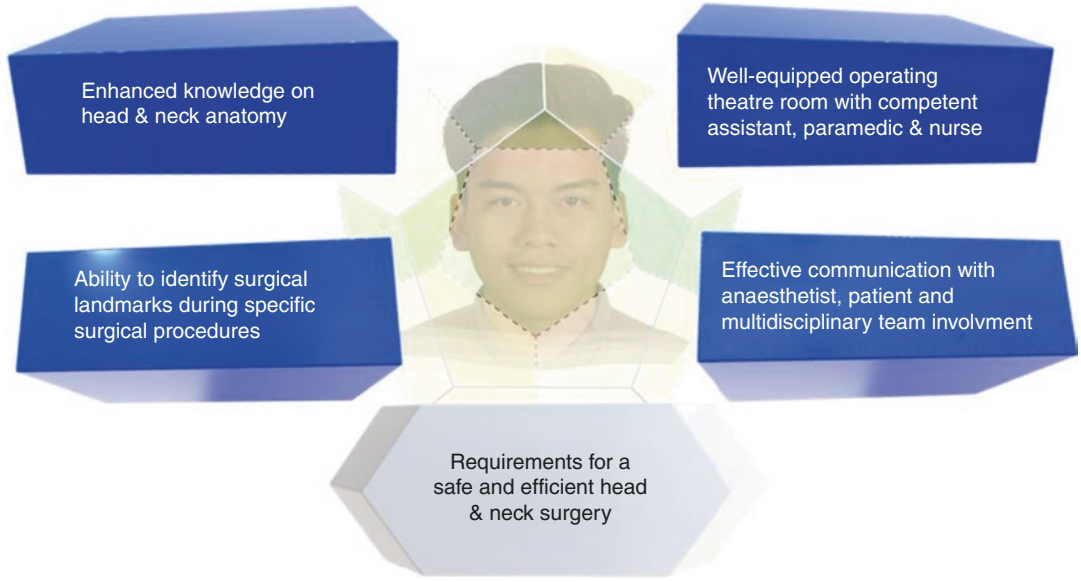

Fig. 3.1 Determining factors for a safe surgery

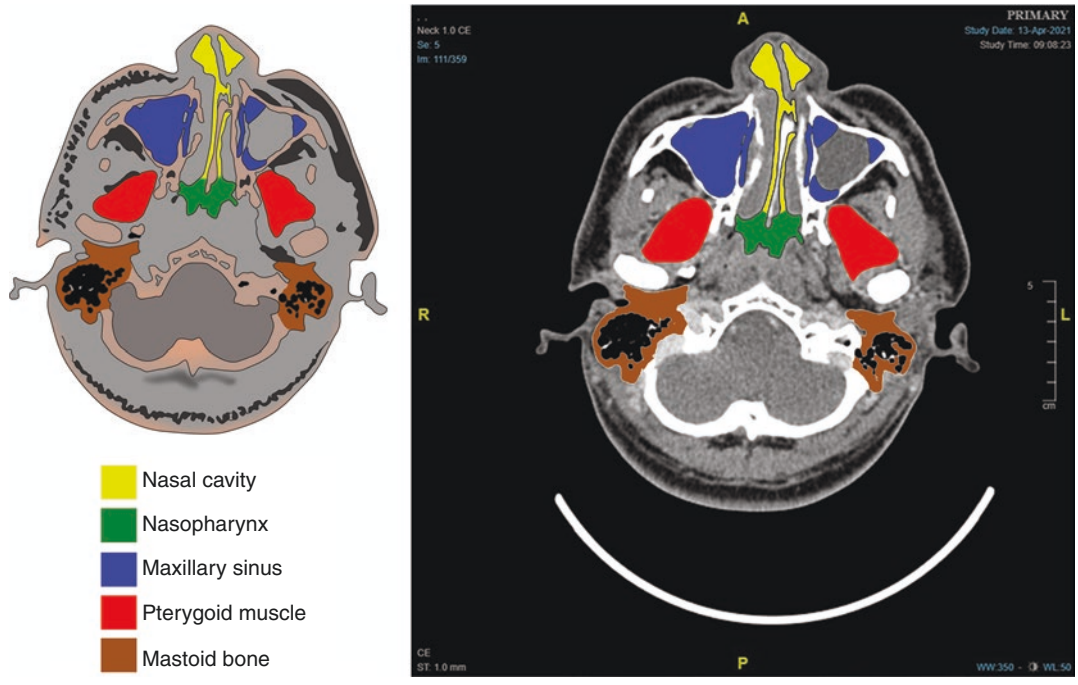

Fig. 3.2 Identification of the structures visualized in the CT scan images such as nasopharynx, pterygoid muscle, maxillary sinus, nasal cavity, mastoid air cells, and adjacent critical structures is vital for preoperative surgical mapping

Table 3.1 Clinical importance of deep spaces of head and neck region

	Deep spaces of head and neck	Clinical and surgical importance
1.	Parapharyngeal space	• Paraganglioma and deep lobe pleomorphic adenoma originate from this space • Abscess formation
2.	Retropharyngeal space	• Collection of abscess and infection • Origin of deep neck infection (DNI) • Nodes of Rouviere/ retropharyngeal nodes impact prognostication of NPC
3.	Danger space	• Spaces posterior to retropharyngeal space • At risk of airway obstruction in extensive cases
4.	Prevertebral space	• Indicative of inoperability if tumour infiltrated this space
5.	Carotid space	• Contains the neck nodes especially on the IJV wall, at risk of neck metastasis recurrence
6.	Submandibular space	• At risk of infection like Ludwig's angina, and in severe cases can cause airway obstruction
7.	Masticator space	• Tumour spread

technically challenging and requires a thorough knowledge of the anatomical and surgical landmarks of these spaces. In addition, a meticulous surgical technique is necessary during dissection with regard to the preservation of the delicate neurovascular structures and its relation to the adjacent tissues, so that complications could be avoided.

The surgical plane is a plane of dissection which is used in relation to the tissues and organs, so that the normal structures can be preserved. In the surgery of malignant mass, the intention is to excise a tumour, leaving the muscles and the neurovascular tissues that are not affected by the tumour intact. In the majority of cases, if the dissection continues in a correct plane, severe tissue damage is avoided, and bleeding can also be minimized. If the surgeon loses the surgical planes

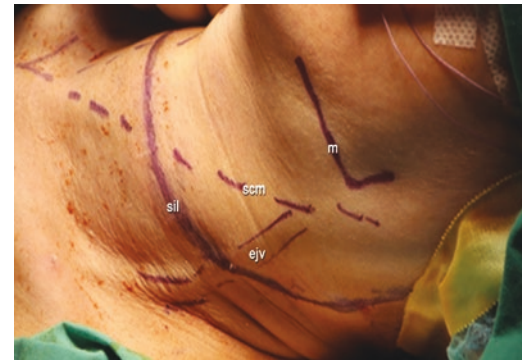

Fig. 3.3 Skin incision and landmarks have been drawn for a bilateral selective neck dissection. The landmarks include sternocleidomastoid muscle (scm), mandible (m), external jugular vein (ejv), and outline of skin incision (sil)

during surgery and lacks the detailed knowledge of anatomical structures of the related organs, the vessels, nerves, muscles, and other organs might be injured. Consequently, the risk of surgery will be higher. Many critical tumours are located in the head and neck and need to be addressed according to the principle of oncologic surgery. Therefore, surgeons should have a thorough knowledge of this critical region's surgical anatomy so that the tumour can be excised with free surgical margins and without compromising the adjacent structures. Of note, an inexperienced junior surgeon with fear of causing damage to important structures may lead to inadequate surgical treatment efficacy, with a consequent risk of tumour persistence or recurrence [2].

During a neck surgical procedure, for instance a bilateral selective neck dissection for a tongue carcinoma, the surgeon should identify the landmarks of the neck structures which are ideally marked with a marker pen, before starting a skin incision (Fig. 3.3). This is a good practice in order to orientate the structures or tumoural mass dissection, so as to avoid the unnecessary bleeding or iatrogenic injury to neural structures.

In head and neck surgery, the subplatysmal flap is the simplest flap that is ideal for an illustration for a teaching purpose, especially to the junior trainees in head and neck surgical oncology practice for attaining a right plane of dissection during the surgery. In fact, it is a cornerstone flap for access and removal of significant neck

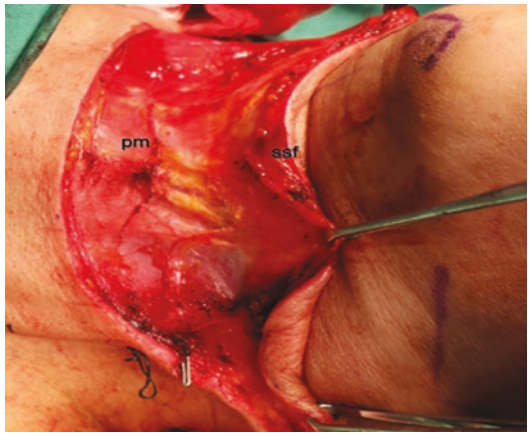

Fig. 3.4 A subplatysmal skin flap (ssf) is raised and reflected superiorly. The thicker the flap, the better it is for flap vascularization in order to avoid flap necrosis. The distal end of cut platysma is also shown (pm)

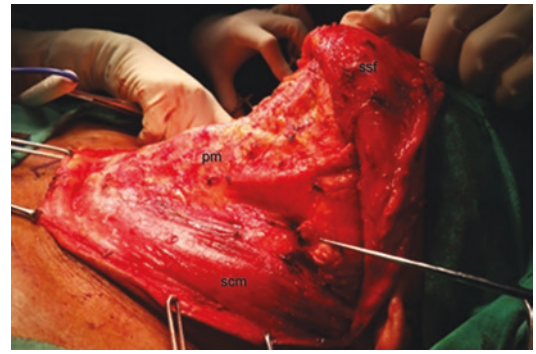

Fig. 3.5 A subplatysmal skin flap (ssf) is raised exposing the sternocleidomastoid muscle (scm) and tissue at levels I, II, III, and IV. This is the extent of exposure required in selective neck dissection. The SCM is retracted laterally, in order to dissect the fibrofatty tissue and fascia overlying IJV (levels II, III, and IV). The distal end of cut platysma is also shown (pm)

tumours such as thyroid tumour, laryngeal cancer, and neck node metastases; submandibulectomy; and most of the excision of the pathology of neck region. All of these surgical procedures require the elevation of subplatysmal flap. Platysma is a superficial thin muscle that spans from the inferior border of mandible to clavicle. It criss-crosses the sternocleidomastoid muscle (SCM) and is deficient at the anterior and posterolateral parts of the neck (Fig. 3.4). The vascular supply to the flap is through the submental artery, a branch of facial artery, and suprascapular artery, a branch from thyrocervical trunk. The thicker the flap, the better the vascular supply, hence less risk of developing flap necrosis.

Further dissection and skeletonization of the anterior border of SCM are required, so that it can be retracted laterally, thus exposing the carotid sheath. The dissection overlying the internal jugular vein (IJV) and carotid artery equates level II, III, and IV neck dissection (Fig. 3.5). The assistant nurse or surgeon should retract the mandible superiorly with a cold instrument, while the surgeon applies traction inferiorly on the dissected mass (Fig. 3.6). This technique of countertraction and traction will facilitate neck dissection effortlessly.

The knowledge of anatomy and function of the nerves that innervate neck muscles may enable surgeons to avoid inadvertent injury. For example,

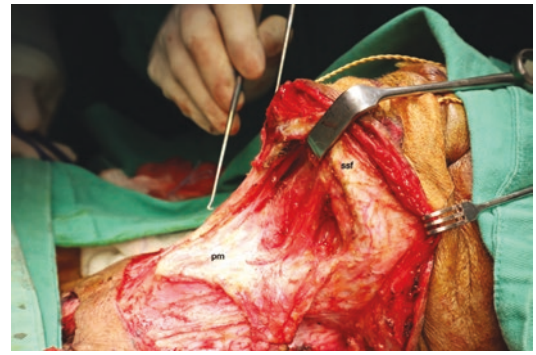

Fig. 3.6 Mandible is retracted with the assistance of a nurse or surgeon to facilitate efficient dissection of fibrofatty tissues and neck node metastases. A good traction and countertraction allow a quick dissection and will shorten the operating time

ansa cervicalis is a loop of nerve that arises from cervical plexus, which lies superficial to the internal jugular vein in the carotid triangle. It is the nerve that innervates the sternohyoid, sternothyroid, and omohyoid muscles. Lesion to this nerve would result in paralysis of these muscles. In addition, the cervical plexus also gives rise to the cutaneous nerves of the neck, which are located superficially on the lateral neck muscles, namely the great auricular, posterior auricular, transverse cervical, and supraclavicular nerves. Lesion to any of these would result in paraesthesia to the skin areas supplied by the respective nerves.

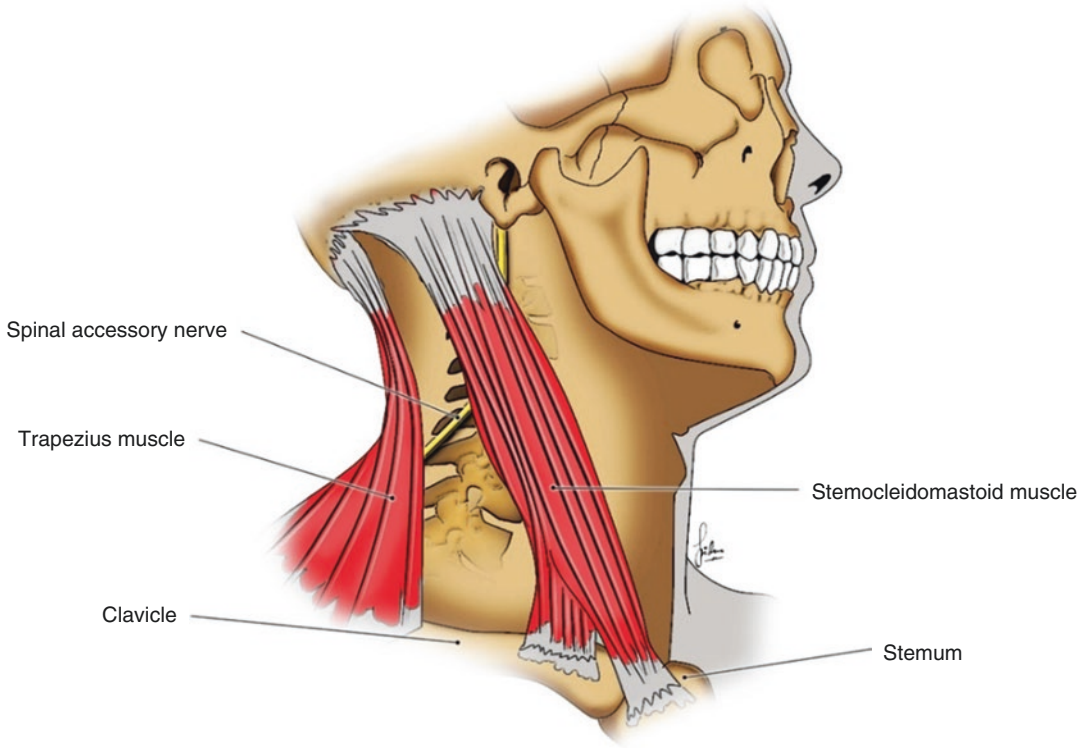

Fig. 3.7 The course of the spinal accessory nerve (SAN) in the posterior triangle or level V is critical for neck dissection. SAN exits at upper two-thirds at the posterior border of SCM and enters the anterior border of trapezius at 5.0 cm above the clavicle. The landmarks for identification of SAN are C2 vertebrae and Erb's point

Another important nerve in the posterior triangle which is of importance is the spinal accessory nerve (SAN). The SAN lies 1–2 cm superior to the exit point of cutaneous nerve branches from cervical plexus at the posterior border of SCM. This nerve runs in the posterior triangle of the neck or level V crossing the carotid sheath, SCM, and trapezius muscle in 45° angles (Fig. 3.7). Several landmarks are being used to identify the SAN. These include

1. Erb's point
2. SCM
3. Trapezius muscle
4. Transverse process of C2 vertebra

These landmarks allow the identification and preservation of SAN during neck dissection at level V region, as this nerve is located superficially (Table 3.2). Injury and traction of the SAN cause significant morbidity like frozen shoulder syndrome, which is characterized by limited arm abduction, painful scapular region, and inability to shrug the shoulder.

In the head and neck region, there is an extensive anastomotic network of the lower cranial nerves. The understanding of the neural intercommunications of the skull base is vital in diagnosing and treating patients with pathology in this critical area [3]. Facial nerve, hypoglossal nerve, and vagus nerve are particularly important nerves that need to be recognized and preserved during the surgery. Injury to these nerves or inadvertent denervation during aggressive dissection causes significant morbidity to patients as these nerves are involved in many critical functions of the facial-neck complex, such as mastication, swallowing, speech, and facial expression. Awareness of the anatomy of these neural connections would be especially useful in facial reconstructive sur-

Table 3.2 Surgical landmarks of the spinal accessory nerves, cranial nerve XI

	Surgical landmarks for SAN (CNXI)	Description
1.	Erb's point	The exit point of cutaneous nerve branches from cervical plexus at the posterior border of SCM. The SAN lies 1–2 cm above this point
2.	Transverse process of cervical vertebra	The SAN can be palpated over the transverse process, at level IIB neck as the nerve runs over this vertebra
3.	Sternocleidomastoid muscle	The SAN pierces through this muscle at its superior one-third. It may also lie deep to this muscle
4.	Trapezius muscle	The SAN runs 5 cm above the clavicle at the anterior border of trapezius, before piercing and supplying the muscle
5.	Great auricular point	The point of exit of great auricular nerve at the posterior border of sternocleidomastoid muscle. The SAN lies 1–2 cm above this point

gery, neck dissection, and various nerve transfer procedures as well as in understanding the pathophysiology of various cranial, skull foundation, and neck disorders [4]. Hypoglossal nerve injury leads to tongue atrophy, fasciculation, and deviation of the tip of the tongue. Vagus nerve injury causes hoarseness of voice and aspiration, whereas facial nerve injury causes facial asymmetry. All of these complications will indefinitely impair the patient's quality of life.

3.2 Importance of Surgical Landmarks

The knowledge on the anatomical and surgical landmarks will assist surgeons to perform the surgery with most minimum complication as possible. During the surgery, dissection is started with the designing and drawing of the skin incision together with other landmarks. For instance, during a tracheostomy, a skin incision drawing is placed at 2.0 cm above the sternal edge. In addition, the cricoid, thyroid, and hyoid cartilage locations are also identified and drawn. This is to ensure that tracheostomy is performed in the midline, thus avoiding the crucial vascular structures such as the carotid artery and the laterally positioned IJV in the carotid sheath. A correct technique of tracheostomy would also prevent the development of post-surgical stenosis, which is due to the recurrence and would be very debilitating.

During the skin incision, surgeons need to anticipate the fascial layer of the neck that would be encountered during the procedure. The superficial cervical fascia is encountered right after the elevation of platysma muscle. The pretracheal fascia layer is the next layer to be incised, exposing the strap muscles. Deep to the strap muscles is the thyroid gland, which needs to be retracted superiorly. Once thyroid gland is retracted, the tracheal ring could be easily palpated and visualized. So, in essence, by knowing the order of the structures of the neck from superficial to deep, it would facilitate a safe dissection and minimize complications such as active bleeding, muscle injury, or nerve transection. The ability to visualize the superficial musculoaponeurotic system and its relationship to crucial neurovascular structures allows surgeons to plan the operation and minimize post-operative complications [2]. As the surgical procedure is performed, crucial neural structure injury should be avoided as it can have a significant impact on patient's functions like swallowing, speech, breathing, and facial expression.

In addition, superficial skin lesion and its related surgery should also be performed with a sound knowledge of anatomical landmarks. Most skin surgical procedures are performed in sun-damaged areas of the face and head because of the development of skin tumour like basal cell carcinoma and malignant melanoma. Surgeons or dermatologists should have a very good knowledge of the important layers of epidermis, dermis, and hypodermis in these areas so that they

can perform an aesthetically safe skin surgical procedure.

3.3 Thyroid Surgery and Related Surgical Landmarks

The thyroid mass surgery is one of the most common neck pathologies that are managed by the ear, nose, and throat (ENT) surgeon in selected centres. The surgical management of thyroid tumour is critical as it is involved with the preservation of the recurrent laryngeal nerve (RLN), which innervates the intrinsic muscles of the larynx (except the cricothyroid muscle). The mobility of vocal cord is crucial for the normal voice production. Injury to the RLN will impair the vocal cord mobility, hence resulting in hoarseness of voice. This impairs patient's effective communication and quality of life.

In the identification and safe dissection of the RLN, sufficient knowledge of its surgical anatomy, clinical experience, and meticulous surgical techniques are key factors. The RLN can be identified during a thyroidectomy using four different approaches, depending on the type of thyroid growth and the surgeon's choice. These approaches include the lateral, inferior, superior, and medial approaches [5]. It depends on the surgeon's preference and intraoperative findings in choosing the type of surgical approach. The surgical landmarks that are commonly used during thyroid surgery include the laryngeal cartilages such as the thyroid, cricoid, hyoid bone, and also trachea. The easily palpable parts of laryngeal cartilages are, for instance, the inferior cornua of the thyroid cartilage, the thyroid cartilage inferior tubercle, and the most anterior portion of the cricoid cartilage arch. These palpable landmarks have been recognized as critical landmarks during thyroid surgery (Fig. 3.8). Of note, the distances between these structures and the RLN entry point on the medial aspect of the cricoid cartilage arch have been recognized as a landmark for the identification and preservation of recurrent laryngeal nerves [6].

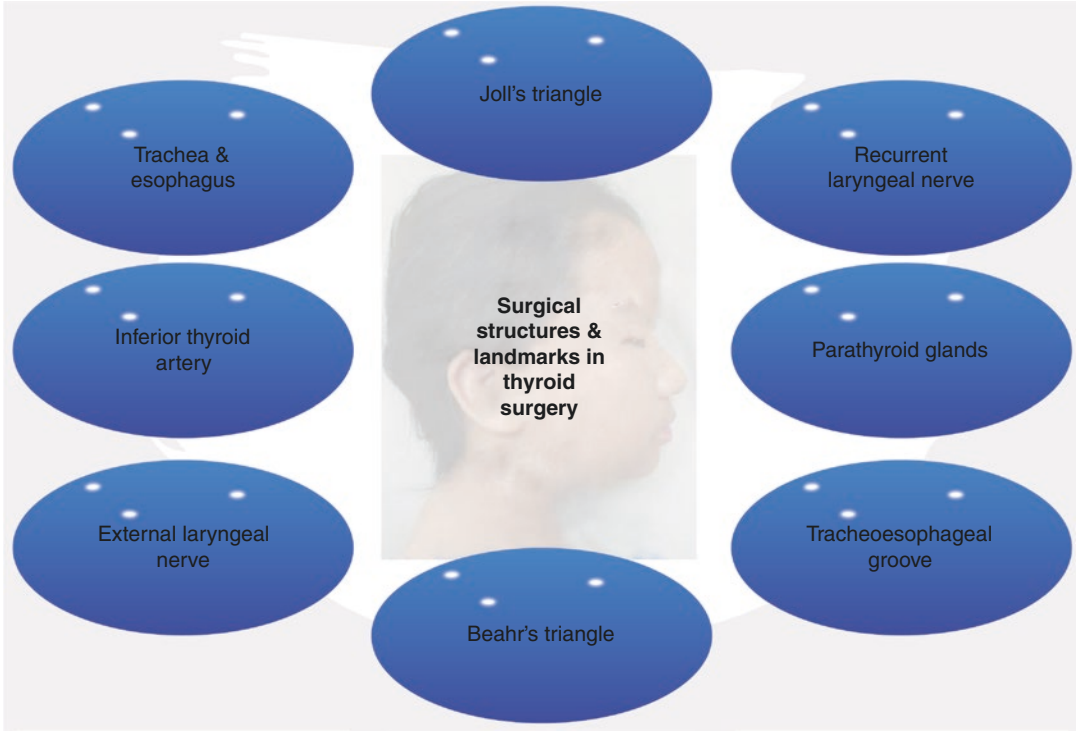

Fig. 3.8 The critical structures encountered during a thyroid surgery

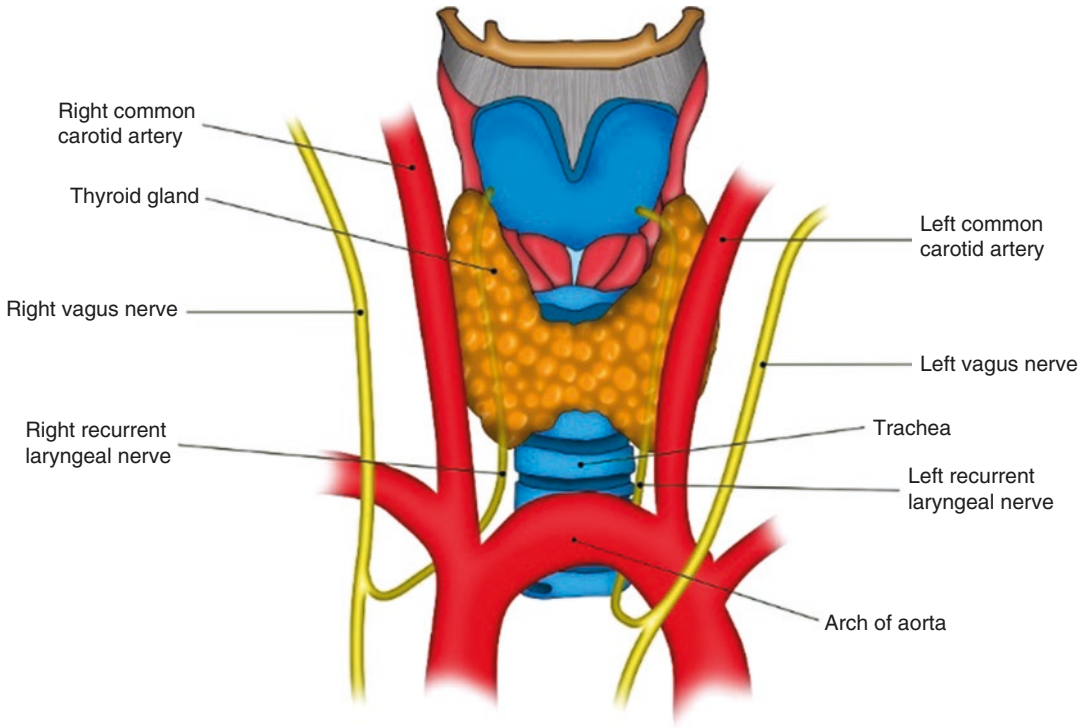

Fig. 3.9 Anatomical relationship between vagus nerves, recurrent laryngeal nerves, arch of aorta, right subclavian artery, common carotid arteries, and thyroid glands

The anatomical course of the RLN is different between the right and the left sides of the neck. At the point where the brachiocephalic artery is divided into two branches, the right RLN, which arises from the vagus nerve, rotates backwards around the right subclavian artery and advances towards the tracheoesophageal groove after passing the trachea at an angle of 15–45° posterior to the carotid artery. While on the left neck, at the level of the ligamentum arteriosum, the left RLN branches out from the vagus nerve, turns posteriorly from the anterior aspect of the aortic arch, and reaches the tracheoesophageal groove from the medial side of the left common carotid artery (Fig. 3.9) [5].

The inferior thyroid artery (ITA) is one of the important structures associated with the RLN. In majority of the cases, the RLN is located anterior or posterior to ITA, or passes within its branches. After passing the ITA level, the RLN usually follows the same anatomical route on both sides, and next runs close to the Zuckerkandl tubercle (ZT) and the Berry's ligament. The Berry's ligament is encountered when the dissection is performed posterior to the thyroid glands. The risk of RLN injury in this area of Berry's ligament is very high [5]. The surgical procedure in thyroid surgery is illustrated in Figs. 3.10, 3.11, 3.12, and 3.13.

During the thyroid surgery, other important neural structures are also at risk. In addition to the recurrent laryngeal nerve (RLN), protection must be provided to the external branch of the superior laryngeal nerve (EBSLN) [7]. This EBSLN supplies the cricothyroid muscle, which tenses vocal cord. This is particularly crucial for a professional voice user like singer, teacher, and tutor. The entry point of the EBSLN into the muscle is usually 1.1 mm from the insertion of the sternothyroid into the oblique line of the thyroid cartilage and 5–12 mm from the muscle's anterior border. There is a classification system by Cernea et al., which highlights the course of the external laryngeal nerve in relation to the upper lobe of the thyroid glands. Ideally, the superior

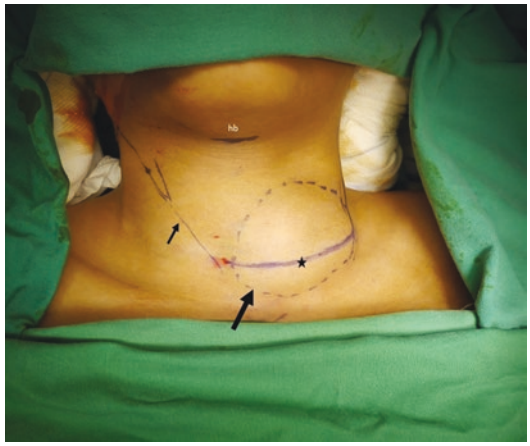

Fig. 3.10 Important landmarks should be marked before the first skin incision in order to orientate the critical structures that need to be addressed safely during the surgery. Outline of the mass is in dotted lines (big arrow), skin incision (star), anterior border of SCM (small arrow), and hyoid bone (hb)

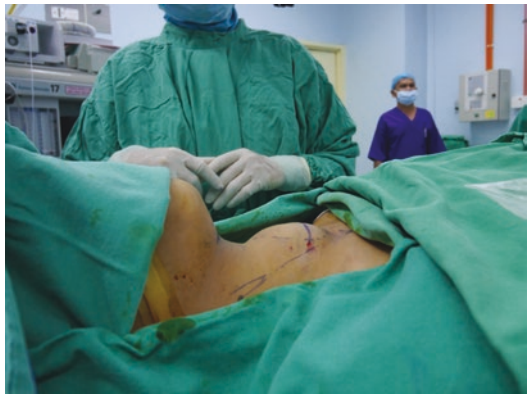

Fig. 3.11 A midline thyroid mass is visualized on lateral inspection

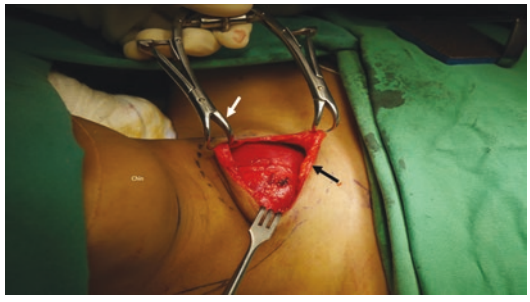

Fig. 3.12 A subplatysmal skin flap has been raised (black arrow), and the strap muscle overlying the thyroid mass is exposed. Classically, the skin flap can be retracted with a Joules retractor (white arrow) or an assistant with a cold retractor instrument

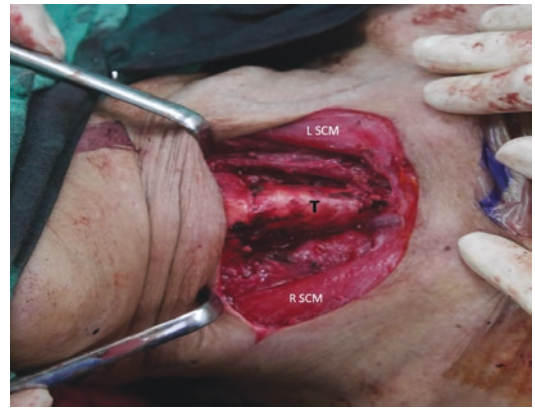

Fig. 3.13 Thyroid mass has been removed exposing the trachea (T). The sternocleidomastoid muscle is visible on either side of the neck, left SCM (L SCM) and right SCM (R SCM)

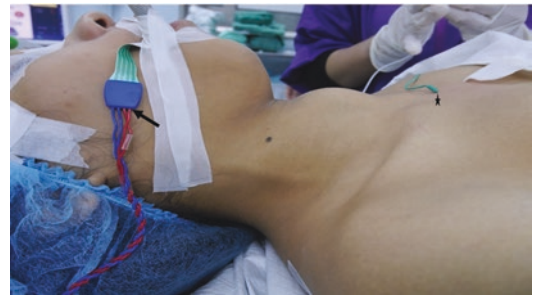

Fig. 3.14 Intraoperative neural monitoring in thyroid gland surgery is vital for preservation of the recurrent laryngeal nerve. The ground electrode (star) and the electric lead inserted to the intubation tube (arrow) are secured

thyroid artery should be ligated 1.0 cm away from the upper pole of thyroid gland to avoid injury to EBSLN. Before ligating the superior thyroid vessels, these useful landmarks enable the nerve to be consistently located, identified, and preserved during thyroid surgery [8]. Thus, a meticulous dissection needs to identify and preserve these nerves.

In addition to visual identification, the intraoperative neural monitoring (IONM) (Fig. 3.14) is able to assist surgeons to better identify the nerves, both the RLN and ESBLN. The use of IONM application can functionally locate the EBSLN so that muscle twitch, i.e. the cricothyroid muscle, is a reliable evidence of the EBSLN's functional integrity. In the majority of patients, activation of the EBSLN causes a recordable

motor response [7]. Additionally, in order to identify these nerves, a meticulous dissection technique and diligent assistant are crucial for a safe conduct of the surgery (Fig. 3.15).

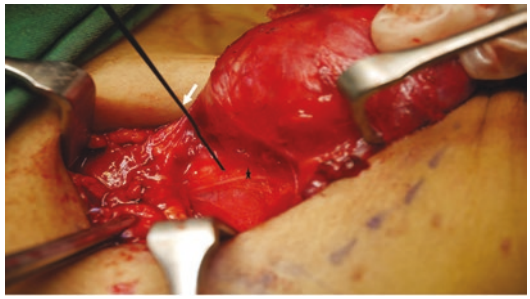

Fig. 3.15 The right recurrent laryngeal nerve (star) is seen at the tip of the nerve probe (white arrow)

3.4 Salivary Gland Surgery and Surgical Landmark

Salivary gland surgery is another critical head and neck surgery as it involves the facial nerve. The facial nerve and its branches supply the muscle of facial expression. Injury to the nerves will result in facial asymmetry with impairment of facial expression. This results in dysfunction of social integration and affects patient's quality of life (Figs. 3.16 and 3.17).

The facial nerves and its branches have great variation in their anatomical details. Thus, the surgeon needs to be well versed with the facial nerve anatomical variation and relation to the adjacent structures (Fig. 3.18). This is especially in relation to the facial nerve trunk identification, so that it

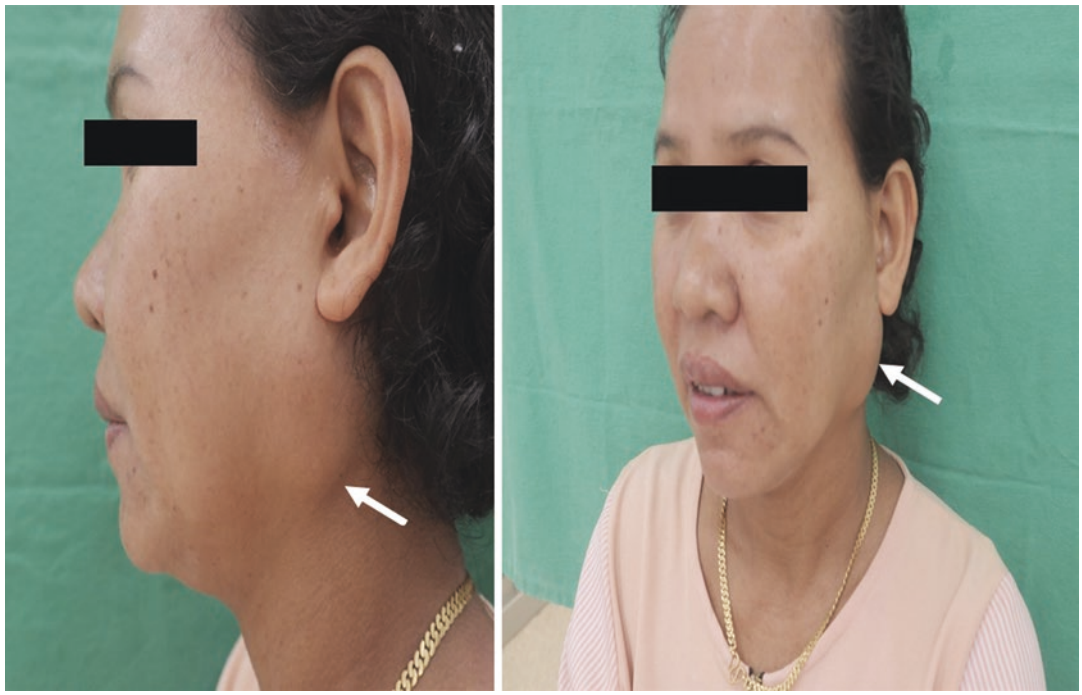

Fig. 3.16 One of the common salivary gland tumours is the parotid gland tumour (arrow)

will facilitate the identification and preservation of five main branches of the facial nerve (Fig. 3.18). In most of the cases, the trunk divides into two major branches, the upper cervical and lower cervical branch (Fig. 3.19). Indeed, the anatomy of facial nerve is highly delicate. It displays a highly variable and complex pattern of branching and forms interactions with several other cranial nerves. The facial nerve connects to branches of the trigeminal nerve including branches of the auriculotemporal nerve, buccal nerve, mental nerve, lingual nerve, infraorbital nerve, zygomatic nerve, and ophthalmic nerve [4]. Importantly, the five main branches of the facial nerve should be identified and preserved during any parotid gland's surgery, especially in benign cases.

Several landmarks are commonly used during the parotid gland surgery for the identification of facial nerve trunk and its branches. These include

1. Tragal pointer
2. Upper border of posterior belly of digastric
3. Tympanomastoid suture
4. Styloid process

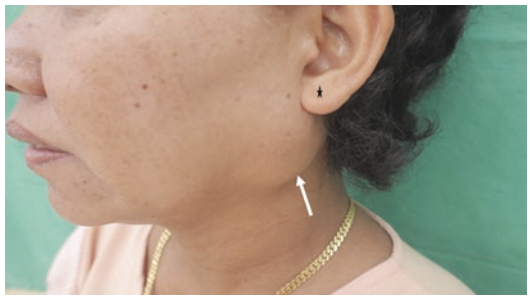

Fig. 3.17 On clinical examination, a parotid mass will characteristically displace the ear lobule anteriorly

Tragal pointer is the cartilaginous portion of the external auditory canal. The facial nerve trunk lies 1.0 cm inferior and medial to this pointer. The posterior belly of digastric muscle is an important landmark as the majority of neurovascular structures in the neck are located deep to this muscle. The facial nerve trunk lies about 0.5–1.0 cm above the upper border of the posterior belly of digastric muscle (Figs. 3.20, 3.21, 3.22, and 3.23).

Multiple connections exist between the facial nerve and other nerves in the head and neck

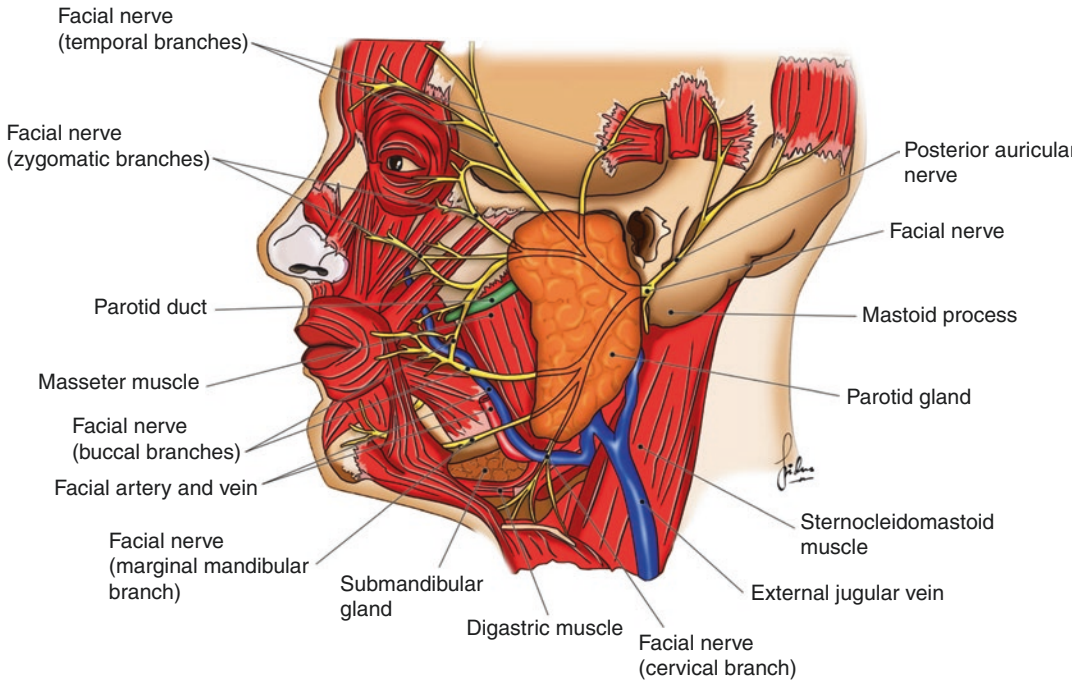

Fig. 3.18 The facial nerve anatomy in relation to parotid glands, EJV, SCM, masseter muscle

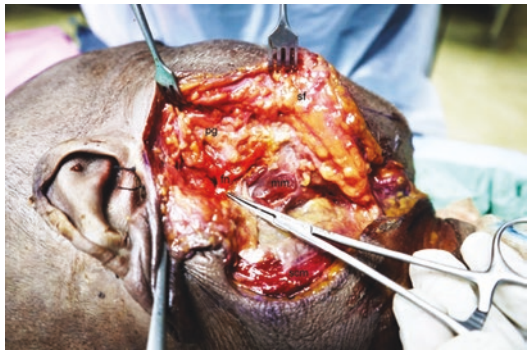

Fig. 3.19 The skin flap is retracted anteromedially (sf). The facial nerve trunk (fn) is divided into upper temporal and lower cervical branch. The substance of parotid gland (pg). Masseter muscle (mm) is visible below the lower branch

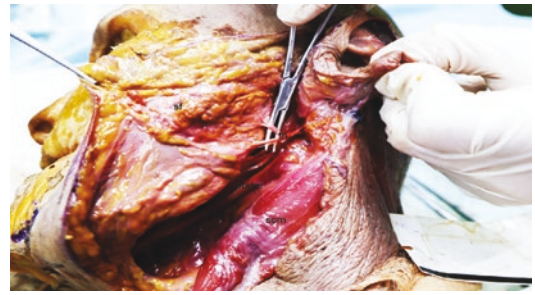

Fig. 3.22 Facial nerve trunk and its division (fn) are lifted with forceps. The posterior belly of digastric (pbdm) is seen deep to the sternocleidomastoid muscle (scm). Tragal pointer (TP) is shown where facial nerve trunk is located 1.0 cm deep and medial to the TP

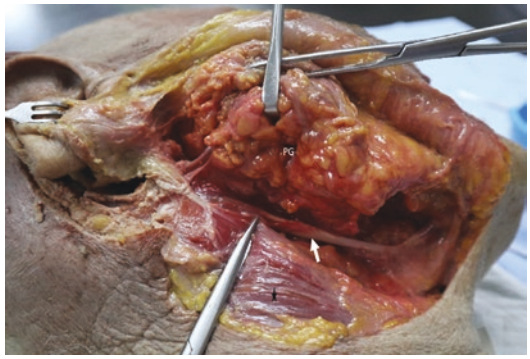

Fig. 3.20 Posterior belly of digastric muscle (arrow) is located deep to parotid glands (PG). This is a critical landmark during a parotid surgery as the facial nerve lies medial to this muscle. The sternocleidomastoid muscle is also shown (star)

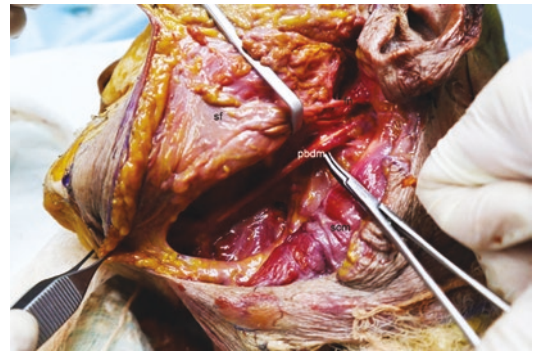

Fig. 3.23 Facial nerve trunk lies 1.0 cm superior and medial to the upper border of the digastric muscle (pbdm). The superficial lobe of parotid gland (sf) and sternocleidomastoid muscle (SCM) are also shown

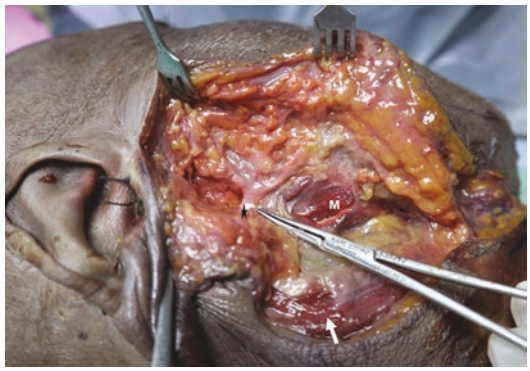

Fig. 3.21 Facial nerve trunk (star) divides into two main peripheral branches. The masseter muscle (M) is visualized, and sternocleidomastoid muscle (arrow) is located more inferolaterally

region. During clinical examination and surgical procedures of the facial nerve, such connections may have significance [4]. This is in the form of assessing the nerve integrity and the possibility for reinnervation. If a branch is sacrificed during the surgery, there is still possibility of reinnervation especially if the nerve has multiple anastomoses with other nerves.

The auriculotemporal nerve is one of the many branches of the mandibular nerve. This nerve hitch-hikes the facial nerve branches and supplies the secretomotor fibres to the parotid gland. The aberrant regeneration of this secretomotor fibre from the parotid bed to the sweat glands will cause Frey's syndrome [9, 10]. Frey's syndrome is characterized by involuntary sweating on the cheek at the parotid bed region upon mastication and eating due to stimulation of the parasympathetic fibre that shares the same neurotransmitter, acetylcholine, which also innervates sweat glands.

Cheek contour deformity, gustatory sweating, and a visible scar on the neck are the three most

common problems after a parotidectomy. The facelift-type incisions that eliminate the neck incision and the temporoparietal fascia interposition at the parotidectomy site that fills the defect and provides a barrier to aberrant neuronal regeneration can potentially avoid these problems [11]. There are a variety of ways to prevent Frey's syndrome [12]. The incidence of Frey's syndrome may be decreased by intra-auricular modification of the facelift incision or by using a traditional lazy-S incision.

Additionally, this critical facial nerve anatomy is also related to facial rejuvenation surgeries [13]. Corrugator originates mainly from the medial supraorbital rim followed by the medial frontal bone, the medial infraorbital rim, and the upper nasal process. Most of the corrugators are inserted into the middle of the eyebrow or the medial half of the eyebrow but also into the glabella region [13]. The frontalis muscle plays a major role in our everyday social experiences. As the only muscle that raises the eyebrows, its function goes beyond simply keeping the brows out of one's visual field. It is also necessary to convey emotions and non-verbal communication. The antagonist muscles of the frontalis muscle are the procerus muscle, the corrugator supercilii muscle, and the orbicularis oculi muscle [14].

To ensure a safe surgery, facial nerve stimulator is commonly employed during parotidectomy. There are four channels of nerve stimulator that can be applied to identify the main five branches of the facial nerve (Fig. 3.24). A modified Blair skin incision is used, and this will expose the parotid mass and the sternocleidomastoid muscle (Figs. 3.25 and 3.26). During skin flap elevation, care should be taken to identify the greater auricular nerve which lies superficial to the sternocleidomastoid muscle (Fig. 3.27).

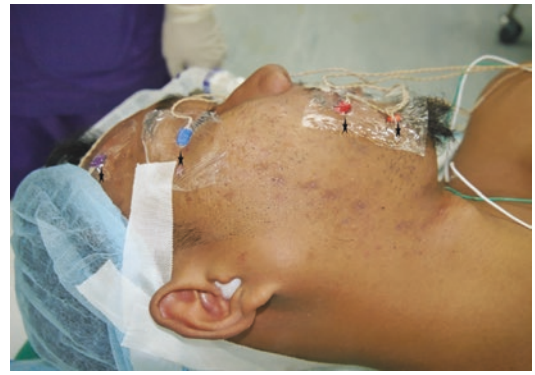

Fig. 3.24 A four-channel facial nerve monitoring has been applied (star). The branches that are monitored are the frontalis (purple), orbicularis oculi (blue), orbicularis oris (red), and mentalis (orange)

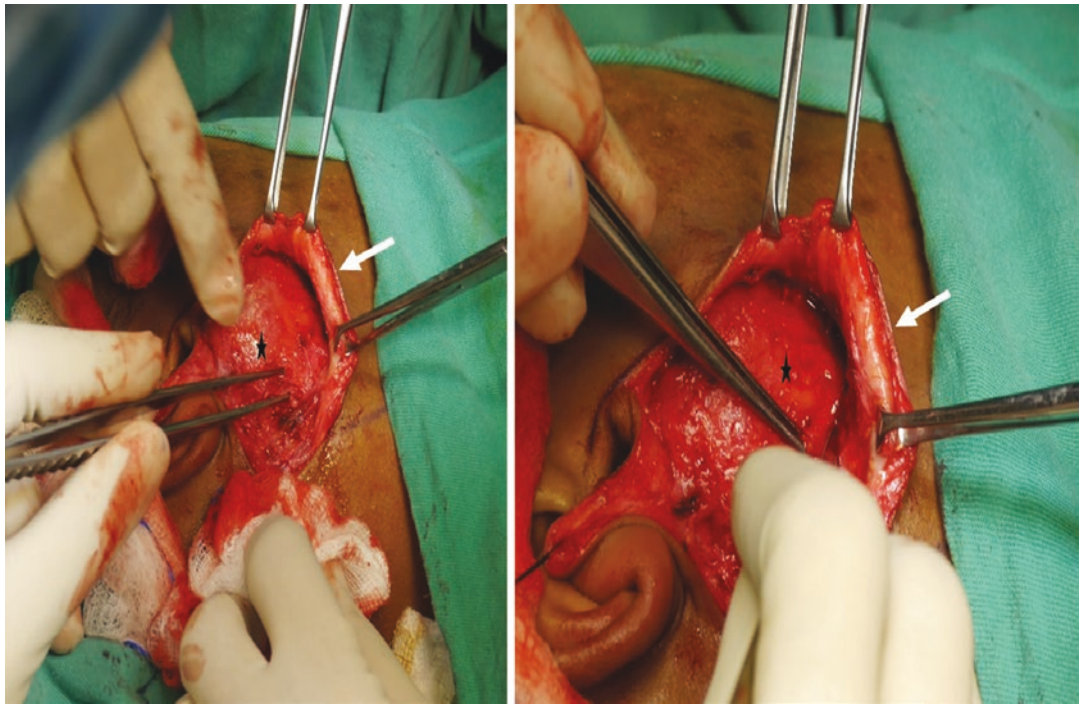

Fig. 3.25 A good traction on the skin flap (arrow) allows exposure of parotid tumour (star). This facilitates dissection around the tumour

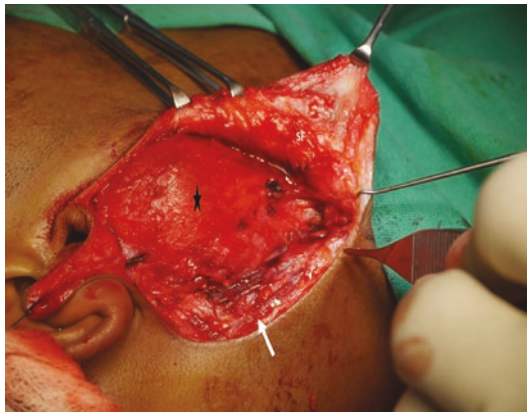

Fig. 3.26 The anterior border of sternocleidomastoid muscle needs to be skeletonized to expose the lateral margin of parotid mass (star). The skin flap (sf) is retracted to allow a good dissection

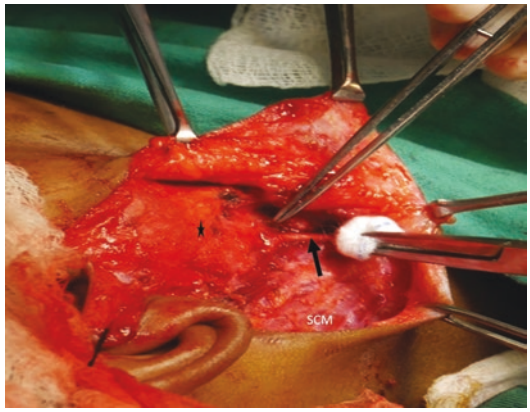

Fig. 3.27 A greater auricular nerve GAN (arrow) is visualized as it traverses superficial to sternocleidomastoid muscle (SCM) before entering the parotid capsule overlying the parotid tumour (star)

3.5 Oral Cavity and Oropharyngeal Surgery

Oral cavity is critical as it harbours many structures and is affected by significant pathology like squamous cell carcinoma. Pertinent consideration of the oral cavity and its subsites and adjacent structures is vital for a safe surgery. The subsite of oral cavity includes lip, teeth, gum, floor of mouth, tongue, buccal mucosa, hard palate, and retromolar trigone. The tongue is a highly muscular organ, composed of extrinsic muscle and intrinsic muscle, which form an easy route for spread of cancer. The adjacent mandible can be infiltrated by cancerous cell, especially in T3 and T4 tumours, which needs to be addressed with proper surgical excision, either marginal mandibulectomy, segmental mandibulectomy, or hemimandibulectomy.

The knowledge of precise course of the mandibular canal, from the mandibular foramen to the mental foramen, and its variations is necessary to perform dental implants and pre-implant surgery in selected cases of oral cavity pathology. Similarly, mandibular sagittal osteotomies are increasingly commonly performed and require optimal knowledge of intramandibular structures to improve the surgical approach to tongue tumour. If not performed correctly, mandibulotomy will result in serious sequelae that are challenging to treat especially in patients with medical comorbidity.

The soft-tissue characteristics can be assessed via an image-guided method like a narrowband imaging. This allows the detection of suspicious areas that are highly likely to be malignant [15] (Fig. 3.28).

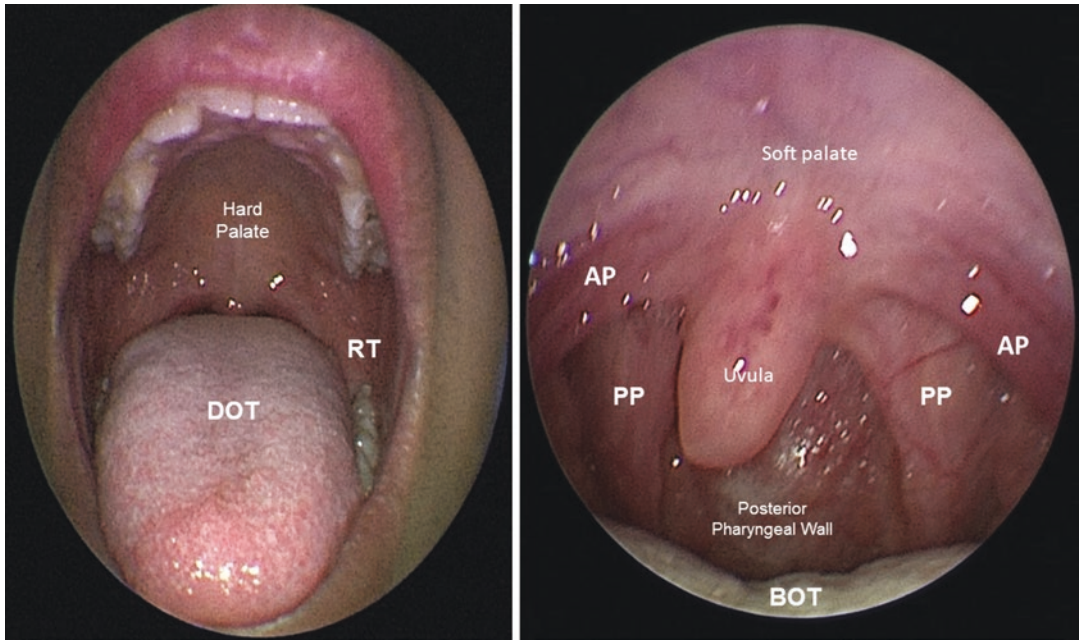

Fig. 3.28 The oral cavity and oropharynx structures are critical for tumour assessment and selected surgical approach. The dorsum of tongue (DOT), retromolar trigone (RT), and base of tongue (BOT) are the common sites for a malignant growth. Anterior pillar (AP) and posterior pillar (PP) harbour the tonsils, which can be affected by tonsillar carcinoma or lymphoma

3.6 Laryngeal and Pharyngeal Surgical Landmark

The laryngeal cartilage and structures play an important role in maintaining adequate airway, humidification, and vocalization. The major cartilaginous larynges are epiglottis, thyroid cartilage, cricoid cartilage, and trachea (Fig. 3.29). The other small cartilages make up the aryepiglottic folds like the cuneiform, corniculate, and arytenoid cartilage (Fig. 3.30). This cartilage is stabilized by muscles and ligaments (Fig. 3.31).

The physiological and anatomical function of larynx is based on a classification system. The larynx is divided into supraglottic larynx, glottic larynx, and subglottic larynx. The supraglottic larynx consists of vestibular fold, aryepiglottic fold, epiglottis, and false cord. The glottic larynx mainly comprises the vocal cord and anterior and posterior commissures. The subglottic larynx refers to an area 1.0 cm below the inferior border of the vocal cord.

The supraglottic view during the direct laryngoscopy allows the assessment of vocal cord, false cord, anterior commissure, laryngeal surface of epiglottis, postcricoid area, and posterior pharyngeal wall (Figs. 3.32 and 3.33).

Identification of this anatomical structure plays a critical role in ensuring that a safe surgical procedure can be performed. Details of boundaries of structures need to be verified to facilitate a correct plane of excision and instrumentation. For instance, endoscopic microlaryngoscopy surgery, EMLS, utilizes multiple instruments which occupy a limited space area of pharynx and larynx. The laryngoscopy and bronchoscopy in paediatric patients pose significant challenges. In selected cases, excision of the tumour or procedure to relieve airway is necessary. Hence, a refined knowledge of airway anatomy and its differences in children and adults is of utmost importance. Laryngeal cancer surgical treatment modalities encompass transoral surgery, open partial resection, and laryngectomy. Transoral surgery of larynx especially poses dif-

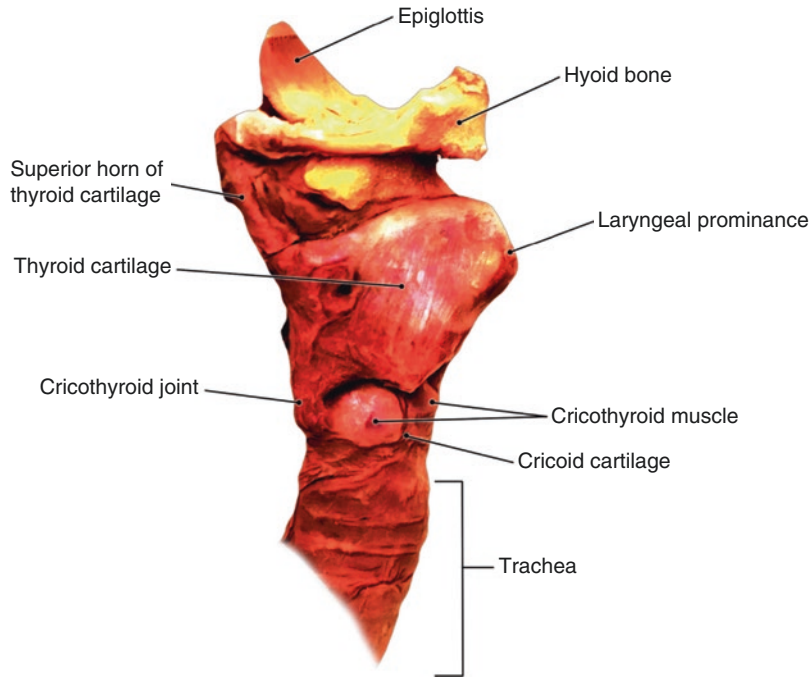

Fig. 3.29 The laryngeal structures are made up of cartilage and muscle

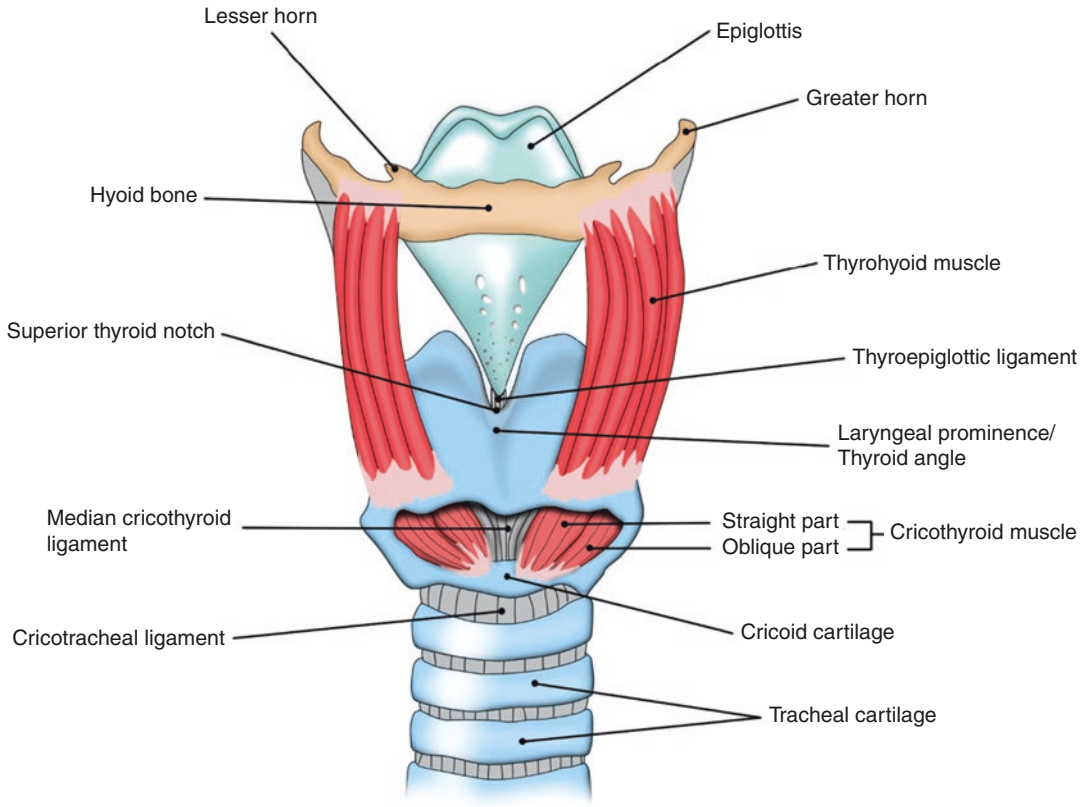

Fig. 3.30 The anterior view of the laryngeal structures. The muscles and ligaments bind the cartilaginous part of hyoid, epiglottis, thyroid cartilage, and trachea

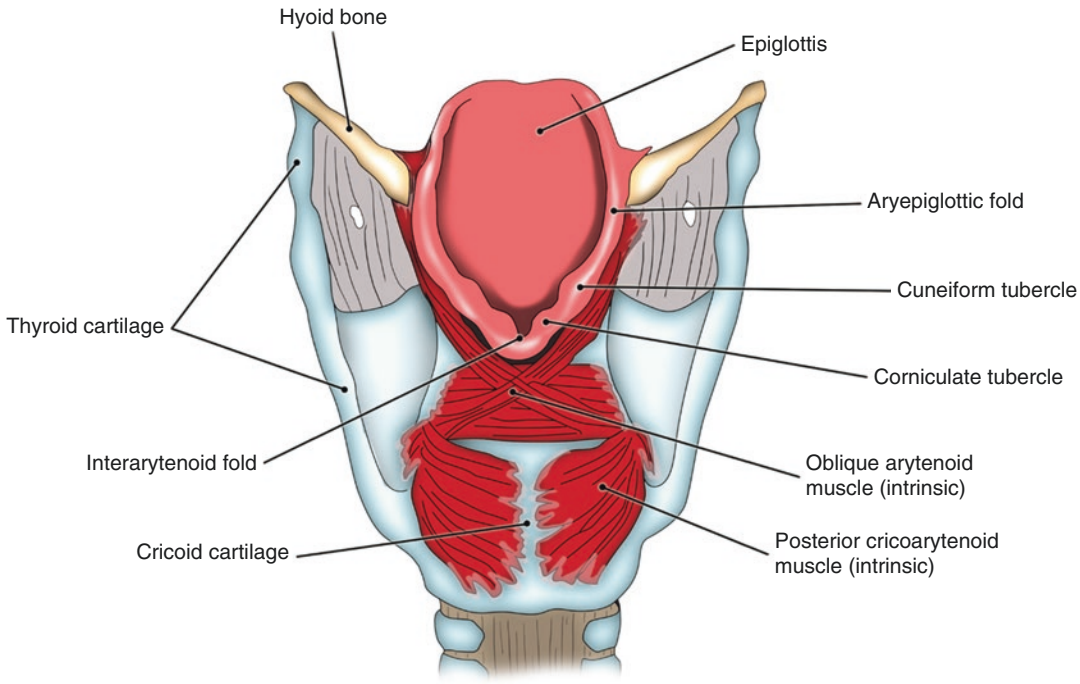

Fig. 3.31 The posterior view of the laryngeal structures shows the muscles that control the vocal cord movement

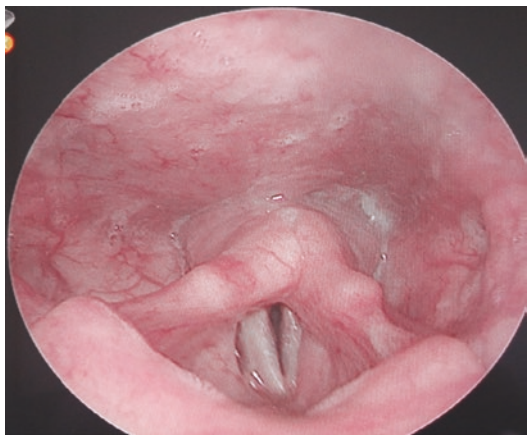

Fig. 3.32 The normal appearance during rigid laryngoscopy examination showing structures of importance like laryngeal surface of epiglottis (LE), aryepiglottic fold (AF), left vocal cord (LVC), right vocal cord (RVC), pyriform fossa (PF), posterior pharyngeal wall (PPW)

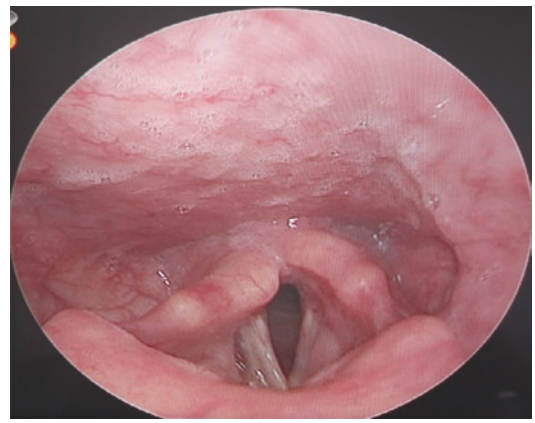

Fig. 3.33 The same figure shows abducted vocal cord during inspiration. The vocal cord will be adducted during the vocalization

ferent challenges, especially in the setting where laser is used for excision. Safety precautions should also be practised with vigilance to avoid unnecessary complications that can endanger the staff and the patients.

The cartilages thyroid cricoid and hyoid bone are the most prominent landmarks that are commonly used during laryngeal surgery. Features of these cartilages plus the associated vascular supply, neural innervation, and lymphatic drainage are vital to consider during the decision-making of appropriate surgical approach for each case. Early

glottic carcinoma, T1 or limited T2 tumours, can be treated with transoral approach, whereas T3 and T4 tumours necessitate partial, hemilaryngectomy, or total laryngectomy. For patients with T3 tumours and selected T4 tumours, open partial laryngectomy may be an alternative to primary radiochemotherapy or total laryngectomy. The treatment of T1 and T2 tumours, if the larynx is difficult to expose, if transoral therapy is not possible or sufficient safety margins may not be maintained, or if the anterior commissure is involved, is another indication of open surgery [16].

Laryngectomy types can be further classified into supracricoid laryngectomy or vertical hemilaryngectomy and so forth. The techniques will be different, and different anatomical and surgical landmarks are used during the surgery. Radiotherapy alone in cases of early stages of laryngeal cancer as well as combined radiochemotherapy and induction chemotherapy followed by radiotherapy are concepts of non-surgical curative therapy [16].

3.6.1 Pharynx

Pharyngeal area can be affected by pathology such as chronic inflammatory disease, tumour, or effects of chemoradiation that causes persistent dysphagia. For instance, oropharynx can be affected by lymphoma or tonsillar carcinoma. Management of lymphoma is vastly different from management of tonsillar squamous cell carcinoma. Part of the pharynx also contributes to the airway functioning other than swallowing (Fig. 3.34). Knowledge of the critical parts of pharynx plays a key role in determining the success of surgery in this area. The successful planning of treatment for the correction of upper airway anatomical abnormalities by surgical progression of the mandible depends on extensive knowledge of the space of the pharyngeal airway [17].

Selected cases of tongue base tumour, lateral pharyngeal wall, soft palate, and tonsillar mass can also be addressed by using a robotic system to excise the tumour. Transoral robotic surgery (TORS) is a new approach, which uses a powerful robotic arm and magnifying optics to perform a minimally invasive procedure in the pharynx. TORS provides an excellent approach to benign pharyngeal lesions [18]. Many head and neck surgical oncology centres globally have performed pharyngeal surgery via TORS with different outcomes and success rates. Additionally, the surgeon needs to master the detailed anatomy of pharynx and use the consoles and buttons to manoeuvre the system efficiently.

Transoral robotic surgery is a popular treatment method used to treat cancers of the larynx and pharynx, but the effect is limited. Although TORS has been used in the treatment of cancer in the tongue and pharynx, its application in the larynx is still limited. Laryngectomy has been the most common method for performing the surgery, with some practice in total laryngectomy and cordectomy [19].

3.6.2 Nasopharyngeal Surgery

Surgery to nasopharynx is mainly involved with limited tumour such as benign tumours or recurrent NPC. Benign tumour such as papilloma or adenoma is very rare. Juvenile nasoangiofibroma may sometimes extend posteriorly to involve the nasopharynx region, and it needs to be addressed appropriately. There are many structures located around the nasopharynx that can be critically injured during the surgical procedures. These include skull base and cranial nerves superiorly and internal carotid artery laterally.

Surgery of the paranasopharyngeal space is very hazardous due to the position of the internal carotid artery, which is surrounded by soft tissue with few anatomical landmarks. The stylopharyngeal groove, longus capitis, and Eustachian tube canal are the main surgical landmarks of the internal carotid artery. The artery can be found along the Eustachian tube, the foramen ovale, and the lateral pterygoid plate. The carotid artery remains an extremely dangerous area, only millimetres away from the pharyngeal recess [18] (Fig. 3.35).

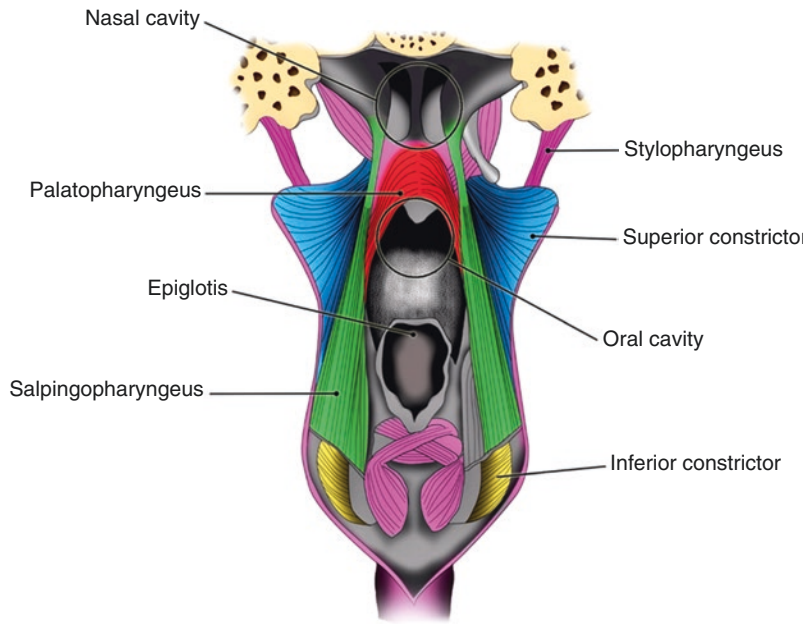

Fig. 3.34 Posterior superior view of the pharynx

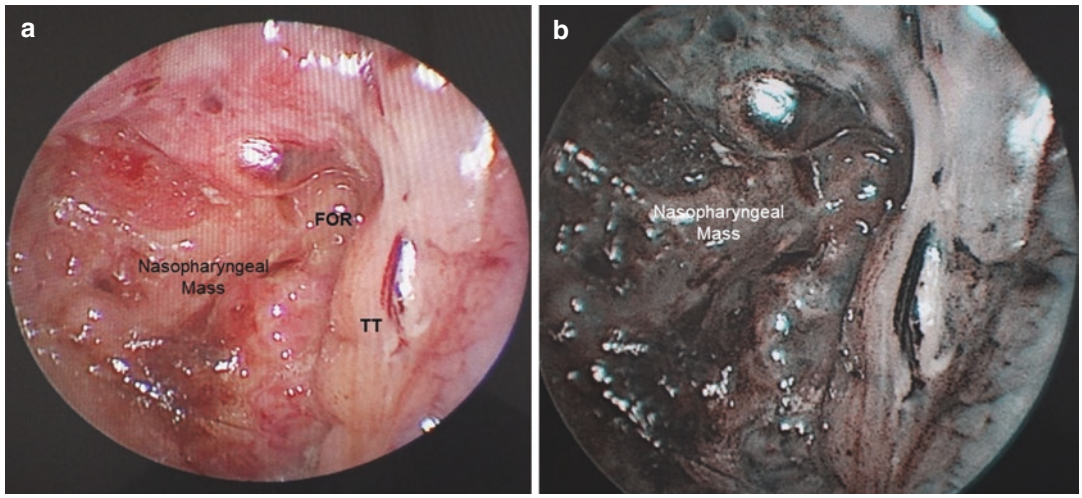

Fig. 3.35 The nasopharyngeal area showing a suspicious mass (**a**), which could be a carcinoma. The vascular change can be observed on the narrowband imaging photos (**b**). *FOR* fossa of rosenmuller, *TT* torus tubarius

3.6.3 The Importance of Surgical Landmark During Neck Dissection

Details of neck node region and its relevant structures are crucial for performing a safe neck dissection. The boundary, floor, roof, and content of each neck node level area are vital as they contain multiple structures that can sustain complications like neurovascular structure injury, which is difficult to manage. Inadvertent injury to the major cranial nerve like transection necessitates immediate repair. The majority of critical structures in the neck are located deep to the posterior belly of digastric muscle (Fig. 3.36).

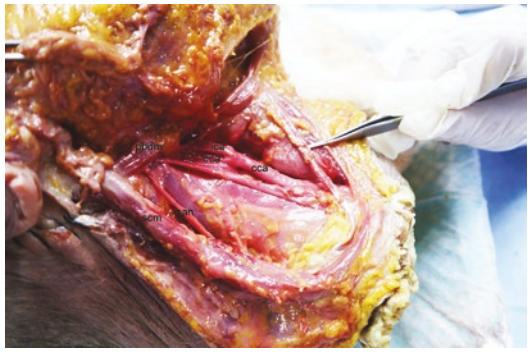

Fig. 3.36 The neck dissection exposes major neurovascular structures of the neck including common carotid artery (cca), internal carotid artery (ica), external carotid artery (eca), internal jugular vein (ijv), spinal accessory nerve (san), sternocleidomastoid muscle (scm), and posterior belly of digastric muscle (pbdm)

The common carotid artery bifurcates at the level of hyoid bones. The external carotid contains multiple branches, whereas internal carotid artery does not have any branches in the neck. The vagus nerve lies in between the common carotid and IJV and should always be preserved.

The omohyoid is the main landmark for identification of the IJV. IJV lies just deep or inferior to the omohyoid muscle. During dissection at level IV, once the omohyoid muscle is visualized, the IJV is already exposed. Meticulous dissection is necessary in order to avoid injury or puncture to IJV wall, which can cause profuse bleeding.

3.6.4 Sinus and Paranasal Sinus Surgery

Endoscopic sinus surgery represents the gold standard for surgical treatment of chronic sinus diseases. Four main pairs of sinuses, the maxillary, ethmoid, sphenoid, and frontal sinuses, are equally important as each can be affected by different pathologies and necessitate different surgical approaches. For instance, maxillary sinus is mostly involved with carcinoma and requires external approach in late-stage disease. Ethmoid sinusitis and polyps on the other hand are suffice with endoscopic approach. Frontal sinus tumour may necessitate a combination of approaches. There are many factors to consider in order to select the optimal approaches for these patients and that need to be judiciously discussed with patient and the managing teams.

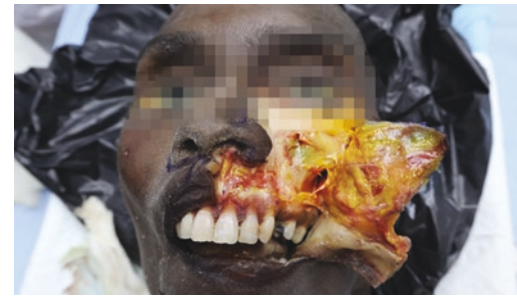

Fig. 3.37 Lower cheek flap for access of mandibulotomy or maxillary swing

The development of minimally invasive surgical methods in rhinology has been aided by the introduction of endoscopic sinus surgery (ESS). Poorly managed bleeding, which limits the sight of the surgical field, can hamper the proficiency of ESS procedures (VSF). This can result in more time spent operating and, more critically, a higher risk of major and minor problems [20]. Thus, detailed knowledge of the anatomy of critical structures like osteomeatal complexes, sinus and its drainage pathway, and surrounding soft tissues and neurovascular structures is highly important for ensuring the success of a surgery.

Nasopharyngeal carcinoma is the most common malignancy affecting the pharyngeal regions. This attributes to multiple risk factors such as dietary and environmental carcinogens [21]. The availability of narrowband imaging may assist in the identification of suspicious area that might harbour malignancy [22].

Maxillectomy can cause numerous complications if not performed meticulously. The principle of bony cut and the steps of disarticulation of maxilla are prerequisites for the success of maxillectomy. Types of maxillectomy, whether to perform partial maxillectomy, medial maxillectomy, subtotal maxillectomy, or total maxillectomy, will depend on the extent of tumour involvement in the surrounding tissues, i.e. stage of the tumour (Figs. 3.37, 3.38, and 3.39).

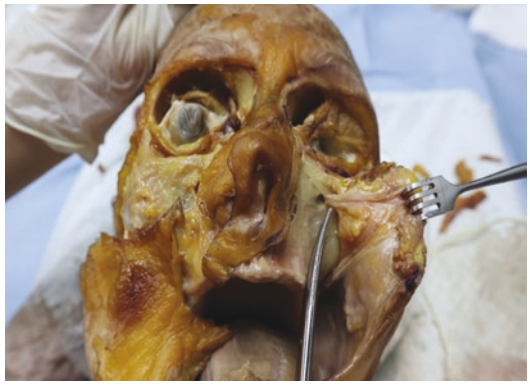

Fig. 3.38 Lower cheek flap exposes the infraorbital nerve

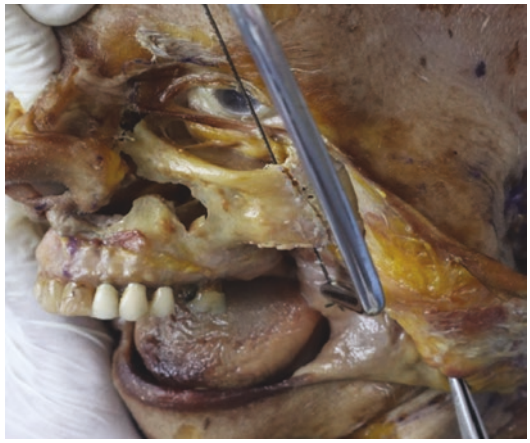

Fig. 3.39 Maxillectomy cut during maxillectomy

3.6.5 Skull-Based Surgery and Landmarks

Skull-based surgery is critical as many important structures located in the skull base can be injured during the surgery. There are many approaches used and currently in practice by skull-based surgeons in order to address the tumours and pathology more efficiently. Endoscopic endonasal surgery is one of the common and important techniques in skull base surgery due to limited surgical areas that require angled endoscopes for a better visualization of the structures. The expertise of surgeons with multiport multisystem endoscope is crucial to ensure the success of surgery. Endoscopic endonasal surgery provides an optimum access to anterior skull base, sphenoethmoidal area, and other paranasal sinuses. It allows resection of intradural and extradural tumours. With the advent of a more refined system of 3D endoscopes, distal chip cameras, and robotic surgery, the techniques allow a surgeon to perform a complex surgery with minimally invasive skull base surgery [23].

A skull base tumour represents a wide cohort of tumours with different locations, extension, and histology. Different size and location of tumours require different surgical approaches. Image reconstruction with 2D or 3D techniques will allow accurate assessment of the tumours. The images can be mapped to help with the surgical planning preoperatively. One of the most promising surgical planning technologies is virtual reality. Under virtual reality conditions, it can conduct quick three-dimensional reconstruction of computed tomography, magnetic resonance imaging, and other imaging data sets. Surgical simulation allows for a more intuitive understanding of the anatomical relationship of the surgical area [24]. The visualization and identification of structures like cribriform plate, sellar area, fovea ethmoidalis, and optic prominence are enhanced by using the 3D multi-angle endoscopes. These endoscopic techniques minimize the complications since they reduce the brain and nerve traction, reduce incision size, and hasten the patient's recovery [25].

A versatile method is the endoscopic endonasal transpterygoid approach, providing direct access through an anterior surgical corridor to the petrous apex [26]. In cadavers, the endoscopic endonasal transpterygoid route has been widely evaluated and is currently used for specific diseases involving the lateral skull base during surgery [27]. The gateway for lateral skull base exposure has been the endoscopic endonasal transmaxillary transpterygoid (TMTP) approach. The endoscopic endonasal approach is being used for anatomical regions, which can be quite complex. The use of the Eustachian tube as a landmark for the identification of the petrous internal carotid artery has recently been reported. Removal of the Eustachian cartilaginous tube (ET) and lateral internal carotid artery

mobilization (ICA) are technically demanding adjunctive steps used to access the petroclival region [28].

Although this approach is a useful strategy for many petrous apex lesions, extension of the disease into lateral, upper, or posterior compartments may limit the extent of resection provided solely by an anterior approach [26]. A key step during this approach is the identification of the petrous segment of the internal carotid artery (ICA), and the vidian nerve (VN) has been described as the main landmark for the safe endonasal localization of the petrous ICA at the level of the foramen lacerum [27].

By resection of the cartilaginous ET and mobilization of the paraclival ICA, the transpterygoid corridor into the petroclival region is maximally expanded. These additional manoeuvres extended the deep window almost six times and gave the petroclival region more lateral access [28]. In order to avoid injury in skull base surgery through the endoscopic endonasal route, the Eustachian tube is a consistent and reliable landmark of the internal carotid artery. By an intranasal endoscopic approach, the bony-cartilaginous junction of the Eustachian tube was just anterior to the first genuine internal carotid artery [29].

The Eustachian tube and sphenoid spine have been previously described as landmarks for endonasal surgical identification of the most distal segment of the parapharyngeal internal carotid artery (PhICA). A novel and palpable bony landmark, the inferomedial edge of the tympanic bone, referred to as the tympanic crest, was identified, leading from the sphenoid spine to the lateral carotid canal. Variable anatomy is present in the sphenoid spine and the pericarotid space. In an endoscopic transmasticator approach to the infratemporal fossa, the tympanic crest, sphenoid spine, and vaginal process of the tympanic bone represent the closest landmarks leading to the PhICA [30].

To describe the various anatomical structures surrounding the anterior genuineness of the petrous ICA, the endoscopic endonasal transpterygoid approach was used. The VN, the Eustachian tube, the foramen lacerum, the petroclival fissure, and the pharyngobasilar fascia have been identified and described as five key anatomical structures [27].

3.6.6 Temporal Bone Surgery

The temporal bone is separated into the squamous, petrous, styloid, tympanic, and mastoid portions of the skull base. The most medial aspect of the temporal bone is the petrous portion, which encloses the vestibule, semicircular canal, facial canal, carotid canal, and cochlea. It consists of three surfaces and margins, a base and an apex, and is between the sphenoid's larger wing and the occipital bone [31].

The Eustachian tube is divided into the osseous and cartilaginous parts into the bones and cartilage. Based on its relationship to the skull base, the cartilaginous portion can be further subdivided into the posterolateral, middle, and anteromedial sections. The Eustachian tube is closely associated with the pterygoid process of the sphenoid bone, the foramen lacerum, and the petrosal apex, and nearly perpendicular to the oblique sagittal line [32] (Figs. 3.40, 3.41, 3.42, and 3.43).

The petrous apex is a complex temporal bone region that can harbour surgically difficult-to-access lesions. Petrous apex pathology is divided into extradural and intradural aetiology. Cholesterol granulomas, cholesteatoma, or epidermoid cysts and osteomyelitis are included in extradural pathology [31].

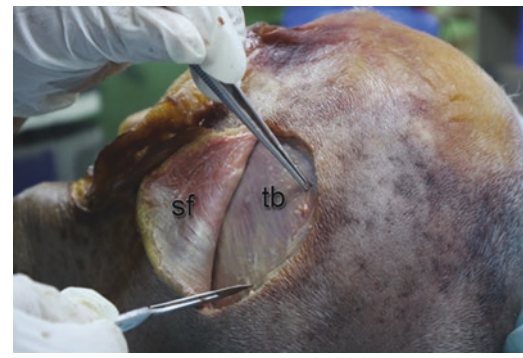

Fig. 3.40 The skin flap (sf) has been elevated, and temporalis muscle is visible with overlying temporalis fascia (tb)

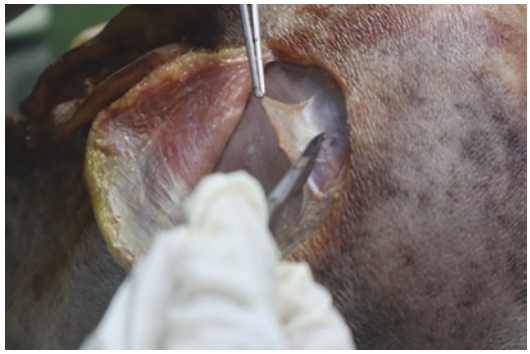

Fig. 3.41 The temporalis fascia is harvested meticulously using micro instruments

Some lesions can be managed with drainage, such as cholesterol granulomas, while neoplastic lesions must be fully resected. Open, endoscopic, and combined techniques are used for surgical options and are categorized into anterior, lateral, and posterior approaches. The approach is determined by the nature of the pathology and location relative to vital structures and extension into surrounding structures and requires thorough preoperative evaluation and discussion with the patient regarding surgical objectives [31] (Fig. 3.44).

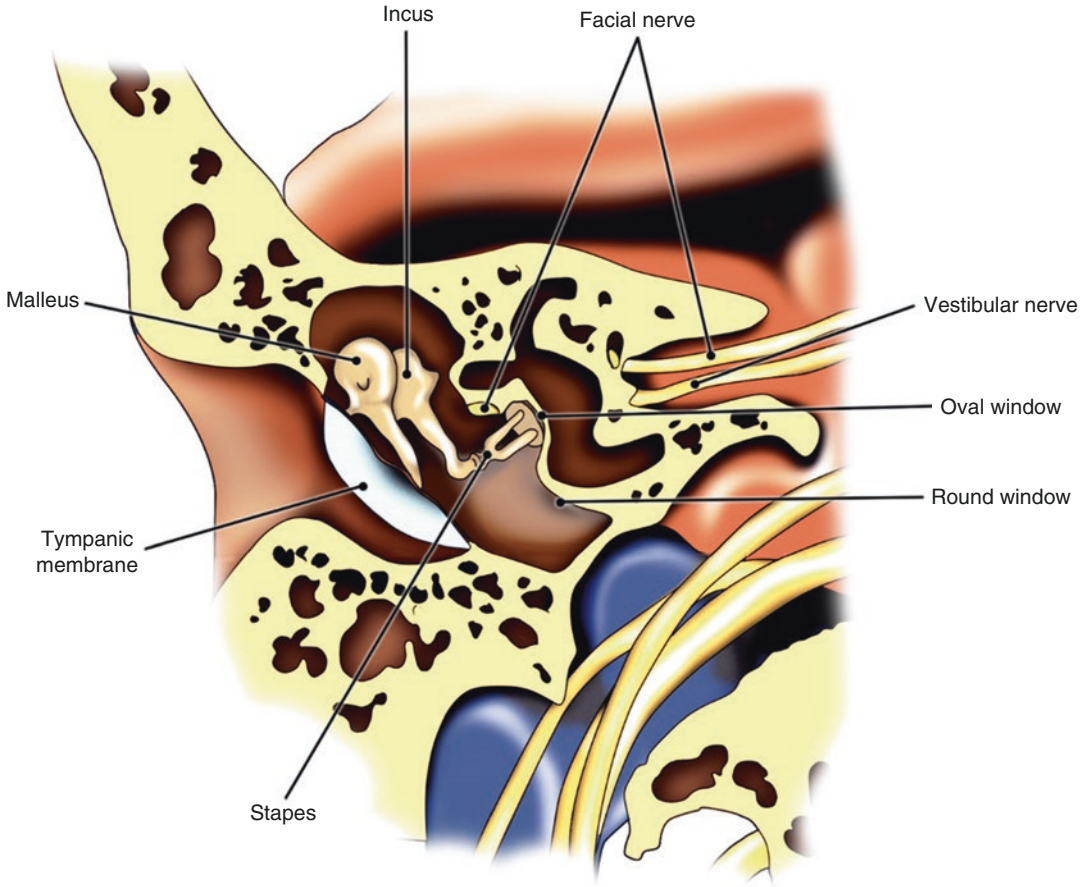

Fig. 3.42 The middle-ear and inner-ear structures and facial nerves are commonly encountered during a mastoidectomy

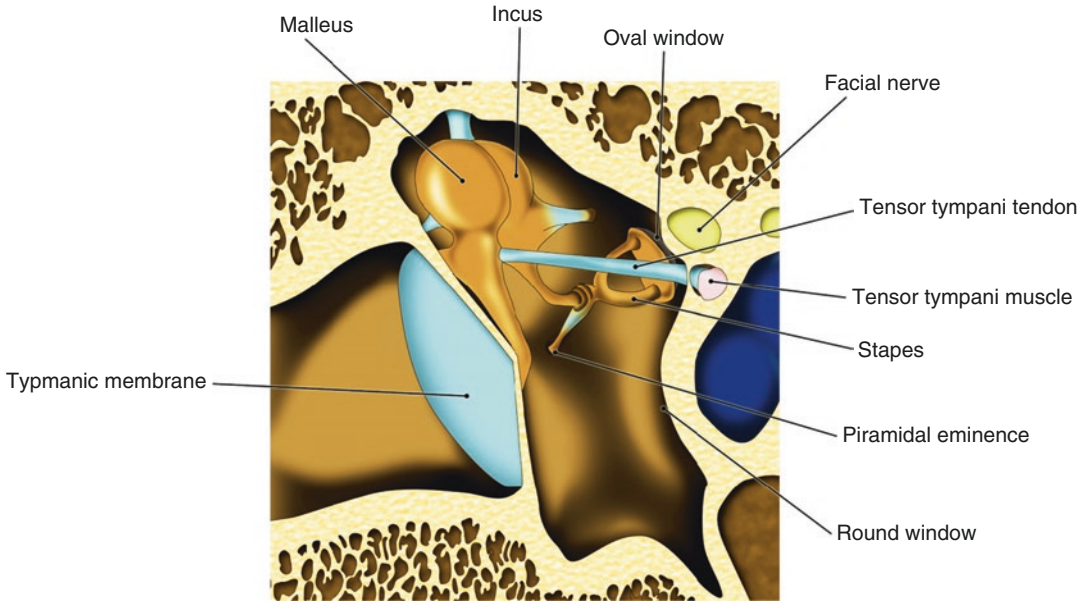

Fig. 3.43 The relation of facial nerve to middle-ear structures like stapes, tensor tympani muscle, and incus is an important landmark for the identification of facial nerve during ear surgery

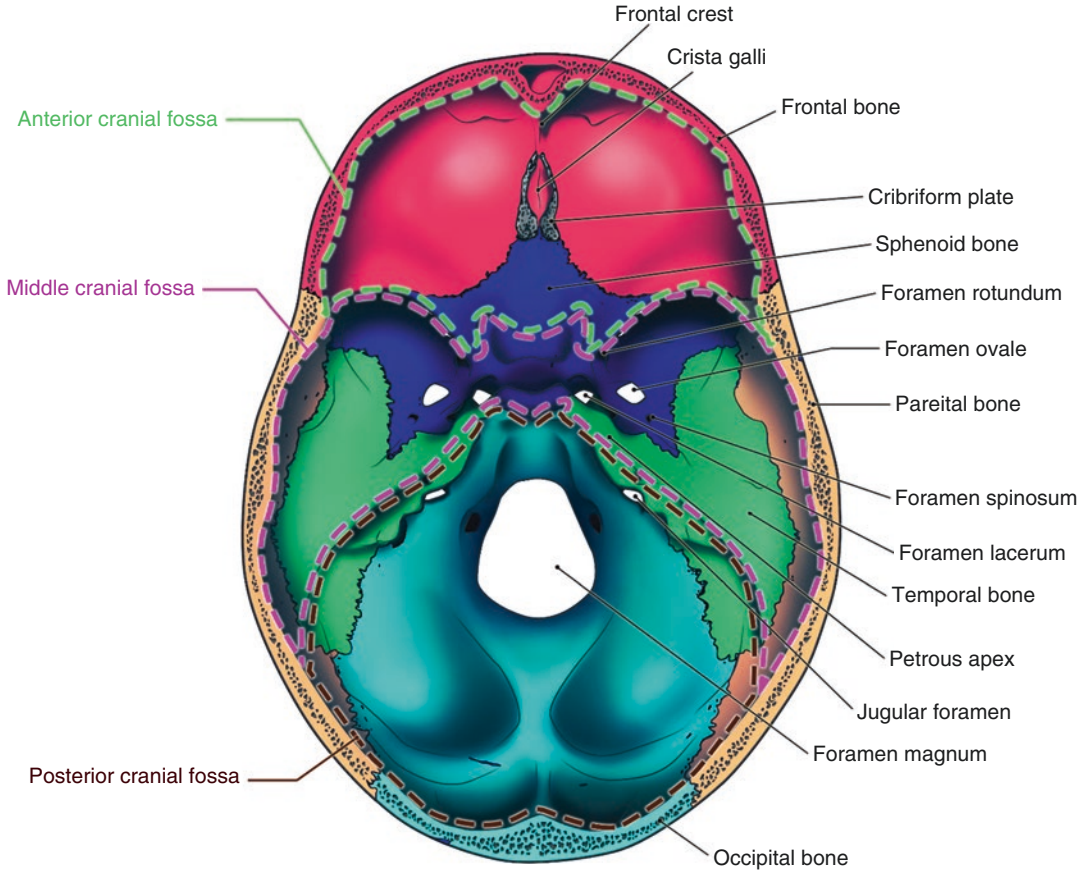

Fig. 3.44 The cranial fossa is divided into three segments and harbours different organs and structures that pass through the skull base to the neck region

3.7 Conclusion

Anatomical structures play an important role in defining the surgical landmarks of any types of head and neck surgery to ensure a safe and effective surgery. Refining techniques of surgery in addition to enhanced surgical landmarks' knowledge will avoid unwanted hazards that can arise from the surgical procedures. The outcome of surgery influences the patient's post-operative quality of life and may reduce the cost on the health institution due to shortened hospital stay and reduced usage of medications, staff, and facility.

References

1. Bock A, Modabber A, Hölzle F, Prescher A, Classen-Linke I. Improvement of anatomical knowledge and surgical skills in head and neck region—an interdisciplinary hands-on course for clinical students. Ann Anat. 2019;224:97–101. https://doi.org/10.1016/j.aanat.2019.03.011.
2. Samaniego E, Prada C, Rodríguez-Prieto MÁ. Planos quirúrgicos en cabeza y cuello [Surgical planes of the head and neck]. Actas Dermosifiliogr. 2011;102(3):167–74. https://doi.org/10.1016/j.ad.2010.07.005.
3. Shoja MM, Oyesiku NM, Griessenauer CJ, et al. Anastomoses between lower cranial and upper cervical nerves: a comprehensive review with potential significance during skull base and neck operations, part I: trigeminal, facial, and vestibulocochlear nerves. Clin Anat. 2014;27(1):118–30. https://doi.org/10.1002/ca.22340.
4. Diamond M, Wartmann CT, Tubbs RS, Shoja MM, Cohen-Gadol AA, Loukas M. Peripheral facial nerve communications and their clinical implications. Clin Anat. 2011;24(1):10–8. https://doi.org/10.1002/ca.21072.
5. Uludağ M, Tanal M, İşgör A. A review of methods for the preservation of laryngeal nerves during thyroidectomy. Sisli Etfal Hastan Tip Bul. 2018;52(2):79–91. Published 2018 Jun 18. https://doi.org/10.14744/SEMB.2018.37928.
6. Cakir BO, Ercan I, Sam B, Turgut S. Reliable surgical landmarks for the identification of the recurrent laryngeal nerve. Otolaryngol Head Neck Surg. 2006;135(2):299–302. https://doi.org/10.1016/j.otohns.2006.03.026.
7. Gurleyik E, Gurleyik G. Intraoperative monitoring of external branch of the superior laryngeal nerve: functional identification, motor integrity, and its role on vocal cord function. J Investig Surg. 2018;31(6):509–14. https://doi.org/10.1080/08941939.2017.1362489.
8. Ng SK, Li HN, Chan JY, Wong EWY, Vlantis AC. A useful landmark to locate the external branch of the superior laryngeal nerve during thyroidectomy. Gland Surg. 2020;9(3):647–52. https://doi.org/10.21037/gs.2020.03.25.
9. Iwanaga J, Fisahn C, Watanabe K, et al. Parotid branches of the auriculotemporal nerve: an anatomical study with implications for Frey syndrome. J Craniofac Surg. 2017;28(1):262–4. https://doi.org/10.1097/SCS.0000000000003260.
10. Young A, Okuyemi OT. Frey syndrome. In: StatPearls. Treasure Island, FL: StatPearls Publishing; 2020.
11. Movassaghi K, Lewis M, Shahzad F, May JW Jr. Optimizing the aesthetic result of parotidectomy with a facelift incision and temporoparietal fascia flap. Plast Reconstr Surg Glob Open. 2019;7(2):e2067. Published 2019 Feb 8. https://doi.org/10.1097/GOX.0000000000002067.
12. Chen CY, Chen PR, Chou YF. Intra-auricular modification of facelift incision decreased the risk of Frey syndrome. Ci Ji Yi Xue Za Zhi. 2019;31(4):266–9. Published 2019 Sep 16. https://doi.org/10.4103/tcmj.tcmj_117_18.
13. Hwang K, Lee JH, Lim HJ. Anatomy of the corrugator muscle. J Craniofac Surg. 2017;28(2):524–7. https://doi.org/10.1097/SCS.0000000000003304.
14. Pessino K, Patel J, Patel BC. Anatomy, head and neck, frontalis muscle. In: StatPearls. Treasure Island, FL: StatPearls Publishing; 2020.
15. Saraniti C, Greco G, Verro B, Lazim NM, Chianetta E. Impact of narrow band imaging in pre-operative assessment of suspicious Oral cavity lesions: a systematic review. Iran J Otorhinolaryngol. 2021;33(116):127–35. https://doi.org/10.22038/ijorl.2021.51485.2746.
16. Wiegand S. Evidence and evidence gaps of laryngeal cancer surgery. GMS Curr Top Otorhinolaryngol Head Neck Surg. 2016;15:Doc03. Published 2016 Dec 15. https://doi.org/10.3205/cto000130.
17. do Vale F, Rodrigues ML, Francisco I, et al. Short-term pharyngeal airway space changes after mandibular advancement surgery in class II patients-a two-dimensional retrospective study. Orthod Craniofac Res. 2019;22(2):81–6. https://doi.org/10.1111/ocr.12264.
18. Chan JY, Richmon JD. Transoral robotic surgery (TORS) for benign pharyngeal lesions. Otolaryngol Clin N Am. 2014;47(3):407–13. https://doi.org/10.1016/j.otc.2014.02.003.
19. Smith RV. Transoral robotic surgery for larynx cancer. Otolaryngol Clin N Am. 2014;47(3):379–95. https://doi.org/10.1016/j.otc.2014.03.003.
20. Alsaleh S, Manji J, Javer A. Optimization of the surgical field in endoscopic sinus surgery: an evidence-based approach. Curr Allergy Asthma Rep. 2019;19(1):8. Published 2019 Feb 2. https://doi.org/10.1007/s11882-019-0847-5.
21. Lazim NM, Abdullah B. Risk factors and etiopathogenesis of NPC: an evidence-based management of NPC from basic science to clinical presentation and treatment. ISBN: 9780128144046, London: Elsevier; 2020.

22. Abdullah B, Rasid NSA, Lazim NM, et al. Ni endoscopic classification for Storz Professional Image Enhancement System (SPIES) endoscopy in the detection of upper aerodigestive tract (UADT) tumours. Sci Rep. 2020;10(1):6941. Published 2020 Apr 24. https://doi.org/10.1038/s41598-020-64011-6.
23. Wasserzug O, Margalit N, Weizman N, Fliss DM, Gil Z. Utility of a three-dimensional endoscopic system in skull base surgery. Skull Base. 2010;20(4):223–8. https://doi.org/10.1055/s-0030-1247630.
24. Shao X, Yuan Q, Qian D, et al. Virtual reality technology for teaching neurosurgery of skull base tumor. BMC Med Educ. 2020;20(1):3. Published 2020 Jan 3. https://doi.org/10.1186/s12909-019-1911-5.
25. Ottenhausen M, Rumalla K, Alalade AF, Nair P, La Corte E, Younus I, Forbes JA, Ben Nsir A, Banu MA, Tsiouris AJ, Schwartz TH. Decision-making algorithm for minimally invasive approaches to anterior skull base meningiomas. Neurosurg Focus. 2018;44(4):E7. https://doi.org/10.3171/2018.1.FOCUS17734.
26. Mehta GU, Raza SM. Endoscopic endonasal transpterygoid approach to petrous pathologies: technique, limitations and alternative approaches. J Neurosurg Sci. 2018;62(3):339–46. https://doi.org/10.23736/S0390-5616.18.04302-3.
27. Kaen A, Cárdenas Ruiz-Valdepeñas E, Di Somma A, Esteban F, Márquez Rivas J, Ambrosiani FJ. Refining the anatomic boundaries of the endoscopic endonasal transpterygoid approach: the "VELPPHA area" concept. J Neurosurg. 2018;131(3):911–9. https://doi.org/10.3171/2018.4.JNS173070.
28. Freeman JL, Sampath R, Quattlebaum SC, et al. Expanding the endoscopic transpterygoid corridor to the petroclival region: anatomical study and volumetric comparative analysis. J Neurosurg. 2018;128(6):1855–64. https://doi.org/10.3171/2017.1.JNS161788.
29. Liu J, Sun X, Liu Q, Wang D, Wang H, Ma N. Eustachian tube as a landmark to the internal carotid artery in endoscopic skull base surgery. Otolaryngol Head Neck Surg. 2016;154(2):377–82. https://doi.org/10.1177/0194599815616799.
30. Li W, Chae R, Rubio RR, Benet A, Meybodi AT, Feng X, Huang G, El-Sayed IH. Characterization of Anatomical Landmarks for Exposing the Internal Carotid Artery in the Infratemporal Fossa Through an Endoscopic Transmasticator Approach: A Morphometric Cadaveric Study. World Neurosurg. 2019;131:e415–24. https://doi.org/10.1016/j.wneu.2019.07.185.
31. Li KL, Agarwal V, Moskowitz HS, Abuzeid WM. Surgical approaches to the petrous apex. World J Otorhinolaryngol Head Neck Surg. 2020;6(2):106–14. https://doi.org/10.1016/j.wjorl.2019.11.002.
32. Komune N, Matsuo S, Miki K, et al. Surgical Anatomy of the Eustachian Tube for Endoscopic Transnasal Skull Base Surgery: A Cadaveric and Radiologic Study. World Neurosurg. 2018;112:e172–81. https://doi.org/10.1016/j.wneu.2018.01.003.

4 Radiological Assessment and Its Roles in Head and Neck Surgical Oncology

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4.1 Introduction of Head and Neck Squamous Cell Carcinoma

Cancers of the head and neck are the sixth most frequent cancer worldwide and are associated with significant morbidity. Head and neck squamous cell carcinoma (HNSCC) represents the most common malignancy, arising from the mucosal epithelium in the oral cavity, pharynx, and larynx [1]. The reported incidence rate in 2008 was 6.8%. From 1990 to 2017, incidence rates for larynx and nasopharyngeal cancers decreased, whereas they increased for other pharyngeal cancers and lip/oral cavity cancers [2]. Geographical variations of incidence rates of HNSCC are related to differences in genetic susceptibility and socio-economic status. In developing countries, such as India and China, exposure to carcinogenic air pollutants and particulate matter is an important risk factor. However, high-risk factors are represented by tobacco consumption (i.e. smoking and betel nut chewing), alcohol, and presence of infectious agents. Persistent infections with human papillomavirus (HPV) and Epstein–Barr virus (EBV) are known aetiological risk factors for HNSCC arising from the oropharynx and nasopharynx, respectively. HPV infection is an increasing risk factor (mainly transmitted by oral sex), particularly for oropharyngeal cancer, most often associated with HPV-16 (secondly HPV-18) [3–6]. In the USA, the cases of HPV-associated oropharyngeal cancers exceed the number of cervix cancers [2].

HNSCC is locally invasive, tends to spread to regional lymph nodes, and has a propensity for perineural spread. A substantial percentage of HNSCC has nodal involvement at initial presentation, and lymphadenopathy may represent the initial complaint. Moreover, lymphadenopathy is an important prognostic indicator in HNSCC, and for this reason, all of the cervical lymph node chains should be evaluated when the primary tumour is imaged [7, 8]. Perineural spread (PNS) is typically retrograde, from the primary site toward the skull base. PNS is a negative prognostic factor, and its presence is an indication for adjuvant radiation therapy [9]. HNSCC can metastasize by hematogenous routes, usually in

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N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_4

advanced disease. The lungs are the most common sites of distant metastases from head and neck cancer followed by bone and liver [10]. Patients with HNSCC have an increased risk of second primary malignancies, predominantly involving the upper aerodigestive tract, but there is also a high incidence of second primary lung cancers. A higher percentage of second primary malignancies are metachronous (i.e. identified at least 6 months after identification of the primary tumour) than synchronous. Following the successful therapy of the primary tumour, second primary tumour has a reported annual incidence of 3–7% [11, 12].

4.1.1 Clinical Presentation and Assessment of Head and Neck Malignancy

HNSCC is a cancer of adults, more frequent in male than in women, with a median age at diagnosis of 66 years for HPV-negative HNSCC, 53 years for HPV-positive HNSCC, and 50 years for EBV-positive HNSCC [6, 13, 14]. The clinical presentation depends on the anatomical site of the primary tumour and tumour extension. Early recognition and diagnosis may improve the survival rate, which depends on the stage of disease and clinical status of the patient. The diagnosis of HNSCC must be established by histologic examination of tissue biopsy [15]. In the setting of oropharyngeal tumour and unknown primary tumour, HPV testing is mandatory as HPV status is a determinant factor in the current staging [6, 16]. Multiple techniques are available for the determination of HPV status, and currently the cheaper and more reliable test is the identification of the upregulation of a cyclin-dependent kinase inhibitor, known as p16 [17].

After the histological diagnosis, the second step to determine the adequate treatment strategy is the tumour staging. In the American Joint Committee on Cancer (AJCC)/Union for International Cancer Control (UICC) cancer staging manuals, staging is described by the primary tumour, nodal disease, and distant (metastatic) spread, designing the TNM system. Oncologists designate a final clinical stage, termed cTNM, after combining information from the physical examination, histological evaluation, radiology findings, sentinel node biopsy, and other diagnostic tests. After tumour resection, the pathological examination enables to provide the pTNM. The cTNM or pTNM may be combined with additional specific factors. In an ideal staging system, each stage group should provide a specific prognosis and accurate outcome prediction, meaning that patients in the same group should have similar survival rates [18].

Currently, both HNSCC stage and HPV status are recognized as the major determinants of HNSCC prognosis. The 8th edition of the Cancer Staging Manual contains three important changes: addition of depth of invasion (DOI) to tumour staging in oral cavity cancers, addition of extracapsular nodal extension (ENE) to nodal staging in non-viral HNSCC, and codification of a novel staging system for HPV-positive HNSCC. Staging of nasopharyngeal carcinoma remains strictly based on anatomy, without incorporation of viral or environmental aetiology. The staging evaluation includes complete head and neck clinical examination and cross-sectional imaging. In fact, clinical examination, with direct inspection and endoscopy as required, permits to visualize the mucosa of the upper aerodigestive tract; however, submucosal and deeper tumours cannot be seen. Cross-sectional imaging allows to establish the extent of locoregional disease, to detect bony invasion and perineural or perivascular spread, to assess lymph node metastases, to rule out distant metastatic disease, and to exclude a second primary tumour [18, 19].

In the treatment planning, there are three points to rule out: evaluating the extension and the boundaries of the tumour, detecting potential infiltration of adjacent structures (e.g. vessels, cranial nerves), and differentiating between tumour infiltration and inflammatory reaction of surrounding tissue. Imaging is not only fundamental in the planning therapy, but also a crucial tool in the follow-up of patients under therapy, to evaluate response to treatment, and to detect recurrences before it becomes clinically evident. Treatment is generally multimodal, consisting of

surgery resection, radiotherapy, and chemotherapy. Pathological features indicative of increased risk of recurrence include extranodal extension, close or involved surgical margins, or perineural invasion [20].

4.1.2 Cross-Sectional Imaging of Head and Neck Tumours

Imaging modalities available include computed tomography (CT), magnetic resonance imaging (MRI), ultrasound (US), and positron emission tomography/computed tomography (PET/CT). When staging HNSCC, the tumour sites, availability of the imaging modality, patient compliance to the imaging evaluation, and possible contraindications should be considered. Imaging examinations should be performed with intravenous contrast medium, and its related contraindications must be taken into account. A well-known contraindication of MRI is the presence of ferromagnetic devices, due to the magnetic field that can displace implants, affect the function of devices, and cause tissue heating [11].

CT is usually the first imaging modality used for the staging process, thanks to its wide availability, reproducibility, and high space resolution. CT can provide information on primary tumour extent, cervical lymph node metastasis, and bone involvement with short scan times. However, low soft-tissue resolution will not always enable the visualization of exact lesion boundaries, particularly in the context of surrounding soft tissues with similar attenuation. Visualization of vestibule mucosa can be improved using the 'puffed-cheek manoeuvre', resulting in dilatation of the vestibule with air and separation of the mucosal surfaces [11, 21].

However, CT can have limitations in the oral region, due to the metal artefacts from dental amalgams and beam hardening from adjacent mandible and maxilla. However, many advances have contributed to reducing metal artefacts. New software algorithms including iterative metal artefact reduction (IMAR) have contributed to improved metal artefact reduction. Dual-energy CT with various supplementary reconstructions may gain a relevant role in the imaging evaluation, thanks to various supplementary reconstructions for artefact reduction and improvement of soft-tissue contrast [20, 22].

MRI offers a superior soft-tissue contrast compared to CT, providing a better delineation of soft-tissue invasion. MRI is the preferred staging tool for nasopharyngeal carcinoma, enabling the detection of skull base infiltration (T3) or intracranial extension of disease (T4) [23, 24]. MRI is often used for the study of oral cavity and oropharynx, due to the high soft-tissue contrast enabling the detection of small primary tonsillar tumours and evaluating the deep extent of an infiltrative lesion when planning surgical resection or intensity-modulated radiation therapy [21]. In the larynx, CT is the preferred imaging modality, due to MRI motion artefact in this anatomic district. MRI may be reserved for cases of uncertain cartilage invasion (T4a) [25]. Nodal disease can be evaluated with CT, MR, and US, as described subsequently.

In PET/CT examination, it is important to know that different tissues have variable degrees of normal FDG uptake, particularly muscles, brown fat, salivary and lymphoid tissue, and recent biopsy sites. These all serve as potential false-positive pitfalls in PET imaging. A potential false-negative finding is the absence of uptake in a predominantly cystic node. Correlation with neck CT imaging will allow correct identification of cystic nodal metastases. US has a limited role in HNSCC, mainly reserved for interrogation of nodes that are equivocal on other imaging modalities, and particularly when a positive finding, such as a contralateral node, might significantly alter staging and management. US can also serve as an imaging guidance for fine needle aspiration [7].

4.2 Preoperative Imaging Evaluation

Cross-sectional imaging has a fundamental role in the preoperative tumour evaluation. Together with clinical and histological examination, imaging provides information required for the tumour staging. In the treatment planning, preoperative

imaging is fundamental to evaluate particular spread or tumour extension: perineural tumour spread, carotid involvement, invasion of prevertebral space, and bone or cartilage invasion. Lymph node evaluation is discussed separately.

4.2.1 Perineural Tumour Spread

In head and neck tumours, perineural spread (PNS) represents an important route of spread, extending along the nerves. PNS is common in adenoid cystic carcinoma, HNSCC, and salivary duct carcinoma. Currently, PNS is considered an independent prognostic indicator, associated with a nearly threefold increase in local recurrence and approximately 30% decrease in 5-year survival rate. In almost 50% of patients, PNS can be asymptomatic. The most commonly involved nerves are the trigeminal and facial nerves. Typically, perineural spread is retrograde toward the skull base; however, antegrade spread can also occur from branch points. The high soft-tissue contrast resolution makes MRI the optimal imaging modality for the detection of direct signs of PNS along a nerve: contrast enhancement and enlargement (Fig. 4.1). Nerve enlargement can lead to obliteration of the perineural fat tissue at foraminal openings or fissures. Further involvement can result in bone changes, such as foramina/fissure widening and bone erosion, better evaluated on CT. Muscle denervation changes are indirect signs of PNS. In the acute or subacute phase of denervation, muscle oedema and increased enhancement are typical findings. Chronic denervation results in fatty replacement and muscle atrophy. Differential diagnoses of PNS in case of nerve enlargement or enhancement are primary nerve tumours and inflammatory and infectious conditions. In case of bone changes, differential diagnoses are radionecrosis and odontogenic infections [26, 27].

4.2.2 Carotid Artery Involvement

Carotid space, often referred to as the retrostyloid compartment of the parapharyngeal space, is an important landmark in treatment planning. Besides the carotid arteries (i.e. common carotid and internal carotid arteries, and a portion of the external carotid artery and the internal jugular vein), the nerve structures contained in the carotid space should be kept in mind: cranial nerves IX, X, XI, and XII; cervical sympathetic trunk; and ansa cervicalis, a part of the cervical plexus. Preoperative

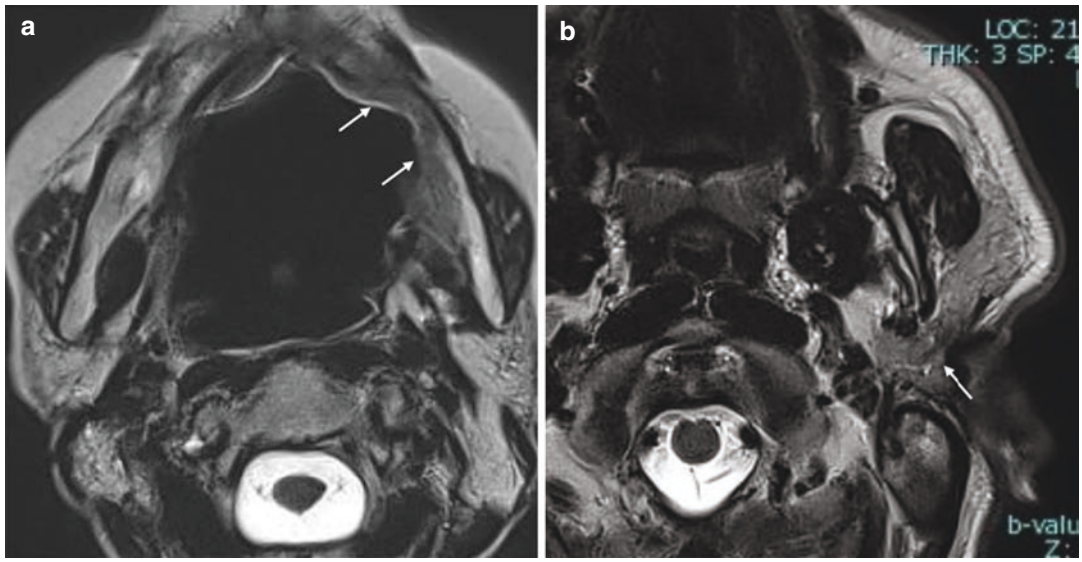

Fig. 4.1 Perineural spread. (**a**) Enlargement of inferior alveolar nerve and its canal (white arrow). (**b**) Auriculotemporal nerve enlargement from squamous cell carcinoma of the skin (white arrow)

evaluation of direct invasion of carotid space has staging and treatment implications, identifying patients with poor prognosis. Moreover, also a metastatic lymph node can invade the carotid artery. According to the 8th AJCC, in case of oropharyngeal non-HPV-associated squamous cell carcinoma, encasement of the carotid artery upstages the lesion to T4b disease. Hence, involvement of carotid sheath is a critical issue in tumour resectability, and there are three possible settings: unresectable tumour, resectable tumour with limited 'collateral damage' and morbidity, and resectable tumour requiring extensive complicated surgery with related quality-of-life issues.

Radiological criteria of carotid involvement in literature are carotid encasement defined as more than 270° of circumferential contact of the tumour with the vessel (Fig. 4.2), obliteration of the fat between the lymph node/primary tumour and the carotid artery, deformation of the carotid artery, and length of contact between the carotid artery and tumour mass. Several studies have been conducted to classify carotid invasion on preoperative imaging including US, MRI, and CT. Currently, MRI can be considered the most sensitive imaging modality to detect carotid encasement [28, 29].

4.2.3 Invasion of Prevertebral Space

Prevertebral space involvement is associated with poor outcomes, due to the high rate of adenopathy (in particular retropharyngeal nodes) and local recurrence, and even hematogenous metastases are increased. Tumour fixation to the longus colli/capitis muscle complex implies an incomplete surgical resection; hence, detection of this extension is fundamental to define tumour resectability. MRI provides higher soft-tissue contrast and more anatomic detail than CT, visualizing the preservation of the retropharyngeal fat planes [30, 31].

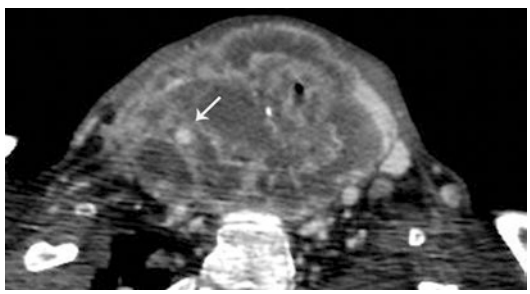

Fig. 4.2 Carotid artery encasement by the tumour

4.2.4 Bone and Cartilage Invasion

Bone and cartilage invasion is a decision-making information in the planning treatment, in particular for oral and laryngeal cancer, respectively. In the setting of oral cancer, preoperative evaluation of mandibular invasion is critical for planning the type of mandibular resection. The common route of spread is along the buccal cortices, where a wide bone invasion may be detectable even in a clinical examination. However, imaging is the appropriate tool to detect bone invasion, specifying the extension of involvement. Bone involvement can vary from superficial cortical to deep cortical to marrow invasion and mandibular canal involvement. CT is generally considered superior for detection of bone invasion, in particular for early cortical erosion. However, MRI permits the identification of marrow invasion and has a high negative predictive value, demonstrating also marrow replacement without grossly visible cortical breakthrough. Hence, CT and MRI result to be complementary imaging modalities for the evaluation of bone invasion (Fig. 4.3) [32, 33].

Also, in the setting of laryngeal cancer, CT has a primary role in the detection of cartilage invasion. Classical criteria of tumour invasion of the thyroid cartilage are erosion, lysis, and transmural extralaryngeal tumour spread. Extralaryngeal spread can be considered in case of substitution by tumour tissue on the outside of the membrane/cartilage, or obliteration of fat tissue between the extralaryngeal structure and laryngeal components. In case of subtle cartilage invasion, CT alone may result to be insufficient, and MRI can be useful for excluding cartilage invasion. Moreover, there is an increasing role of dual-energy CT [25, 34].

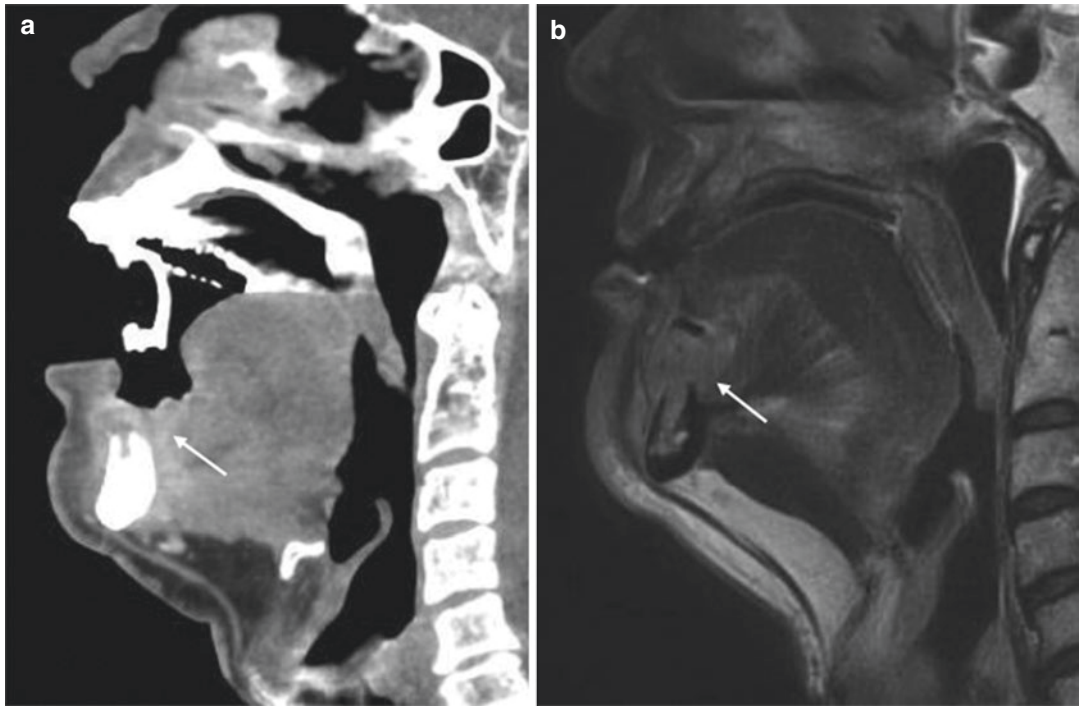

Fig. 4.3 Mandibular bone invasion (white arrow) from squamous cell carcinoma of the head and neck. (**a**) CT scan. (**b**) MR T2w image

4.3 Imaging Highlights of Head and Neck Anatomy

Head and neck anatomy is complex, and on cross-sectional imaging, various anatomical spaces are defined by the presence of fascial planes. However, the main anatomic subdivision concerns the aerodigestive tract, defining the oral cavity, the three regions of pharynx (i.e. nasopharynx, oropharynx, and hypopharynx), and the larynx. The definition of these portions is useful from a clinical point of view because malignancies such as HNSCC tend to differ in presentation, routes of spread, and clinical management.

4.3.1 Oral Cavity

The oral cavity is the most ventral portion of the aerodigestive tract and is separated from the oropharynx by the circumvallate papillae, the anterior tonsillar pillars, and a line connecting the upper margins of the tonsillar pillars along the soft palate. The oral cavity includes the oral tongue (anterior two-thirds of the tongue), floor of the mouth (FOM), lips (inner mucosal surface of the lips), gingivobuccal and buccomasseteric regions, and adjacent portions of the maxilla and mandible. The tongue consists of two symmetric halves, divided by a midline septum, and it is composed of muscular tissue distinguished in intrinsic and extrinsic muscles. The extrinsic muscles provide attachment of the tongue to the hyoid bone, mandible, and styloid process, and they are represented by genioglossus, hyoglossus, styloglossus muscles, and palatoglossus. The FOM is a U-shaped structure where the mylohyoid muscles represent the primary supporting structure. Additional support structures are represented by the paired paramedian geniohyoid muscles and the anterior bellies of digastric muscles.

The retromolar trigone (RMT) is an important landmark of tumour spread. It is defined as a triangular area of mucosa posterior to the lower and upper third molars covering the anterior surface of the lower ascending ramus of the mandible. It is located at the crossroads of buccal, masticator,

and parapharyngeal spaces. Squamous cell carcinomas at this site are frequently diagnosed at an advanced stage, are prone to bone invasion, and tend to have a poor prognosis.

The pterygomandibular raphe, a thick fascial band between the hamulus of the medial pterygoid plate, and the posterior border of the mylohyoid ridge of the mandible may represent the route of spread of RMT lesions. The pterygomandibular raphe is also defined as the line of attachment for the buccinator and superior pharyngeal constrictor muscles at the junction of the oropharynx and oral cavity. The glossomylohyoid gap is another pathway of spread. It is identified between the mylohyoid and the lateral glossal muscle group (i.e. hyoglossus, styloglossus, and palatoglossus muscles) and provides a communication between the sublingual and submandibular spaces [21, 32].

4.3.2 Nasopharynx

The nasopharynx is the cranial section of the pharynx, extending from the skull base to the level of the hard palate. The lateral walls are formed and supported by the margins of the superior constrictor muscle and the pharyngobasilar fascia. The nasopharynx is in communication with the middle ear via the Eustachian tube. Next to the opening structure of the Eustachian tube (torus tubarius), there is the fossa of Rosenmüller, a common site of origin of nasopharyngeal cancer. The pathway of access for the Eustachian tube and levator veli palatini muscle through the pharyngobasilar fascia is represented by the sinus of Morgagni.

The anatomy of the central skull base is a fundamental knowledge to understand the pathways of perineural spread. It should be reminded that in the region of Meckel's cave, the trigeminal nerve (V) forms three branches: the ophthalmic nerve (V1) extends through the superior orbital fissure; the maxillary nerve (V2) extends through the foramen rotundum into the pterygopalatine fossa where it branches into the infraorbital nerve and palatine nerves; and the mandibular nerve (V3) exits through the foramen ovale. An important landmark is represented by the pterygopalatine fossa, containing fat, branches of the maxillary nerve, pterygopalatine ganglion, and small vessels. The foramen rotundum and the vidian canal enter the pterygopalatine fossa [24].

Sinus of Morgagni may represent the route of spread for cancer to the parapharyngeal space and skull base. Perineural spread along the mandibular nerve (V3) can cause an intracranial extension. Further intracranial spread may involve the cavernous sinus, Meckel's cave, and prepontine cistern. Anterior tumour extension may involve sinonasal cavities and pterygopalatine fossa, allowing perineural spread. Tumour extension into the carotid space may permit perineural spread in cranial nerves IX to XI. The retropharyngeal nodes are the primary nodal drainage in nasopharynx [35].

4.3.3 Oropharynx

The oropharynx is posterior to the oral cavity and includes the tongue base, palatine tonsils, posterior tonsillar pillars, soft palate, and constrictor muscles. Bilaterally, the tonsillar fossa, containing the palatine tonsil, is delimited by the anterior tonsillar pillar made up by the palatoglossus muscle, and the posterior pillar formed by the palatopharyngeus muscle. The mucosa and the musculature are surrounded by the visceral fascia. Posterior tumour extension can cause disruption of the visceral fascia and invasion of longus capitis and colli muscles and the vertebrae. Lateral tumour extension may invade the parapharyngeal space and the carotid space [32].

4.3.4 Hypopharynx

The hypopharynx or laryngopharynx, which extends from the level of the hyoid bone to the upper margin of the cricopharyngeus muscle, is at the lower level of the cricoid cartilage. The post-cricoid region is the anterior wall of the hypopharynx. The posterior wall of the hypopharynx represents the continuation of the posterior wall of the oropharynx. The lateral recesses of the hypopharynx are defined by the pyriform sinuses, which in most caudal portions are located

at the level of the true vocal cords. The medial wall of the pyriform sinus is formed by the lateral surface of the aryepiglottic fold. Squamous cell carcinoma of hypopharynx commonly arises in the pyriform sinus [25, 36].

4.3.5 Larynx

The larynx can be distinguished in three portions: supraglottic larynx, glottis, and subglottic larynx. The supraglottic larynx extends from the tip of the epiglottis to the level of the laryngeal ventricle. The glottis includes the anterior and posterior commissure at the level of the true vocal folds. The subglottic larynx extends below the glottis to the level of the lower margin of the cricoid cartilage. The hyaline cartilaginous structures included in the larynx are the thyroid cartilage, cricoid cartilage, arytenoid cartilage, and corniculate cartilage. The cricoid, thyroid, and arytenoid cartilages are all hyaline cartilages, and there are various degrees of ossification. Cartilage evaluation may be difficult due to the common asymmetric ossification. Ossified areas tend to be more sensitive to cancer invasion in comparison with cartilaginous areas. The epiglottis consists of yellow elastic fibrocartilage and seldom calcifies. The epiglottis has a laryngeal surface and a lingual surface, with a superior portion extending above the level of the hyoid bone although considered supraglottic. The larynx is delimited anteriorly by thyrohyoid membrane. A common route of tumour spread from the larynx is through areas of weakness via the thyrohyoid membrane (Fig. 4.4). Another route of extralaryngeal spread

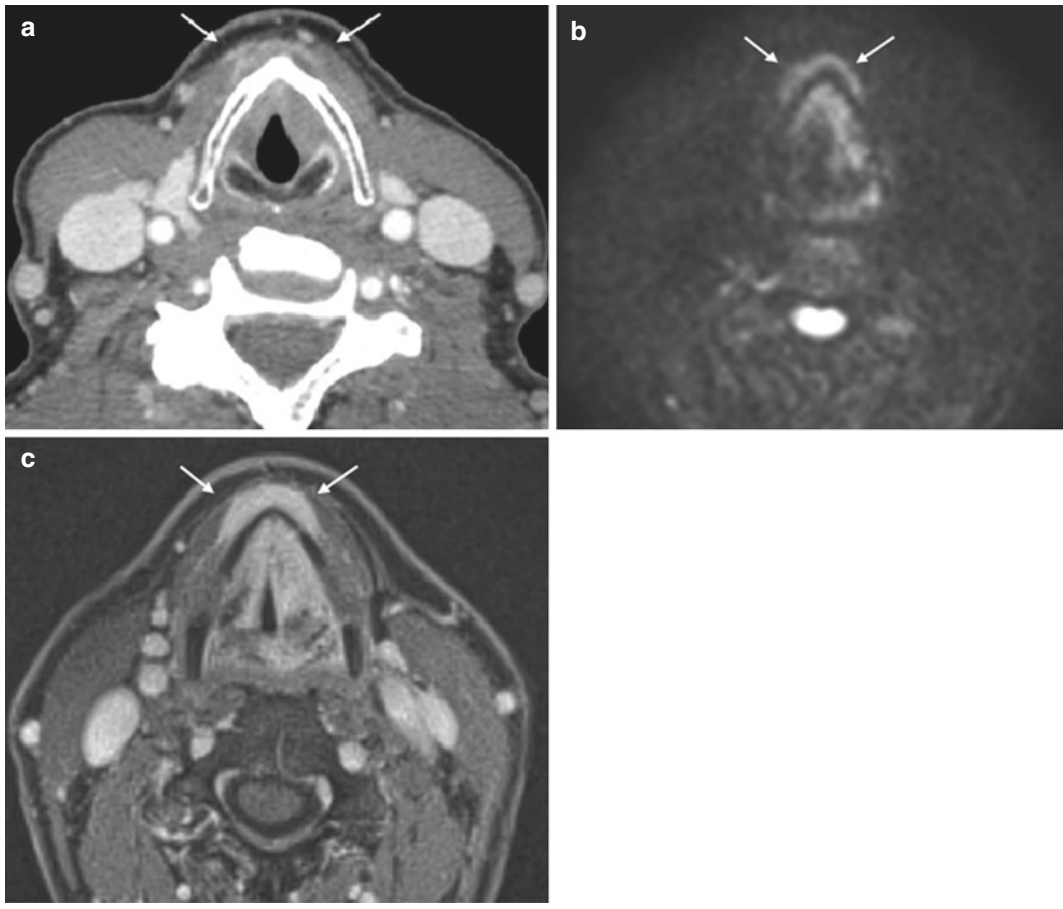

Fig. 4.4 Laryngeal cancer T4: invasion of tissue beyond the larynx with involvement of strap muscles (white arrows). (**a**) CT scan. (**b**) High-resolution DWI. (**c**) 3D T1w post-contrast

is via the inferior pharyngeal constrictor muscle. Submucosal extension may permit the extralaryngeal extension via the cricothyroid membrane [25, 34].

4.4 The AJCC Head and Neck Tumour Classification Changes

The 8th edition of the AJCC has introduced changes that reflect new advances in the knowledge of pathophysiology of these cancers. Moreover, in response to growing evidence of prognostic relevance, additional criteria have been added: the depth of invasion and extranodal extension [7, 18, 23]. Subsequently, the major changes are summarized.

4.4.1 Oral Cavity Squamous Cell Carcinoma

In the 8th edition of the AJCC staging system, tumours arising from the external dry lip are considered cutaneous carcinomas. Tumours arising from the inner lip, which is a wet mucosal surface, are still considered to be oral cavity tumours. Oral cancers are typically asymptomatic and painless at an early stage; thus, intraoral lesions can be diagnosed at advanced stage. The most commonly affected sites are the floor of the mouth and the lateral and ventral aspects of the tongue with less frequent involvement of the retromolar trigone (RMT), buccal mucosa, maxillary and mandibular gingiva, and mucosal lining of the hard palate. Intraoral lesions tend to be diagnosed at a more advanced stage. Oral cavity tumour staging has undergone a substantial alteration, with removal of the criterion of extrinsic muscle invasion for T4 category, which is most relevant for oral tongue malignancies. This is a criterion that was frequently determined by radiologic evaluation since pathologists often have difficulty distinguishing extrinsic from intrinsic muscle invasion. The depth of invasion (DOI) is a new pathologic criterion for determining T status, according to the recognition of its prognostic significance. This pathologic measurement, at surgical resection, is different from the total thickness of the tumour (Fig. 4.5). The accuracy of CT and MRI for determining the depth of invasion and therefore permitting more accurate preoperative tumour staging for oral cavity lesions remains to be proven.

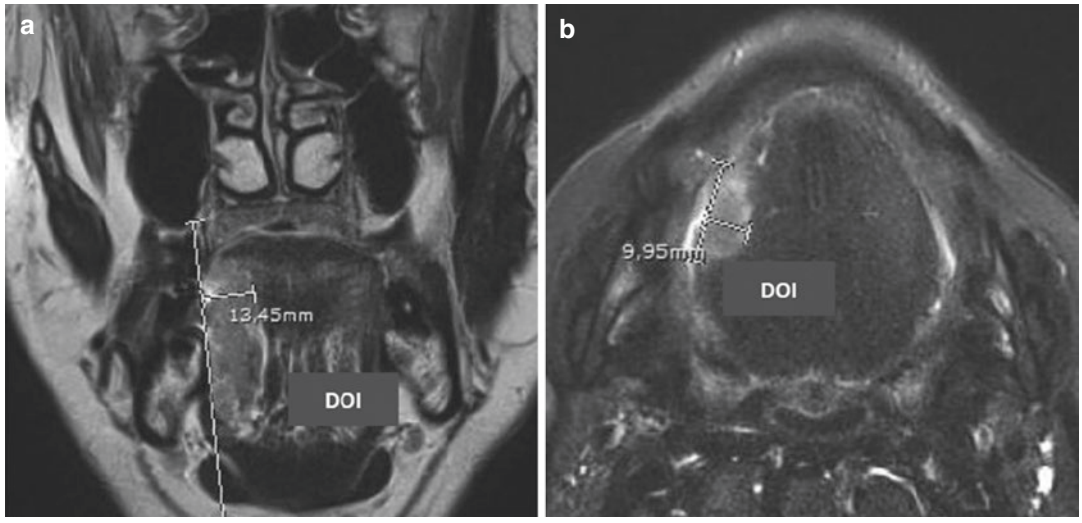

Fig. 4.5 Tongue cancer. (**a**) T3 lesion with DOI of 13 mm. (**b**) T2 lesion with DOI of 10 mm

4.4.2 Oropharyngeal Squamous Cell Carcinoma

It has been stated that an oropharyngeal squamous cell carcinoma (OPSCC) that demonstrates the positivity HPV status (i.e. p16 positive at immunohistochemistry test) shows a better prognosis than p16 negative, which is often associated with tobacco and alcohol (Fig. 4.5). The AJCC7 designated stage III disease when one metastatic OPSCC node is identified and stage IV disease for more than one node or a node larger than 3 cm. HPV-mediated OPSCC has a tendency to present with multiple or large nodes, and such cases, with the prior staging system, were frequently designated as stage IV despite an overall survival rate of around 90%. The AJCC8 proposed a new staging system for HPV-associated OPSCC, stating that all ipsilateral nodal diseases are to be designated as N1, bilateral or contralateral nodes are to be designated as N2, and nodes that are larger than 6 cm are to be designated as N3. Stage I is determined by T1–2 and N0–1, stage II by T1–2 and N2 or T3 and N0–2, and stage III by T4 or N3. Stage IV is reserved for patients with metastatic disease. Thus, patients with a small primary tumour and multiple ipsilateral nodes would now be staged as T1N1, stage I. With AJCC8 staging, up to 80% of patients with HPV-associated OPSCC will be stage I with a 90% 5-year overall survival. A small percentage of patents will have metastatic disease and be stage IV with a 20% 5-year overall survival rate. In case of tumour resection, nodal evaluation in the pTNM system diverges from the clinical nodal system, with N1 being defined by the presence of four or fewer positive nodes and N2 being defined as the presence of more than four malignant nodes, removing the N3. However, at many institutions, OPSCC remains to be treated with definitive chemoradiation therapy, which obviates this somewhat confusing pathologic nodal category. Hence, for radiologists, the HPV status of OPSCC is a fundamental information.

The only modification to the T category that occurs in HPV-associated OPSCC is that T4 is not separated into two categories (Fig. 4.6). T4 is described as tumour invading the larynx, extrinsic muscles of the tongue, medial pterygoid, hard palate or mandible, or beyond.

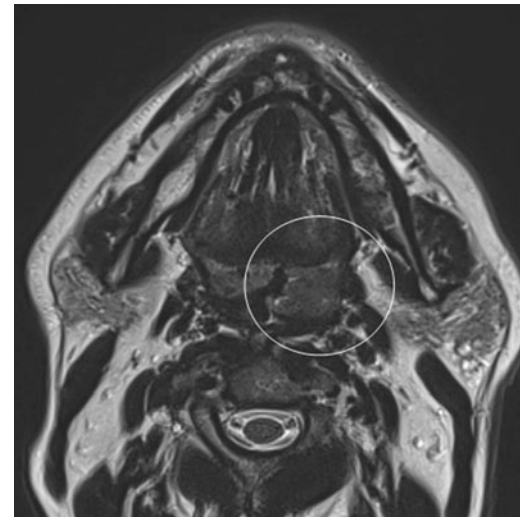

Fig. 4.6 Carcinoma of the tonsil, oropharynx, p16+, T3 lesion with max diameter of 43 mm. T2w image

4.4.3 Nasopharyngeal Squamous Cell Carcinoma

In nasopharyngeal cancer, clinical presentation depends on tumour size and extent as well as cervical nodal metastasis. Metastatic adenopathy is often the initial complaint, and it is independent of tumour size. A serous otitis media can occur due to Eustachian tube obstruction. Advanced lesions may present with neurologic signs secondary to perineural spread or invasion of the skull base. Involvement of the cavernous sinus may produce neuropathies of cranial nerves III, IV, V, or VI. Posterior spread to the carotid sheath may lead to the involvement of cranial nerves IX, X, or XI or sympathetic chain.

Even if NPC is often related to EBV, currently there is not a separate staging system for non-EBV- and EBV-associated NPC. According to the prognosis, the involvement of the pterygoid muscles, previously categorized as T4, has now been reduced to T2. The infiltration is categorized as T4 when a tumour is more extended, in particular lateral to the lateral pterygoid and into the parotid gland. The terms masticator space and

infratemporal fossa, which were part of the AJCC7 terminology, have been removed and replaced with specifically named soft-tissue structures to simplify and clarify staging. In AJCC8, the nodes in levels IV and VB are designated N3 disease. Also, nodal masses larger than 6 cm are in N3 category with removal of the prior subgroups. In AJCC8, N3 now determines a prognostic stage grouping of IVA, rather than IVB.

4.4.4 Non-HPV Oropharyngeal Squamous Cell Carcinoma

The 8th edition of AJCC has introduced a modification in N designation in case of metastatic nodes of non-HPV oropharyngeal cancers, and no changes in T designation. Whereas the criteria of N1–N3 are foundationally unchanged, in comparison to AJCC7, an additional clinical criterion of extranodal extension (ENE) has been added, which determines N3b status. New pathologic nodal table also incorporates pathologic ENE. Pathologic ENE is described as 2 mm or less for microscopic ENE or more than 2 mm for major ENE. In literature, the radiological definition includes different features, such as indistinct nodal margins, irregular nodal capsular enhancement, interruption in the nodal capsule, or infiltration into the perinodal fat or into adjacent muscle.

4.4.5 Unknown Primary Tumours

An unknown primary tumour is defined as HNSCC detected from fine needle aspiration of a nodal mass in the absence of a clinically evident primary source. Most of these cases are from HPV-related tumour. In adult patients, a new neck mass must be first of all suspicious for carcinoma (commonly primary oropharyngeal tumour), and a FNA should be performed. If p16 is positive and no oropharyngeal primary is clearly found at cross-sectional imaging or tonsillectomy, then HPV in situ hybridization is recommended because p16 can be positive in non-HPV-related, non-oropharyngeal tumours, including up to 30% of skin cancers.

4.4.6 Tumour Types Without Changes from the 7th Edition of AJCC

For all non-HPV, there are no changes to the T designation. There are no changes to the T designation also for salivary neoplasms, and to nasal cavity and paranasal sinus tumours. Criteria for T4b cancers remain, i.e. the vascular encasement and invasion, prevertebral space invasion, and invasion of mediastinal structures.

4.5 Lymph Nodes

4.5.1 Introduction

The assessment of lymph node metastasis in head and neck oncology is a critical prognostic factor in terms of treatment planning and patient survival. Metastasis can arise from primary head and neck squamous cell carcinoma (HNSCC), thyroid gland, skin, or distant sites like melanoma, or breast, lung, or gastrointestinal carcinomas. The presence of cervical nodal metastasis may affect the choice of treatment as well as the patient prognosis. With a single lymph node metastasis from HNSCC of the head and neck, a patient's 5-year survival rate is estimated at 50%, which is reduced to 33% in the presence of contralateral lymph node involvement. More than 50% of advanced stages of HNSCC as T3–T4 show ipsilateral nodal metastasis, whereas 2–35% have bilateral or contralateral nodal metastasis [37]. For these reasons, detecting cervical lymph node metastasis is an essential step in predicting patient prognosis and evaluating treatment options. Treatment options in cases of cervical lymph node metastasis include selective, radical, or modified neck dissection and co-adjuvant radiotherapy and/or chemotherapy depending on the histologic findings of the nodes.

Imaging has a central role in the diagnosis and follow-up of cervical lymphadenopathies. The

American Joint Committee on Cancer has stated that clinical staging should include physical examination as well as results of the imaging modalities. The National Comprehensive Cancer Network (NCCN) guidelines recommend the use of CT and MR with contrast medium for the initial staging in patients with HNSCC [38]. However, clinical criteria alone are not sufficiently accurate in the identification of nodal metastasis. The detection rate of nodal involvement with palpation has an accuracy rate of 70% [39, 40]. Furthermore, deep-seated nodes such as the retropharyngeal type can be properly evaluated exclusively with the support of imaging modalities.

Radiologic evaluation of head-neck nodes has shown to identify metastasis in 7–19% of patients with a negative clinical evaluation. In case of positive imaging results, even in the presence of low pretest likelihood for potential nodal metastasis, the risk of positive nodal metastasis remains very high (estimated at >20%) [41] and so elective neck dissection should be performed in all cases when positive radiologic findings for potential nodal metastasis are present. Different imaging modalities exist for identifying cervical nodal metastasis, including ultrasound (US), computer tomography (CT), magnetic resonance (MR), and CT/positron emission tomography (PET).

Currently, the use of preoperative MR or CT imaging is an essential part of the workup. Both modalities have demonstrated good diagnostic performance in detecting head-neck nodal metastasis, even if no significant diagnostic accuracy had been found in comparison with the other modalities. CT and MR should be preferred to the other imaging modalities in the assessment of primary radiologic staging, as it has the advantage of being able to evaluate both primary tumour 'T' and nodal involvement 'N' [42, 43] and for nodal surveillance especially in patients with an advanced tumour, when the site of the primary tumour also requires surveillance of the deep-seated lymph node as in the case of the nasopharyngeal SCC and when neck dissection is performed. PET is an expensive exam, is generally less available, and does not provide any better sensitivity and specificity in the detection of nodal metastasis. It therefore should not be used in routine nodal surveillance.

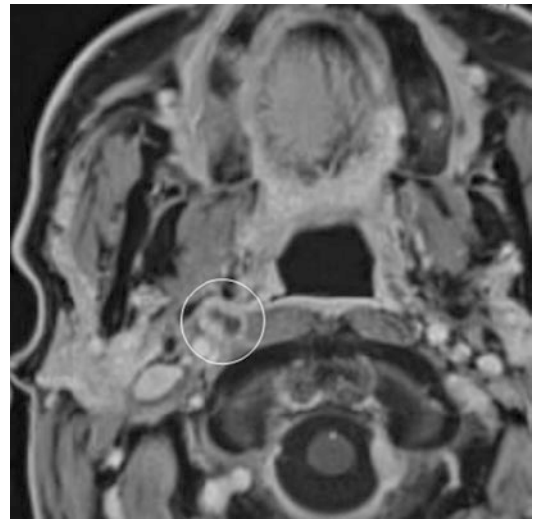

Fig. 4.7 Right single Rouviere nodal metastasis with central necrosis from oropharynx carcinoma

The lack of ionizing radiation and the relative low cost of US mean that this method can be used more frequently than CT and MR. US demonstrates similar sensitivity and specificity to other modalities and can be used with concomitant real-time-guided fine needle aspiration (US-FNA); however, deep-seated lymph nodes cannot be identified with this method (Fig. 4.7). US should be considered as the modality of choice in the follow-up of the cervical lymph nodes in patients with a low-grade HNSCC, such as T1–2 N0 of the lips, when a 'watchful waiting' policy is adopted. Furthermore, in the case of positive or inconclusive US findings, US-FNA should be used due to the high correlation between positive cytology results and histologic positive findings for nodal metastasis [41].

4.5.2 Radiologic Criteria for Assessment of Head-Neck Lymph Nodes

The radiological evaluation of the neck lymph nodes is based on the criteria that identify abnormal lymph nodes in imaging: characteristics that increase the level of suspicion of the presence of

intranodal metastases and that help the radiologist to discriminate these lymph nodes from hyperplastic ones. It is based on five main features: clustering, morphology, inhomogeneity, size, and pattern of spread.

4.5.2.1 Clustering

Clustered lymphadenopathy is recognized as groups of >3 contiguous enlarged lymph nodes with the loss of fat tissue planes between them. This clustering appearance, particularly evident in HNSCC, is associated with a poorer prognosis than isolated lymph node metastasis. This feature can increase the level of suspicion when the size of nodes is borderline [44]. In the presence of reactive adenopathy secondary to infectious process, surgery, or radiation, the detection accuracy is reduced for clustering.

4.5.2.2 Morphology

A normal lymph node appearance is a reniform shape with smooth well-defined margins. Abnormal lymph nodes are defined on imaging as nodes with altered shape and margins. A reniform or oblong shape is more representative of normal nodes, whereas lymph nodes with spherical appearance suggest the presence of an expansive process and are more associated with metastases (Fig. 4.8).

To classify a round lymph node on imaging, the criterion of a long-to-short axis is used, and a ratio of less than 2 is more correlated with metastases. To correctly calculate the long-to-short axis with CT and MR, it is not correct to measure the lymph nodes only on the axial plane. This is because it would not identify the real major axis of the lymph nodes that in the neck-head area is almost always oriented on a cranio-caudal direction. It is therefore recommended that multiplanar reconstructions (MPR) be used in order to correctly identify the major and minor axis. Benign hyperplastic adenopathies, even if they are enlarged in terms of the size criteria, usually maintain a long-to-short axis greater than 2. Shape is important but is not the only aspect to include in the evaluation of suspicious nodes. Roundness alone does not necessarily imply the presence of intranodal metastasis and must be considered with respect to all other worrisome features, above all if the lymph node level involved can be traced back to primary neoplasia (sentinel node). This criterion can be helpful in increasing the level of suspicion in case of enlarged lymph nodes, such as in SCC of the tongue where it is not uncommon to find intranodal metastases in sub-centimetric lymph node at level III. Intranodal metastasis proliferation can replace normal fatty hila; however, this can also be present in infectious processes and in chronic inflammatory lymphadenopathies. In addition, fatty hila may be so thin that it is indistinguishable at CT and MRI (if less than 3 mm) from an

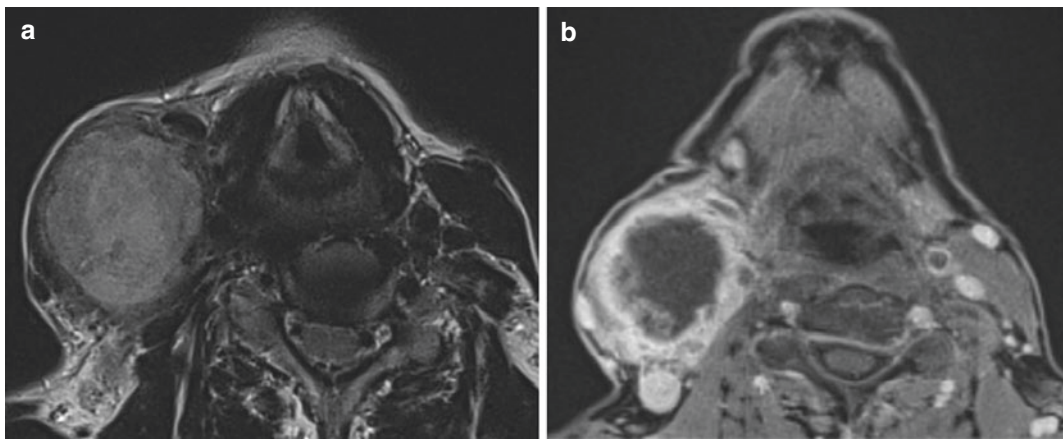

Fig. 4.8 Multiple lymphadenopathies (**a**, **b**) with round morphology and intranodal inhomogeneity, due to necrosis and extranodal extension (ENE+)

initial central necrosis area. In cases where there is doubt, US can be used as a second tool in conjunction with cytology.

In the pathological lymph node, the subcapsular proliferation of metastatic foci causes an alteration of the node margins that can change from smooth and regular to thick, irregular, blurred, or indistinct. The CT is more accurate than other methods for the evaluation of extranodal diffusion; however, both CT and MR are valid methods for this evaluation. Irregular or ill-defined margins on CT and MR are features that significantly improve the detection of cervical lymph node metastases. The extranodal extension (ENE) represents the most important prognostic factor in terms of survival, operability, and comorbidity, with the exception of tumours associated with HPV infection. Only unquestionable clinical evidence is to be used for clinical staging.

The guiding principle is to assign ENE negative if there are doubts in a particular case in order to avoid stage migration, with the concept that whenever there is a doubt, the lesser stage should be chosen. Only clear evidence of gross ENE on clinical examination supported by strong radiographic evidence permits classification of disease as ENEc [45]. Extracapsular spread is microscopically present in 25% of nodes that do not meet the size criteria for suspicion, enlarged lymph nodes smaller than 3 cm are demonstrated to have an incidence of 60% extracapsular spread, whereas nodes larger than 3 cm have an incidence of 74% [37]. Imaging findings of extracapsular spread are indistinct or blurred margins, fat stranding, and loss of fat planes between the lymph node and the surrounding anatomical structure. Pathological lymph nodes can infiltrate adjacent structures such as vessels, nerves, muscles, skin, and bone. CT and MR have been shown to have low sensitivity (65–80%) but high specificity (86–93%) for the detection of ENE (Fig. 4.9) [45]. Arterial invasion influences the surgical options and can lead to dangerous complications (pseudoaneurysms, vascular occlusions). Identification of arterial encasement >di 270° on CT or MR is associated with increased likelihood of arterial invasion with a sensitivity and specificity [46].

4.5.2.3 Inhomogeneity

Metastatic lymph nodes have a heterogeneous structure represented by a portion of the healthy lymph node and part of the tumour process. Very

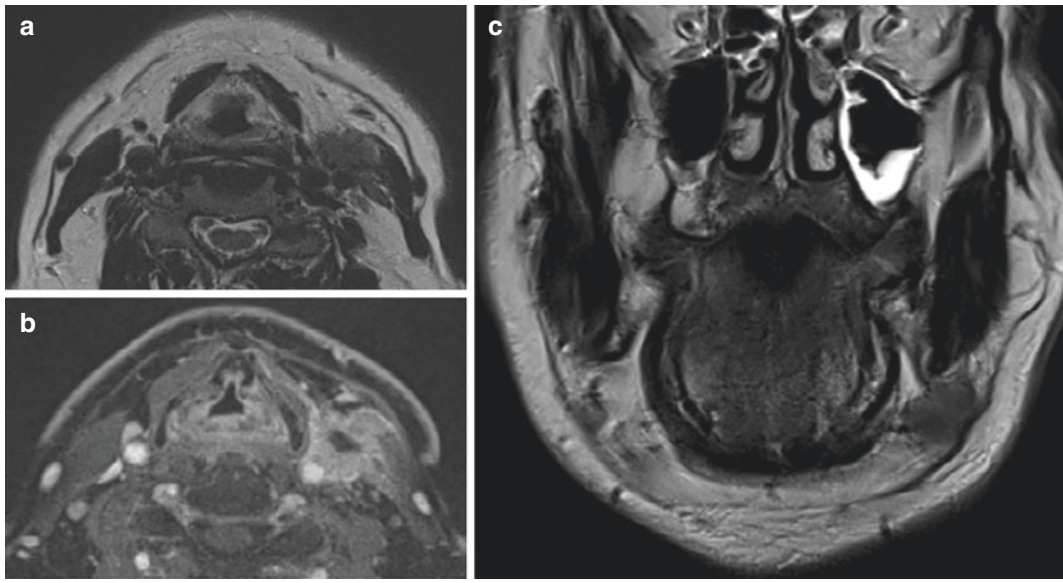

Fig. 4.9 Nodal metastasis with ENE+. (**a**, **b**) Loss of fatty plane with infiltration of SCM muscle and thrombosis of jugular vein. (**c**) Loss of fatty plane with infiltration of platysma muscle

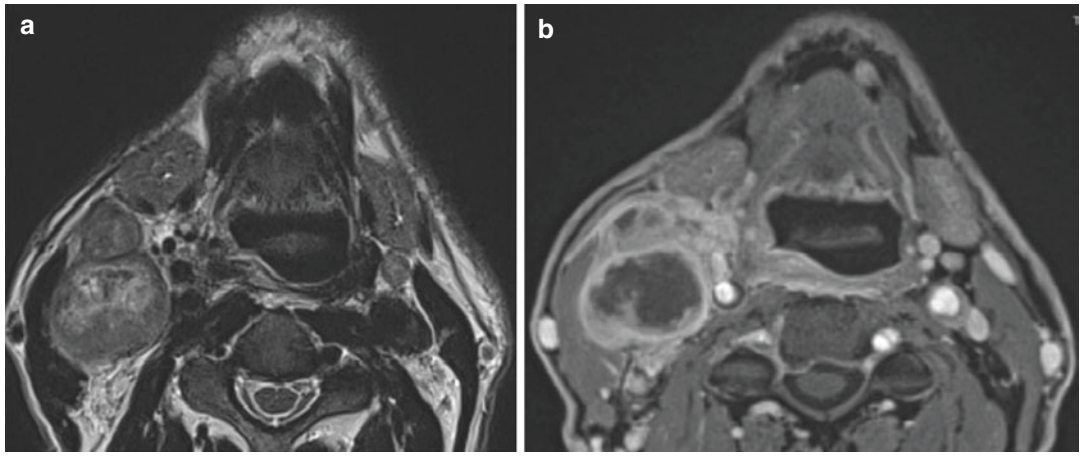

Fig. 4.10 Nodal metastasis from oropharynx carcinoma with round shape and central necrosis. (**a**) T2w image. (**b**) 3D T1w post-contrast image

often, metastatic lymph nodes of the head and neck region can present phenomena of central necrosis and cystic appearance, calcifications, or hyper-enhancement. Regardless of nodal size, the presence of intranodal necrosis (Fig. 4.10) should be considered pathologic and is reported to be present in one-third of all metastatic nodes [47].

Cases of cystic lymph nodes are more likely to have oropharyngeal (HPV-associated HNSCC) or thyroid (papillary carcinoma) origin. Calcified lymph nodes are most commonly present with thyroid carcinoma; other causes of nodal calcification are mucinous adenocarcinoma, treated lymphoma, treated or untreated HNSCC, and tuberculosis. Intranodal necrosis may be differentiated in US as a cystic ill-defined echolucent area within the nodes, the most common form of intranodal necrosis, and coagulation necrosis as an echogenic focus within lymph nodes but not continuous with the surrounding fat and that does not produce acoustic shadowing [48]. With CT, necrosis is identified as a focus of hypodensity with water attenuation density (10–25 HU) with an enhancing post-contrast rim. With MR, necrotic areas are defined as a focus of intranodal high signal intensity on T2-weighted imaging that corresponds to an intranodal nonenhancing area in contrast-enhanced T1-weighted imaging. Calcifications are better identified on US as punctuated echogenic foci with acoustic shadowing and on CT as hyperdense foci on pre-contrast scan.

Another aspect of inhomogeneity is vascular alterations that occur in metastatic lymph nodes. With CT and MR, metastatic adenopathy can show an increased vascularity, especially with specific histologic entities as thyroid carcinoma or melanoma, but it should be noted that a variety of conditions can demonstrate lymph node enhancement as infectious conditions or post-chemoradiotherapy. Doppler US is a very accurate method to detect vascular nodal anomalies; normal lymph nodes demonstrate hilar vascularity, while metastatic nodes show mixed vascularity both from hilum and from periphery. The presence of pericapsular vessels is a common appearance of metastatic nodes, and it is related to tumour infiltration in which tumour cells produce tumour angiogenic factor (TAF). Usually, reactive lymphadenopathy shows hilar vascularity or absent vascularity.

With US, it is also possible to distinguish different internal textures of lymph nodes reflecting in a different echogenicity. They are defined as hypo- or hyperechogenicity in contrast to the echogenicity of the surrounding muscle structures. Laterocervical lymph node metastases can be both hypoechogenic (lymphoma, HNSCC) and hyperechogenic (thyroid carcinoma, HNSCC).

4.5.2.4 Size

The classification according to the size of lymph nodes in the neck-head region can be confusing; in the literature, there are different studies on the cut-off of the laterocervical lymph nodes. However, the 10 mm shot-axis cut-off for the lymph node levels I–VII and the 8 mm short-axis cut-off for the remaining lymph nodes (retropharyngeal, nuchal, etc.) show a higher sensitivity [49, 50]. Due to the low specificity of this parameter, reactive lymph nodes (as ones secondary to infections) may show an increase in size, particularly in submandibular, upper jugular lymph nodes and in younger patients. Consequently, this parameter should be evaluated by looking for other ancillary signs.

4.5.2.5 Lymphatic Drainage

When suspicious nodes were located in the drainage pathway of the primary tumour, radiographic suspicion increased. Cervical lymph nodes should be classified on the basis of the system devised by the American Head and Neck Society and the American Academy of Otolaryngology-Head and Neck Surgery (Table 4.1).

In the majority of head and neck cancers (66.7%), the jugulodigastric node represents the sentinel node by way of internal jugular and deep

Table 4.1 Classification of nodal levels and drainage sites

Nodal levels	Landmarks	Drainage sites
I: IA—submental nodes, IB—submandibular nodes	Above the hyoid, below the mylohyoid muscle, anterior to the posterior edge of the submandibular gland IA: Between the medial margins of the anterior bellies of the digastric IB: Posterior and lateral to the medial edge of the anterior belly of the digastric	Nose and paranasal sinuses, lips, anterior oral cavity
II: upper jugular—IIA: upper internal jugular nodes, IIB: upper spinal accessory nodes	Below the skull base, above the hyoid, anterior to the posterior edge of the SCM, posterior to the posterior edge of the submandibular gland IIA: Posterior to the internal jugular vein/attached to the vein IIB: Posterior to the internal jugular vein/separate from the vein	Posterior oral cavity, oropharynx, supraglottic larynx, parotid gland
III: Mid-jugular	Below the lower body of the hyoid bone, above the lower margin of the cricoid, anterior to the posterior edge of the SCM, lateral to the medial margin of the common carotid artery/internal carotid artery	Hypopharynx, glottic, subglottic
IV: Lower jugular	Below the lower margin of the cricoid, above the clavicle, anterior and medial to the posterior edge of the SCM, lateral to the common carotid artery	Cervical oesophagus, subglottic, thyroid
V: VA, VB	Below the skull base, above the clavicle, anterior to the anterior edge of the trapezius, posterior to the posterior edge of the SCM VA: Above the lower margin of the cricoid VB: Below the lower margin of the cricoid	Skin carcinomas of the occipital scalp or neck, nasopharynx
VI	Below the hyoid, above the top of the manubrium, medial to the common carotid arteries/internal carotid arteries	Cervical oesophagus, subglottic, thyroid
VII	Below the top of the manubrium, medial to the left and right common carotid arteries	Cervical oesophagus, subglottic, thyroid

cervical lymphatic drainage. The first point of afferent drainage from the face, mouth, pharynx, and tonsils, the jugulodigastric node is the highest of the level II nodes and is located adjacent to the angle of the mandible. This node is commonly affected by tumours from the oral cavity and oropharynx. Tongue-based tumours, in some instances, can bypass the jugulodigastric and other level II nodes and spread directly to an ipsilateral low level III or IV node called the jugulo-omohyoid node. Thus, in the setting of tongue carcinoma, this node is another example of a sentinel node.

4.6 Advanced Imaging

4.6.1 Elastography

Ultrasound elastography provides information about the stiffness of the tissue by measuring the degree of strain on the tissue. Metastatic lymph nodes show an increase of stiffness and the level of suspicion for malignancy increases as the tissue hardens. During real-time ultrasound elastography, stiff components of 50% to less than 90% and 90% or greater of target lesion represent the class of suspicious for malignancy [51]. Ultrasound elastography showed an accuracy of 83.3%, sensitivity of 82.4%, and specificity of 84.6%; it should be helpful for detecting nodal metastasis of head and neck and can be safely used as a support technique to improve diagnostic performance of ultrasound of head-neck lymph nodes [52].

4.6.2 DWI-MRI

Diffusion-weighted MRI (DW-MRI) is a functional technique that measures the motion of water molecules in the extracellular, extravascular space, based on Brownian motion. In metastatic nodes, the microstructural changes such as the decreased extracellular space, increased cellularity, and higher nuclear-to-cytoplasmic ratio result in limited motion of water molecules and are represented as an area of hyperintensity on DWI and low signal intensity on the corresponding ADC map. DWI is a promising imaging technique to detect early metastatic lymph nodes. Vandecaveye et al. [53] showed that apparent diffusion coefficient (ADC) had 84% sensitivity and 94% specificity on a 1.5-T system, and Barchetti et al. [54] showed the ADC values of 97% sensitivity and 93% specificity on a 3-T system, in contrast to Lim et al. [55] who found no differences in ADC values between small metastatic and benign lymph nodes. Currently, DWI can be used as an additional tool in the detection of pathological lymph nodes and can be useful in 'uncertain' cases.

4.7 Preoperative Imaging for Thyroid Cancer Surgery

The success of thyroid cancer surgery relies on accurate preoperative imaging evaluation, which allows complete resection of the primary tumour and pathological lymph nodes. Ultrasound is still the most important imaging modality in the evaluation of thyroid cancer and should be used to evaluate both the primary cancer and all cervical lymph node compartments. Affected lymph nodes may be diagnosed according to size, shape, echogenicity, vascular pattern, loss of hilar structure, and presence of calcifications. Ultrasound-guided fine needle aspiration of affected lymph nodes can help in planning surgical radicality. Cross-sectional imaging may be considered in selected scenarios to better evaluate tumour invasion and/or inferiorly or posteriorly located lymph nodes. Functional imaging with positron emission tomography (PET) or PET/CT may have a selected role in patients affected by recurrent cancer with positive tumour markers and negative morphological imaging evaluation.

4.7.1 Introduction

The overall survival rates of thyroid cancer are high for most subtypes, exceeding 90%, though the risk of recurrence has been reported to be as high as 35% [56]. The majority of recurrent cancers are identified within the first 5 years after

diagnosis, representing persistent disease rather than recurrent one [57]. It is well known that the surgical radicality may be achieved through an accurate preoperative imaging evaluation, ensuring complete clearance of the primary tumour as well as pathological lymph node compartments. As stated in the Revised American Thyroid Association Management Guidelines for Patients with Thyroid Nodules and Differentiated Thyroid Cancer, ultrasound is the first-line imaging choice in the evaluation of thyroid cancer [58]. Furthermore, cross-sectional imaging has a role in selected scenarios to better evaluate tumour invasion and/or inferiorly or posteriorly located lymph nodes.

4.7.2 Preoperative Imaging Examination

According to the last update of TNM staging system (Table 4.2a–c), an accurate preoperative eval-

Table 4.2 Staging classification of thyroid malignancy: (**a**) differentiated thyroid carcinoma, (**b**) anaplastic thyroid carcinoma, and (**c**) medullary thyroid carcinoma

AJCC stage	Age	Stage	(a) Differentiated thyroid cancer
I	Younger than 55 years	Any T Any N M0	Any size with or without spread to lymph nodes (any N) and no distant metastasis (M0)
	OR		
	55 years or older	T1 N0 or NX M0	Any small tumour (<2 cm) with no spread to lymph nodes (N0) and no metastasis (M0)
	OR		
	55 years or older	T2 N0 or NX M0	The cancer is larger than 2 cm across but no larger than 4 cm and confined to the thyroid (T2) It has not spread to nearby lymph nodes (N0) or to distant sites (M0)
II	Younger than 55 years	Any T Any N M1	Any tumour (any T) with any metastasis (M1) regardless of whether it has spread to the lymph nodes (any N)
	OR		
	55 years or older	T1 N1 M0	The cancer is no larger than 2 cm across and confined to the thyroid (T1) with spread to nearby lymph nodes (N1) and no metastasis (M0)
	OR		
	55 years or older	T2 N1 M0	The cancer is larger than 2 cm across but no larger than 4 cm and confined to the thyroid with spread to nearby lymph nodes (N1) and no distant metastasis (M0)
	OR		
	55 years or older	T3a or T3b Any N M0	The cancer is larger than 4 cm but confined to the thyroid (T3a) or it has grown into the strap muscles around the thyroid (T3b), regardless of whether it has spread to the lymph nodes (any N). It has not spread to distant sites (M0)
III	55 years or older	T1/2/3 N1a M0	Any localized tumour (T1, T2, or T3) that has spread to the central compartment of lymph nodes (N1a) but has not metastasized (M0)
IVA	55 years or older	T4a Any N M0	The tumour has spread beyond the thyroid to nearby soft tissues, larynx, trachea, oesophagus, or recurrent laryngeal nerve, regardless of whether it has spread to the lymph nodes (any N). It has not spread to distant sites (M0)
IVB	55 years or older	T4b Any N M0	Tumour that has spread beyond nearby structures (T4b), regardless of spread to lymph nodes (any N), but no distant spread (M0)
IVC	55 years or older	Any T Any N M1	The cancer is of any size (any T) and might or might not have spread to nearby lymph nodes (any N) It has spread to other parts of the body, such as distant lymph nodes, internal organs, and bones (M1)

Table 4.2 (continued)

AJCC stage	Stage	(b) Anaplastic thyroid cancer
IVA	T1, T2 or T3a N0 or NX M0	The cancer is of any size but confined to the thyroid (T1, T2, or T3a) It has not spread to nearby lymph nodes (N0) or to distant sites (M0)
IVB	T1, T2, or T3a N1 M0	The cancer is of any size but confined to the thyroid (T1, T2, or T3a). It has spread to nearby lymph nodes (N1) It has not spread to distant sites (M0)
	OR	
	T3b Any N M0	The cancer is of any size and has grown into the strap muscles around the thyroid (T3b) It might or might not have spread to nearby lymph nodes (any N). It has not spread to distant sites (M0)
	OR	
	T4 Any N M0	The cancer is of any size and has grown extensively beyond the thyroid gland into nearby soft tissues of the neck or back toward the spine or into nearby large blood vessels It might or might not have spread to nearby lymph nodes (any N). It has not spread to distant sites (M0)
IVC	Any T Any N M1	The cancer is of any size (any T) and might or might not have spread to nearby lymph nodes (any N) It has spread to other parts of the body, such as distant lymph nodes, internal organs, and bones (M1)
AJCC stage	**Stage**	**(c) Medullary thyroid cancer**
I	T1 N0 M0	The cancer is 2 cm or smaller and confined to the thyroid (T1). It has not spread to nearby lymph nodes (N0) or to distant sites (M0)
II	T2 N0 M0	The cancer is larger than 2 cm but no more than 4 cm across and confined to the thyroid (T2). It has not spread to nearby lymph nodes (N0) or to distant sites (M0)
	OR	
	T3 N0 M0	The cancer is larger than 4 cm and confined to the thyroid or any size and growing outside of the thyroid but not involving nearby structures (T3). It has not spread to nearby lymph nodes (N0) or to distant sites (M0)
III	T1, T2, or T3 N1a M0	The cancer is of any size and might be growing outside of the thyroid but not involving nearby structures (T1, T2, T3). It has spread to lymph nodes in the neck (pretracheal, paratracheal, prelaryngeal, or upper mediastinal) (N1a) but not to other lymph nodes or to distant sites (M0)
IVA	T4a Any N M0	The cancer is of any size and has grown beyond the thyroid gland into nearby tissues of the neck, such as the larynx (voice box), trachea (windpipe), oesophagus (tube connecting the throat to the stomach), or nerve to the larynx (T4a) It might or might not have spread to nearby lymph nodes (any N). It has not spread to distant sites (M0)
	OR	
	T1, T2, or T3 N1b M0	The cancer is of any size and might be growing outside of the thyroid but not involving nearby structures (T1, T2, T3) It has spread to certain lymph nodes in the neck such as cervical or jugular nodes (N1b). It has not spread to distant sites (M0)
IVB	T4b Any N M0	The cancer is of any size and has grown either back toward the spine or into nearby large blood vessels (T4b) It might or might not have spread to nearby lymph nodes (any N). It has not spread to distant sites (M0)
IVC	Any T Any N M1	The cancer is of any size and might have grown into nearby structures (any T) It might or might not have spread to nearby lymph nodes (any N). It has spread to distant sites such as the liver, lung, bone, or brain (M1)

uation is mandatory for planning the best treatment. The aims of preoperative sonographic assessment in patients affected by or with suspected thyroid cancer are to evaluate the primary tumour and to detect pathological lymph nodes in the central (level 6: pretracheal, right paratracheal, and left paratracheal), lateral (levels 2, 3, and 4: jugular), and posterior (level 5: posterior to sternocleidomastoid muscle) neck compartments, ensuring a compartment-oriented surgical resection.

4.7.3 Ultrasound Evaluation of Primary Tumour

Most of the thyroid nodules are incidental findings discovered by imaging studies unrelated to the thyroidal gland [59]; being found in up to 68% of normal population, most of them are asymptomatic, showing benign appearance, and will never develop into a cancer. The aim of a first-line ultrasound evaluation of thyroid nodules is to differentiate benign nodules from suspicious or malignant ones requiring further management; about that, fine needle aspiration (FNA) plays a pivotal role in this process, but it needs to be performed in a selective way, rather than systematic procedure, regardless of the nodule size or appearance [60]. It is mandatory to evaluate the primary tumour assessing size, location, margins, multifocality, and local invasion (Fig. 4.11). Further, it is important to report postero-medially located tumour beside the recurrent laryngeal nerve may affect patient preoperative evaluation and surgical approach. Local invasion of strap muscles is quite common and usually does not affect resection strategy significantly; nevertheless, visceral or vascular invasion, sonographically depicted by a blurry or indistinct deep margin, may require cross-sectional evaluation and surgical approach changes. Furthermore, additional tumour foci must be evaluated, since contralateral lesions may result in the need to exclude positive contralateral lymph nodes [61, 62].

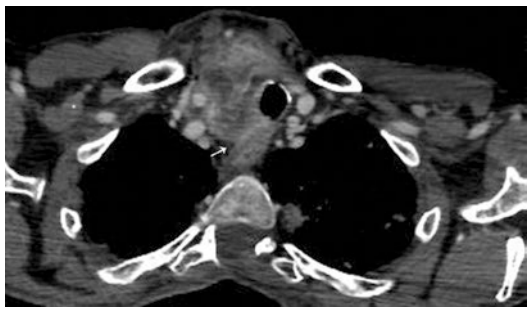

Fig. 4.11 Effaced fatty tissue in the tracheoesophageal groove where the recurrent laryngeal nerve courses

4.7.4 Risk Stratification Systems

Thyroid gland ultrasound evaluation of the risk of malignancy plays a central role in patients with nodules, with the aim of selecting lesions that should have a fine needle aspiration (FNA) performed. According to the key role of thyroid US in the management of patients affected by nodules, several associations, such as the European Thyroid Association, the Korean Society of Thyroid Radiology, the American Thyroid Association, the American Association of Clinical Endocrinologists, the American College of Endocrinology, and the Italian Associazione Medici Endocrinologi, have issued recommendations for US risk stratification of thyroid nodules [63, 64]. Two of the most used ultrasound-based classification systems for thyroid nodules are the American College of Radiology (ACR) TIRADS and European (EU) TIRADS. In 2015, an American committee convened by the ACR presented a system for approaching the thyroid nodules and the proper lexicon for reporting. The white paper was titled ACR Thyroid Imaging, Reporting and Data System (ACR TI-RADS) [65, 66].

The ACR-TIRADS is a scoring system, based on the US features of a given nodule, according to its composition, echogenicity, shape, margin, and echogenic foci; the higher the score, the greater the risk of malignancy, which would imply performing FNA for a better characterization of the lesion. Based on literature evidences and on the American Association of Clinical Endocrinologists, American Thyroid Association, and Korean guidelines, the European Thyroid Association (ETA) states guidelines and a risk stratification system, establishing a US lexicon, a

report template, and definitions of benign and low-, intermediate-, and high-risk nodules, with the estimated risks of malignancy in each category, which was named European Thyroid Imaging and Reporting Data System (EU-TIRADS) [67]. Recommendations for biopsy or US follow-up are based on the nodule's TI-RADS level and its maximum diameter. Both the EU-TIRADS and ACR-TIRADS are practical and useful classification systems recently developed. They share common characteristics, but also some differences; categorization differences are shown in Table 4.3, and different managements are described in Table 4.3. Both systems also recommend checking cervical lymph nodes, especially in the intermediate- and high-risk nodule, and perform FNA in the presence of suspicion feature, such as round shape, loss of echogenic hilum, peripheral disorganized flow, heterogeneity, and gland-like echogenicity within the node.

Table 4.3 Ultrasound characteristic for TIRADS classification of thyroid nodules

Category	**US score**	**Cancer risk**
ACR-TIRADS 1: Benign	0 points	0.3%
ACR-TIRADS 1: Not suspicious	2 points	1.5%
ACR-TIRADS 1: Mildly suspicious	3 points	4.8%
ACR-TIRADS 1: Moderately suspicious	4 to 6 points	9.1%
ACR-TIRADS 1: Highly suspicious	7 points or more	35%
Category	**US features**	**Cancer risk**
EU-TIRADS 1: Normal	No nodules	–
EU-TIRADS 2: Benign	Colloidal cyst, entirely spongiform nodule	Close to 0%
EU -TIRADS 3: Low risk	Ovoid, smooth, iso/hyperechoic, no features of high suspicion	2–4%
EU-TIRADS 4: Intermediate risk	Ovoid, smooth, mildly hypoechoic, no features of high suspicion	6–17%
EU-TIRADS 5: High risk	At least one of the following features of high suspicion: • Non-oval/round shape • Irregular margin • Microcalcifications • Markedly hypoechoic	26–87%
Classification	**ACR-TIRADS**	**EU-TIRADS**
Normal gland	–	EU-TIRADS 1
Benign (cystic/spongiform)	TR1	EU-TIRADS 2
Not suspicious (mixed cystic/solid)	TR2	–
Mildly suspicious/low risk	TR3	EU-TIRADS 3
Moderately suspicious/intermediate risk	TR4	EU-TIRADS 4
Highly suspicious/high risk	TR5	EU-TIRADS 5
TIRADS 1	No F/U-no FNA	–
TIRADS 2	No F/U-no FNA	No FNA unless compressive
TIRADS 3	F/U ≥ 1.5 cm FNA ≥2.5 cm	FNA >2 cm
TIRADS 4	F/U ≥1.0 cm FNA ≥1.5 cm	FNA >1.5 cm
TIRADS 5	F/U ≥0.5 cm FNA ≥1.0 cm	FNA >1.0 cm F/U or FNA <1.0 cm

A recent published article compared in a prospective way five of the most used classification systems (ACR, ATA, AACE/ACE/AME, EU-TIRADS, and K-TIRADS), demonstrating that all of them have a very reliable discriminatory capacity, reducing the number of unnecessary biopsies, being particularly higher in the case of ACR. The article stated that ACR showed a better overall performance, classifying half of the biopsies as unnecessary, with a false-negative rate of 2% [68]. Another recent study published in 2018 assessed the interobserver variability of the classification systems AAC/ACE/AME, ACR, ATA, EU-TIRADS, and K-TIRADS and the interobserver concordance in the indication of FNA biopsy. When selecting the nodules for which FNA biopsy has to be performed, the interobserver agreement is substantial to almost perfect [69].

Another recent study in 2018 was conducted to evaluate the temporal stability of initial risk calculated with five systems and determine whether the risk class increase during the follow-up is indicative of malignancy. It was demonstrated that benign nodules tend to stay stable in time, and changes that require biopsies are rare. Development of new nodules is frequent, but few of them (less than 5%) are classified as a high risk. So, this means that benign nodules could be followed in a secure way with less intense surveillance protocols [70].

Finally, the ACR-TIRADS and EU-TIRADS are very good and useful systems of malignancy risk stratification. Due to the differences between both categorization systems, it is recommended to use one of them and clearly specify the used one in the radiological report to avoid confusion and allow a proper patient management.

4.8 Ultrasound Findings in Benign and Malignant Lymph Nodes

Metastatic papillary thyroid carcinoma (PTC) affects central and lateral lymph nodes in up to 70% of cases [71]. Pathological lymph node involvement may be observed upon the first examination or in follow-up evaluation in cases of recurrence. Ultrasound is approved to be the first-line imaging modality for lymph node assessment in both scenarios [72]. The sensitivity of ultrasound in detecting abnormal lymph nodes varies widely in the literature, ranging from 25% to 60% for the central neck and from 70% to 95% for the lateral neck [73]; further, the specificity of ultrasonography in detecting PTC-affected lymph nodes is high, ranging from 80% to 95% in both the central and lateral neck [74]. As the neck compartments have multiple lymph nodes (100–200), any of which could increase its dimension related to benign or malignant disease, it is crucial to know the ultrasound findings that help to distinguish benign lymph nodes from malignant. The evaluation of lymph nodes for assessing the presence of malignancy must be competent to identify the features of a benign lymph node. Enlarged nodes can be the expression of a benign reactive or malignant process. Benign lymph nodes usually are oval in morphology, with a hyperechoic central hilum and unipolar vascularization at colour Doppler examination. Lack of the hilum may represent a sign of tumour invasion. Nevertheless, the hilum may not always be easily identified by ultrasonography in a benign lymph node; the specificity for predicting the presence of cancer when the hilum is not displayed is 29% according to Lebolleux et al. [75].

Lymph node location is another important factor when searching for potential metastatic involvement. As previously stated, cervical lymph nodes are grouped into six levels. When lymph node dissections are performed, pathological lymph nodes related to thyroid cancer are most frequently identified in ipsilateral level 6 (prevalence 50–70%), followed by ipsilateral levels 2, 3, and 4 (prevalence 30–45%) [76]. In the presence of primary tumours <1 cm, contralateral level 6 is less commonly affected (prevalence 5–25%), and contralateral levels 2, 3, and 4 are rarely affected (prevalence 5–14%) [77]. Although the size of lymph nodes >1 cm in maximum diameter has typically been considered more likely related to tumour invasion, many benign or reactive nodes will exceed this size while remaining fusiform in shape. Conversely,

malignant lymph nodes have the tendency to become rounded in shape, and this helps to distinguish them from benign nodes (Fig. 4.11). The shortest diameter of the lymph node can be a feature that helps in predicting the likelihood of tumour involvement. So, comparing the long and short axes of the lymph node (Solbiati index), a ratio below 2.0 becomes suspicious for the presence of malignant involvement [78].

Just as with thyroid nodules, microcalcifications are a highly specific feature; a lymph node containing microcalcifications in a patient affected by PTC or MTC should be suspected to be positive for malignant involvement. The echogenicity is another key feature that can also be useful for detecting metastatic lymph nodes. Benign lymph nodes typically are uniformly hypoechoic with hyperechoic central hilar structure; however, lymph nodes affected by malignant process may appear hyperechoic, exhibit the same echogenicity of the primary tumour, or even exhibit cystic changes to the point of total cystic replacement with complex structure.

The last but not least feature helping in differentiating malignant from benign lymph nodes is the peripheral and disorganized vascularity. The vascular flow of a lymph node can be assessed by the conventional colour and power Doppler or by the recently developed imaging technique named superb microvascular imaging (SMI), which aims to visualize low-velocity and small-diameter blood vessel flow [79].

Benign lymph nodes exhibit typical unipolar vascularization in the hilum, while tumour invasion stops this flow [80], showing peripheral and disordered flow pattern throughout the node.

4.9 Ultrasound in Presurgical Planning

4.9.1 Preoperative Ultrasound Role in Malignant Cytology

Mapping of bilateral lymph node compartments by using ultrasound should be performed routinely in the scenario of cytologic evidence of carcinoma (positive fine needle aspiration), for ensuring a surgical radicality of the primary tumour as well as a compartment-oriented surgical resection of affected lymph nodes. Surgeons may decide to repeat the US evaluation immediately prior to resection in order to have an anatomic map. After the FNA confirmation of malignancy of the primary thyroid lesion, FNA of lymph nodes which present suspicious features at US examination should be performed to provide strong justification for adding lymph node resection to initial surgery. Preoperative ultrasound may provide insight into the need for further imaging prior to surgery. The US finding of an indistinct margin between the thyroid lesion and nearby structures may prompt cross-sectional imaging. Furthermore, adenopathy in levels 6 and 4 requires cross-sectional imaging of substernal or infraclavicular located lymph nodes that may be difficult to assess by ultrasonography.

4.9.2 Preoperative Ultrasound Role in Indeterminate or Suspicious Cytology

Subcategories of indeterminate cytology include ‘atypia of undetermined significance’ or ‘follicular lesion of undetermined significance’ (malignancy risk 5–15%), ‘follicular neoplasm’ or ‘suspicious for follicular neoplasm’ (malignancy risk 15–30%), and ‘suspicious for malignancy’ (malignancy risk 60–75%) [81]. Although a great number of these patients undergo surgical resection, the majority of lesions classified as indeterminate are ultimately diagnosed as benign [82]. There are several studies exploring the utility of ultrasound to predict the risk of malignancy in patients presenting indeterminate FNA cytology lesion. Hypoechogenicity, increased vascularity, irregular margins, microcalcifications, and taller-than-wide shape are all features related to an increased risk of malignancy [58]. These ultrasound features may be used to predict malignancy risk in FNA cytology indeterminate nodules [83].

Ultrasound evaluation of the central and lateral lymph node compartments may help the cli-

nician in the presurgical planning for cytologically indeterminate lesions. When abnormal central (level 6) or lateral lymph nodes (levels 2, 3, and 4) are identified, FNA cytology should be performed on at least one of these nodes. Further, to find thyroid cells within suspected lymph nodes, confirm the diagnosis of metastatic thyroid cancer, altering significantly the surgical management of the patient with indeterminate thyroid cytology.

4.10 Ultrasound in Revision Surgery

Ultrasound is an important imaging modality for thyroid cancer follow-up and facilitating the detection, localization, and planning of revision surgery in the setting of recurrent/persistent disease. In this scenario, post-surgical inflammation, scarring, and inflammatory adenopathy represent known limitations, advising a 6-month time interval after surgery in order to favour the resolution of alterations resulting from the surgical manipulation of the neck compartments. There are some exceptions arising from incomplete surgery and/or insufficient compartment-oriented nodal resection in the initial surgery. Follow-up examination of thyroid cancer patients should be annually performed [58]. Suspicious lymph nodes should be subjected to FNA cytology in the case where further surgery is planned and lymph nodes exceed 8 mm in diameter.

The scenario of suspected persistent or recurrent thyroid malignancy needs FNA cytology of any tissue or abnormal adenopathy located in the central neck compartment and/or thyroid bed. A cytologic diagnosis would justify a high-risk revision surgery. US abnormal and anatomically hazardous lymph nodes represent exception to these rules, recommending revision surgery regardless of FNA cytology. In this setting, to perform serum thyroglobulin aids clinical decision-making. In thyroid cancer surveillance, it is mandatory to bear in mind any US findings of the primary pathology, surgical report, and TNM staging; in fact, ipsilateral lymph node recurrences occur in up to 25% of patients with primary diagnosis of positive lymph nodes. In patients affected by locally invasive malignancy, the main concern is the risk of local recurrence, requiring the support of cross-sectional imaging.

4.11 Cross-Sectional Imaging

Ultrasound is the first-line modality for an accurate presurgical thyroid and cervical lymph node examination because it is highly available, is time-saving, ensures detailed high-resolution findings, is ionizing radiation free, and aids the characterization of indeterminate nodules guiding fine needle aspiration procedure [84]. Some US limitations, such as the assessment of deep structures and nearby acoustically shielded by air/and or bone, limits the use of cross sectional imaging in preoperative thyroid cancer evaluation. Other circumstances in which computed tomography (CT) or magnetic resonance imaging (MRI) may play an additional role include (1) presence of an invasive primary tumour, (2) presence of a bulky primary tumour or nodal disease partially investigated with ultrasonography, and (3) clinical settings suspected for advanced disease (e.g. vocal cord paralysis, progressive dysphagia, or respiratory symptoms). On the other hand, the increased use of CT and MRI implies a great number of thyroid incidentalomas, becoming a growing problem. The decision to include thyroid nodule in CT or MR report is difficult in the absence of signs of extrathyroidal extension, because there are no clear findings that allow a reliable identification of malignant lesions [85]. Some studies have reported added value performing diffusion-weighted imaging because benign nodules have a higher apparent diffusion coefficient value, even if actually the preferred modality for workup is still ultrasound [86].

4.11.1 Cross-Sectional Imaging Evaluation of the Primary Tumour

Ultrasound features of the thyroid malignancy suggestive for local invasion and/or mediastinal involvement necessarily require cross-sectional imaging. Chest CT aids in determining the caudal

extent of the disease and the involvement of great vessels and tracheobronchial structures. These findings influence surgical planning by implying the need for sternotomy and/or tracheal resection/reconstruction. The CT of neck structures with contrast medium is useful in defining the involvement of nearby structures in the setting of extrathyroidal extension. Hence, the support of cross-sectional imaging is recommended in preoperative evaluation of clinically suspected scenario, though preoperative screening for distant metastasis is actually not performed for differentiated thyroid cancers [83].

Further, communication with the clinician plays an important role before performing a contrast CT scan, because the free iodine load due to contrast medium administration interferes with thyroidal iodine uptake for at least 6–8 weeks [87], resulting in not being able to use diagnostic thyroid scintigraphy and/or radioiodine ablation for 2–6 months depending on the institution [88]. Conversely, MRI contrast (gadolinium chelate) does not interfere with iodine thyroidal uptake, offering a better contrast resolution and better tissue differentiation.

Except in cases of patients affected by anaplastic carcinoma, the routine treatment for thyroid carcinoma includes total or near-total thyroid resection, central lymphadenectomy, and possible radioiodine ablation [83]. Surgical approach limited to lobectomy may be reserved for solitary malignancy less than 10 mm; conversely, complete thyroid gland resection and radioiodine ablation are preferred in the presence of small multifocal tumours. However, the diagnosis of multifocal tumour cannot be based on CT or MRI approach; therefore, presurgical imaging evaluation starts with ultrasound to identify multifocal disease and pathological nodes, continuing with CT and/or MRI if extrathyroidal extension is suspected. The assessment of local invasion, according to the AJCC/UICC tumour (T) staging, accounts for four groups of structures: the airway and nerves centrally, the carotid arteries laterally, the prevertebral space posteriorly, and the mediastinum inferiorly. MRI and CT have similar accuracy for predicting local invasion of the oesophagus, trachea/larynx, and RLN [89]. The main CT/MRI sign suggestive for tracheal and oesophageal involvement is a circumferential ≥180° contact or irregular wall or lumen or intraluminal mass, though it is more difficult to evaluate the oesophageal parietal lining because it is generally not distended with air and is more compressible than the trachea [88, 89].

Another important sign of extrathyroid extension is represented by effaced fatty tissue in the tracheoesophageal groove where the recurrent laryngeal nerve courses (Fig. 4.11) (RLN), predicting a possible nerve involvement [90]. Further, dysfunction of vocal cord, highlighted by a dilated right laryngeal ventricle and anteromedial positioning of the right arytenoid cartilage, may represent an imaging sign or RLN invasion.

Extrathyroidal extension to vascular and prevertebral space results in T4b disease (Table 4.1). Generally, these findings are better appreciated on cross-sectional imaging and preclude the patient from curative surgery. A study published by Seo et al. reported that encasement of 180 or more degree of the common carotid artery and internal jugular vein is a specific sign of vascular involvement, although vascular compression or effaced fatty tissue is a further criterion to keep in mind [88].

MRI prevertebral muscle evaluation may detect effaced retropharyngeal fat plane and/or T2 intensity change and/or enhancement as possible signs of muscle invasion. Further, detecting anomalous anatomic structures at cross-sectional imaging is an important step in the planning of primary surgery; an example is the presence of non-recurrent inferior laryngeal nerve (NRILN). A radiologist could suggest this anatomic variant when there is an aberrant right SCA [50].

4.11.2 Cross-Sectional Imaging in the Assessment of Cervical Lymph Nodes

The most common thyroid malignancy affecting lymph nodes is papillary and medullary subtype, whereas local invasion and distant metastases to

the bone and lung are more common in follicular carcinoma, which rarely affects lymph nodes. Cross-sectional CT or MR imaging may be used as a complementary examination to obtain a complete nodal evaluation when clinical and/or US raises suspicion of extensive nodal involvement. Indeed, the limited ultrasound evaluation of deep and/or acoustically shielded structures represents the strongest indication to use cross-sectional imaging in presurgical assessment. The American Thyroid Association has recently published the evidence that the prognostic value of nodal involvement in papillary thyroid carcinoma is related to the size and number of affected nodes and that extranodal extension is an independent factor of poor outcome [91]. Pathology specimens often demonstrate extracapsular extension in affected large nodes (>3 cm). Affected nodes located in the inferior aspects of level 4 and 6 on US in patients with thyroid malignancy may take advantage from cross-sectional imaging of the lower neck/upper chest to assess mediastinal lymph nodes, such as the deep tracheoesophageal groove and infraclavicular space (Fig. 4.12), resulting in altered surgical approach.

In a patient affected by a nodal mass, the presence of cystic components, calcification, proteinaceous (thyroglobulin results in high T1 signal) or haemorrhagic content, and intense enhancement must suggest a thyroid primary [92].

Therefore, it is mandatory not to define all cystic lesions of the neck as congenital cysts, especially in young adults, but to consider them as suspected secondary lesions of thyroid malignancy until proven otherwise. Nodal staging is better performed if the radiologist is aware of the common sites of lymph node involvement. The most frequent level involved with thyroid malignancy is the central compartment (level IV) and lateral nodal stations (levels II–IV) [93]. Prelaryngeal lymph node is the highest central compartment lymph node and its involvement in patients affected by papillary thyroid cancer is predictive of advanced nodal disease. The TNM staging system, according to the American Joint Committee on Cancer (AJCC)/Union for International Cancer Control (UICC), classified nodal stage as N1a if level VI pretracheal, paratracheal, and Delphian nodes are affected and N1b if there is malignancy involvement of unilateral/bilateral cervical nodes or superior mediastinal nodes (level VII) (Table 4.1). N1b stage may preclude curative surgery or change operative approach; therefore, cross-sectional imaging may be indicated if there are US predictors of mediastinal involvement such as lateral nodes or thyroid malignancy greater than 1.5 cm [93]. Not less important, regarding nodal involvement, is the detection of skip nodal metastasis, occurring in up to 21% of cases of MTC [94].

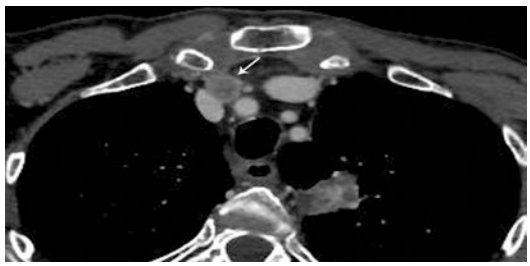

Fig. 4.12 Cross-sectional imaging of the lower neck and upper chest to assess mediastinal lymph nodes, such as the deep tracheoesophageal groove and infraclavicular space

4.11.3 Cross-Sectional Imaging Assessment in Revision Surgery

In previously treated patients, cross-sectional imaging should be taken into account in those suffering from dysphagia, respiratory symptoms, hoarseness, or vocal cord paralysis for assessment of invasive central neck disease. Recurrent or residual differentiated thyroid tumours have to be suspected according to serum thyroglobulin level increase; in this setting, a neck US and/or 131I or 123I whole-body imaging are suggested. When the latter results to be negative (50–80% of patients), a progression with dedifferentiated thyroid cancer has to be excluded [91]. In such a scenario, MRI or PET/CT has a role in detecting recurrent disease. MRI can be readily performed in suspected thyroid recurrence, even if it is not dedifferentiated, because it does not require iodinated contrast and allows to identify nodal

involvement with high protein content from colloid, thyroglobulin, and haemoglobin products [94]. In the setting of prior lateral and central neck dissection, it becomes mandatory to carefully exclude the retropharyngeal nodal disease [94].

PET/CT has usually limited sensitivity in the detection of differentiated thyroid tumour, but it shows the tendency for FDG uptake according to the tumour progressive dedifferentiation and a more aggressive behaviour [94].

4.12 The Post-treatment Role of Radiology

Follow-up imaging in patients with a history of head and neck cancer is essential to assess response to treatment, although it is often difficult to interpret because of anatomic changes in the post-surgery and radiotherapy setting. Anatomic changes in the head and neck region are due to two types of complications; post-surgical complications include wound infection, abscess, fistula, flap necrosis, haematoma, chylous fistula, and seroma; postradiotherapy changes include mucosal necrosis, osteoradionecrosis, radiation-induced vasculopathy, radiation pneumonitis, radiation lung fibrosis, radiation-induced brain necrosis, and radiation-induced neoplasms.

Various imaging modalities, such as radiography, fluoroscopy, endoscopy, ultrasonography (US), computed tomography (CT), magnetic resonance imaging (MRI), single photon emission CT (SPECT), and dual-modality imaging with 2-(fluorine 18)-fluoro-2-deoxy-D-glucose (FDG) positron emission tomography (PET) with CT (PET/CT), are used to evaluate the post-treatment status in patients treated for head and neck cancer [95, 96].

In the literature, combined PET and CT imaging has been reported as a highly sensitive technique for detecting head and neck cancer recurrence in the post-treatment setting [96, 97], although PET can produce a high number of false positives if used too early from the start of radiation therapy (within 3 months of the start of treatment), because of post-radiation inflammation [98, 99].

Therefore, it is seen that MRI in diffusion sequences is a more useful tool at an early stage to differentiate tumour recurrence from normal post-treatment changes [98, 100, 101]. Resection of the neoplasm to be defined as curative must require extensive local excision with all-negative surgical margins; however, given the anatomic complexity of the head and neck, complex reconstructive techniques are often required to close the surgical defect, which can thus be classified into three types of flap reconstruction [95, 102, 103].

Local flap reconstruction involves repositioning by sliding the adjacent tissue. Pedicle flap reconstruction is performed by rotation of donor tissue to cover a defect, using the original vascular pedicle. Free flap reconstructive technique involves the transfer of vascularized tissue from local vessels, with anastomosis to the tissue defect using microvascular techniques. The more common types of free flaps used in the head and neck region are the rectus abdominis myocutaneous free flap, radial forearm free flap, lateral arm flap, anterior lateral thigh flap, iliac crest flap, and fibula free flap. The most frequently used pedicle flaps are the pectoralis major flap, latissimus dorsi flap, deltopectoral flap, trapezius flap, and platysma flap 105]. Myocutaneous flaps are initially depicted as a mass with soft-tissue attenuation and soft-tissue intensity, representing muscle [95, 102, 104]. They will gradually develop innervation atrophy, resulting in volume loss and fat replacement of the muscle [95, 102, 105].

An important radiologic sign to evaluate after reconstructive surgical treatment is the presence of clear boundaries between the flap and adjacent normal structures as an indication of benignity, especially at the upper and lower margins of the flap, where local recurrence most commonly occurs [95, 102, 105]. Imaging is essential for the evaluation of potential tumour recurrence deep within the reconstruction flap, as it often cannot be inspected or palpated clinically. Neoplastic recurrence typically recurs within the first 2 years after treatment. The most common sites of tumour

recurrence are at the soft-tissue level of the surgical bed and at the margins of the surgical site.

CT shows the recurrence as a slightly hyperattenuated infiltrating mass in a muscle-like manner. Therefore, if a suspicious mass has less attenuation than muscle, it is unlikely to be a neoplasm and it is often related to post-treatment oedema [95]. The main CT and MR imaging finding after neck dissection is the absence of resected tissues with cervical lymph nodes, which is more easily identified in patients undergoing radical neck dissection or a modified radical neck dissection [95]. Another imaging finding commonly seen after neck dissection is an area of soft-tissue attenuation surrounding the carotid sheath completely on CT [95, 103].

On MRI, this post-operative area shows low-to-intermediate signal intensity on T1- and T2-weighted MRI images, a result of scar fibrosis. The fat planes often become obliterated, making it more difficult to identify lymph node recurrence [103]. Typical findings of early radiotherapy reactions visible on CT and MRI are thickening of the skin and platysma, cross-linking of subcutaneous fat, oedema and fluid in the retropharyngeal space, increased volume of the major salivary glands, thickening and increased volume of the pharyngeal walls, and thickening of the structures of the larynx. Consequences of radiation therapy include atrophy of the salivary glands and thickening of the pharyngeal constrictor muscle, platysma, and skin [95, 103].

In the evaluation of tumour recurrence, MRI demonstrates that the tumour recurs as an infiltrating mass with intermediate-to-high T1-weighted signal intensity and T2-weighted signal intensity [95, 103, 105]. It is often difficult to make a differential diagnosis between neoplastic recurrence and a vascularized scar, i.e. early fibrosis, because such a scar appears as a soft-tissue mass with indefinite margins and enhancement as well as tumour recurrence on both CT and MRI [103]. In contrast, fibrosis produces retraction and decreased signal intensity on T2-weighted MRI images [106, 107]. The best technique for evaluating suspected tumour recurrence is to signal on diffusion-weighted MRI images with a decreased value for the apparent diffusion coefficient (ADC). The use of ADC has been reported to result in high sensitivity and specificity, with almost no overlap between tumour and nontumour tissue [100]. This low value of ADC is thought to be caused by the restriction of proton movement in the extravascular extracellular space secondary to tumour hypercellularity. On the other hand, necrosis, inflammation, and submucosal fibrosis after treatment show elevated values for ADC, a finding that correlates with increased interstitial space and low cell density [96, 98, 101].

Similarly to its use at the primary tumour site, diffusion-weighted MRI imaging is useful in characterizing persistently enlarged lymph nodes after treatment. In particular, lymph node recurrences or metastases have high signal intensity with a decreased value for ADC on diffusion-weighted MRI images [100].

References

1. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2019. CA Cancer J Clin. 2019;69(1):7–34. https://doi.org/10.3322/caac.21551.
2. Aupérin A. Epidemiology of head and neck cancers: an update. Curr Opin Oncol. 2020 May;32(3):178–86. https://doi.org/10.1097/CCO.0000000000000629.
3. Michaud DS, et al. High-risk HPV types and head and neck cancer. Int J Cancer. 2014;135:1653–61. https://doi.org/10.1002/ijc.28811.
4. Stein AP, et al. Prevalence of human papillomavirus in oropharyngeal cancer: a systematic review. Cancer J. 2015;21:138–46. https://doi.org/10.1097/PPO.0000000000000115.
5. Isayeva T, Li Y, Maswahu D, Brandwein-Gensler M. Human papillomavirus in non-oropharyngeal head and neck cancers: a systematic literature review. Head Neck Pathol. 2012;6(Suppl 1):S104–20. https://doi.org/10.1007/s12105-012-0368-1.
6. Johnson DE, Burtness B, Leemans CR, et al. Head and neck squamous cell carcinoma. Nat Rev Dis Primers. 2020;6:92.
7. Glastonbury CM. Chapter 17: Head and neck squamous cell cancer: approach to staging and surveillance. In: Hodler J, Kubik-Huch RA, von Schulthess GK, editors. Diseases of the brain, head and neck, spine 2020–2023: diagnostic imaging. Cham: Springer; 2020.
8. Schlumpf MF, Haerle S. The current role of imaging in head and neck cancer: a clinician's perspective.

Swiss Med Wkly. 2014;144:w14015. Published 2014 Sept 25. https://doi.org/10.4414/smw.2014.14015.
9. Ong CK, Chong VF. Imaging of perineural spread in head and neck tumours. Cancer Imaging. 2010;10(1A):S92–8. Published 2010 Oct 4. https://doi.org/10.1102/1470-7330.2010.9033.
10. Gupta V, Demmy T. Lung metastases from head and neck cancer, diagnosis and management. In: Kountakis SE, editor. Encyclopedia of otolaryngology, head and neck surgery. Berlin: Springer; 2013. https://doi.org/10.1007/978-3-642-23499-6_40.
11. Tshering Vogel DW, Thoeny HC. Cross-sectional imaging in cancers of the head and neck: how we review and report. Cancer Imaging. 2016;16(1):20. Published 2016 Aug 3. https://doi.org/10.1186/s40644-016-0075-3.
12. Ferlay J, Shin HR, Bray F, Forman D, Mathers C, Parkin DM. Estimates of worldwide burden of cancer in 2008: GLOBOSCAN 2008. Int J Cancer. 2010;127:2893–917. https://doi.org/10.1002/ijc.25516.
13. Windon MJ, D'Souza G, Rettig EM, Westra WH, van Zante A, Wang SJ, Ryan WR, Mydlarz WK, Ha PK, Miles BA, Koch W, Gourin C, Eisele DW, Fakhry C. Increasing prevalence of human papillomavirus-positive oropharyngeal cancers among older adults. Cancer. 2018;124(14):2993–9. https://doi.org/10.1002/cncr.31385.
14. Fung SY, Lam JW, Chan KC. Clinical utility of circulating Epstein-Barr virus DNA analysis for the management of nasopharyngeal carcinoma. Chin Clin Oncol. 2016;5(2):18. https://doi.org/10.21037/cco.2016.03.07.
15. Pynnonen MA, Gillespie MB, Roman B, et al. Clinical practice guideline: evaluation of the neck mass in adults. Otolaryngol Head Neck Surg. 2017;157(2_Suppl):S1–S30. https://doi.org/10.1177/0194599817722550.
16. Taberna M, et al. Human papillomavirus-related oropharyngeal cancer. Ann Oncol. 2017;28(10):2386–98. https://doi.org/10.1093/annonc/mdx304.
17. Lewis JS Jr, et al. Human papillomavirus testing in head and neck carcinomas: guideline from the College of American Pathologists. Arch Pathol Lab Med. 2018;142(5):559–97. https://doi.org/10.5858/arpa.2017-0286-CP.
18. Glastonbury CM. Critical changes in the staging of head and neck cancer. Radiol Imaging Cancer. 2020;2(1):e190022. https://doi.org/10.1148/rycan.2019190022.
19. Zanoni DK, Patel SG. New AJCC: how does it impact oral cancers? Oral Oncol. 2020;104:104607. https://doi.org/10.1016/j.oraloncology.2020.104607.
20. Seeburg DP, Baer AH, Aygun N. Imaging of patients with head and neck cancer: from staging to surveillance. Oral Maxillofac Surg Clin North Am. 2018;30(4):421–33. https://doi.org/10.1016/j.coms.2018.06.004.
21. Mahajan A, Ahuja A, Sable N, Stambuk HE. Imaging in oral cancers: a comprehensive review. Oral Oncol. 2020;104:104658. https://doi.org/10.1016/j.oraloncology.2020.104658.
22. Bongers MN, Schabel C, Thomas C, et al. Comparison and combination of dual-energy- and iterative-based metal artefact reduction on hip prosthesis and dental implants. PLoS One. 2015;10(11):e0143584. https://doi.org/10.1371/journal.pone.0143584.
23. Huang SH, O'Sullivan B. Overview of the 8th edition TNM classification for head and neck cancer. Curr Treat Options in Oncol. 2017 Jul;18(7):40.
24. Thust SC, Yousry T. Imaging of skull base tumours. Rep Pract Oncol Radiother. 2016;21(4):304–18. https://doi.org/10.1016/j.rpor.2015.12.008.
25. Kuno H, Onaya H, Fujii S, Ojiri H, Otani K, Satake M. Primary staging of laryngeal and hypopharyngeal cancer: CT, MR imaging and dual-energy CT. Eur J Radiol. 2014 Jan;83(1):e23–35. https://doi.org/10.1016/j.ejrad.2013.10.022.
26. Frunza A, Slavescu D, Lascar I. Perineural invasion in head and neck cancers - a review. J Med Life. 2014;7(2):121–3.
27. Amit M, Eran A, Billan S, et al. Perineural spread in noncutaneous head and neck cancer: new insights into an old problem. J Neurol Surg B Skull Base. 2016;77(2):86–95. https://doi.org/10.1055/s-0036-1571834.
28. Yoo GH, Hocwald E, Korkmaz H, et al. Assessment of carotid artery invasion in patients with head and neck cancer. Laryngoscope. 2000;110(3 Pt 1):386–90. https://doi.org/10.1097/00005537-200003000-00010.
29. Chengazi HU, Bhatt AA. Pathology of the carotid space. Insights Imaging. 2019;10(1):21. https://doi.org/10.1186/s13244-019-0704-z.
30. Yousem DM, Gad K, Tufano RP. Resectability issues with head and neck cancer. AJNR Am J Neuroradiol. 2006;27(10):2024–36.
31. Sekine T, Barbosa FG, Delso G, Burger IA, Stolzmann P, Ter Voert EE, Huber GF, Kollias SS, von Schulthess GK, Veit-Haibach P, Huellner MW. Local resectability assessment of head and neck cancer: positron emission tomography/MRI versus positron emission tomography/CT. Head Neck. 2017 Aug;39(8):1550–8.
32. Tshering Vogel DW, Zbaeren P, Thoeny HC. Cancer of the oral cavity and oropharynx. Cancer Imaging. 2010;10(1):62–72. Published 2010 Mar 16. https://doi.org/10.1102/1470-7330.2010.0008.
33. Nae A, O'Leary G, Feeley L, Fives C, Fitzgerald B, Chiriac E, Sheahan P. Utility of CT and MRI in assessment of mandibular involvement in oral cavity cancer. World J Otorhinolaryngol Head Neck Surg. 2019;5(2):71–5. https://doi.org/10.1016/j.wjorl.2019.02.001.
34. Tamaki A, Miles BA, Lango M, Kowalski L, Zender CA. AHNS series: do you know your guidelines? Review of current knowledge on laryngeal cancer. Head Neck. 2018;40(1):170–81. https://doi.org/10.1002/hed.24862.

35. Shayah A, Wickstone L, Kershaw E, Agada F. The role of cross-sectional imaging in suspected nasopharyngeal carcinoma. Ann R Coll Surg Engl. 2019;101(5):325–7. https://doi.org/10.1308/rcsann.2019.0025.
36. Becker M, Burkhardt K, Dulguerov P, Allal A. Imaging of the larynx and hypopharynx. Eur J Radiol. 2008;66(3):460–79. https://doi.org/10.1016/j.ejrad.2008.03.027.
37. Dmytriw AA, El Beltagi A, Bartlett E, et al. CRISPS: a pictorial essay of an acronym to interpreting metastatic head and neck lymphadenopathy. Can Assoc Radiol J. 2014;65(3):232–41. https://doi.org/10.1016/j.carj.2013.07.004.
38. Pfister DG, Spencer S, Adelstein D, et al. Head and neck cancers, version 2.2020, NCCN clinical practice guidelines in oncology. J Natl Compr Cancer Netw. 2020;18(7):873–98. https://doi.org/10.6004/jnccn.2020.0031.
39. Dwivedi RC, Agrawal N, Dwivedi RC, Pathak KA, Kazı R. Evaluation, management and outcomes of head and neck cancer. In: Staffieri A, Sebastian P, Kapre M, Varghese BT, Kazı R, editors. Essentials of head and neck cancer. Delhi: Byword Books Private Limited; 2012. p. 19–33.
40. Merritt RM, Williams MF, James TH, Porubsky ES. Detection of cervical metastasis. A meta-analysis comparing computed tomography with physical examination. Arch Otolaryngol Head Neck Surg. 1997;123(2):149–52. https://doi.org/10.1001/archotol.1997.01900020027004.
41. Liao LJ, Lo WC, Hsu WL, Wang CT, Lai MS. Detection of cervical lymph node metastasis in head and neck cancer patients with clinically N0 neck-a meta-analysis comparing different imaging modalities. BMC Cancer. 2012;12:236. Published 2012 Jun 12. https://doi.org/10.1186/1471-2407-12-236.
42. Wu LM, Xu JR, Liu MJ, et al. Value of magnetic resonance imaging for nodal staging in patients with head and neck squamous cell carcinoma: a meta-analysis [published correction appears in Acad Radiol. 2012;19(6):674]. Acad Radiol. 2012;19(3):331–40. https://doi.org/10.1016/j.acra.2011.10.027.
43. Sun J, Li B, Li CJ, et al. Computed tomography versus magnetic resonance imaging for diagnosing cervical lymph node metastasis of head and neck cancer: a systematic review and meta-analysis. Onco Targets Ther. 2015;8:1291–313. https://doi.org/10.2147/OTT.S73924.
44. Lee KJ, Kirsch C, Sayre JW, Bhuta S, Abemayor E. Lymph node clustering in head and neck squamous cell cancer. Otolaryngol Head Neck Surg. 2008;139(2_Suppl):P39–40. https://doi.org/10.1016/j.otohns.2008.05.130.
45. Amin MB, Edge SB. AJCC cancer staging manual; 2017 (Print).
46. Lodder WL, Lange CA, Teertstra HJ, Pameijer FA, van den Brekel MW, Balm AJ. Value of MR and CT imaging for assessment of internal carotid artery encasement in head and neck squamous Cell carcinoma. Int J Surg Oncol. 2013;2013:968758. https://doi.org/10.1155/2013/968758.
47. Som PM. Detection of metastasis in cervical lymph nodes: CT and MR criteria and differential diagnosis. AJR Am J Roentgenol. 1992;158(5):961–9. https://doi.org/10.2214/ajr.158.5.1566697.
48. Ahuja AT, Ying M, Ho SY, et al. Ultrasound of malignant cervical lymph nodes. Cancer Imaging. 2008;8(1):48–56. https://doi.org/10.1102/1470-7330.2008.0006.
49. de Bondt RB, Nelemans PJ, Bakers F, et al. Morphological MRI criteria improve the detection of lymph node metastases in head and neck squamous cell carcinoma: multivariate logistic regression analysis of MRI features of cervical lymph nodes. Eur Radiol. 2009;19(3):626–33. https://doi.org/10.1007/s00330-008-1187-3.
50. Hoang JK, Vanka J, Ludwig BJ, Glastonbury CM. Evaluation of cervical lymph nodes in head and neck cancer with CT and MRI: tips, traps, and a systematic approach. AJR Am J Roentgenol. 2013;200(1):W17–25. https://doi.org/10.2214/AJR.12.8960.
51. Ying M, Bhatia KS, Lee YP, Yuen HY, Ahuja AT. Review of ultrasonography of malignant neck nodes: greyscale, Doppler, contrast enhancement and elastography. Cancer Imaging. 2014;13(4):658–69. https://doi.org/10.1102/1470-7330.2013.0056.
52. Pehlivan M, Gurbuz MK, Cingi C, Adapinar B, Değirmenci AN, Acikalin FM, Pinarbaşli MÖ, Colak E. Diagnostic role of ultrasound elastography on lymph node metastases in patients with head and neck cancer. Braz J Otorhinolaryngol. 2019;85(3):297–302. https://doi.org/10.1016/j.bjorl.2018.01.002.
53. Vandecaveye V, De Keyzer F, Vander Poorten V, et al. Head and neck squamous cell carcinoma: value of diffusion-weighted MR imaging for nodal staging. Radiology. 2009;251(1):134–46. https://doi.org/10.1148/radiol.2511080128.
54. Barchetti F, Pranno N, Giraldi G, et al. The role of 3 tesla diffusion-weighted imaging in the differential diagnosis of benign versus malignant cervical lymph nodes in patients with head and neck squamous cell carcinoma. Biomed Res Int. 2014;2014:532095. https://doi.org/10.1155/2014/532095.
55. Lim HK, Lee JH, Baek HJ, et al. Is diffusion-weighted MRI useful for differentiation of small non-necrotic cervical lymph nodes in patients with head and neck malignancies? Korean J Radiol. 2014;15(6):810–6. https://doi.org/10.3348/kjr.2014.15.6.810.
56. Mazzaferri EL, Kloos RT. Clinical review 128: current approaches to primary therapy for papillary and follicular thyroid cancer. J Clin Endocrinol Metab. 2001;86(4):1447–63. https://doi.org/10.1210/jcem.86.4.7407.
57. Kouvaraki MA, Shapiro SE, Fornage BD, et al. Role of preoperative ultrasonography in the surgical man-

agement of patients with thyroid cancer. Surgery. 2003;134(6):946–55. https://doi.org/10.1016/s0039-6060(03)00424-0.
58. Cooper DS, Doherty GM, et al. American Thyroid Association (ATA) Guidelines Taskforce on Thyroid Nodules and Differentiated Thyroid Cancer, Revised American Thyroid Association management guidelines for patients with thyroid nodules and differentiated thyroid cancer [published correction appears in Thyroid. 2010;20(8):942. Hauger, Bryan R [corrected to Haugen, Bryan R]] [published correction appears in Thyroid. 2010;20(6):674–5]. Thyroid. 2009;19(11):1167–214. https://doi.org/10.1089/thy.2009.0110.
59. Russ G, Leboulleux S, Leenhardt L, Hegedüs L. Thyroid incidentalomas: epidemiology, risk stratification with ultrasound and workup. Eur Thyroid J. 2014;3(3):154–63. https://doi.org/10.1159/000365289.
60. Burman KD, Wartofsky L. Thyroid nodules. N Engl J Med. 2016;374(13):1294–5. https://doi.org/10.1056/NEJMc1600493.
61. Koo BS, Choi EC, Park YH, Kim EH, Lim YC. Occult contralateral central lymph node metastases in papillary thyroid carcinoma with unilateral lymph node metastasis in the lateral neck. J Am Coll Surg. 2010;210(6):895–900. https://doi.org/10.1016/j.jamcollsurg.2010.01.037.
62. Zhao Q, Ming J, Liu C, et al. Multifocality and total tumor diameter predict central neck lymph node metastases in papillary thyroid microcarcinoma. Ann Surg Oncol. 2013;20(3):746–52. https://doi.org/10.1245/s10434-012-2654-2.
63. Na DG, Baek JH, Sung JY, et al. Thyroid imaging reporting and data system risk stratification of thyroid nodules: categorization based on solidity and echogenicity. Thyroid. 2016;26(4):562–72. https://doi.org/10.1089/thy.2015.0460.
64. Gharib H, Papini E, Garber JR, et al., American Association of Clinical Endocrinologists, American College of Endocrinology, Associazione Medici Endocrinologi. Medical guidelines for clinical practice for the diagnosis and management of thyroid nodules. 2016 update. Endocr Pract. 2016;22(5):622–39. https://doi.org/10.4158/EP161208.GL.
65. Tessler FN, Middleton WD, Grant EG, et al. ACR thyroid imaging, reporting and data system (TI-RADS): white paper of the ACR TI-RADS committee. J Am Coll Radiol. 2017;14(5):587–95. https://doi.org/10.1016/j.jacr.2017.01.046.
66. Grant EG, Tessler FN, Hoang JK, et al. Thyroid ultrasound reporting lexicon: white paper of the ACR thyroid imaging, reporting and data system (TIRADS) committee. J Am Coll Radiol. 2015;12(12 Pt A):1272–9. https://doi.org/10.1016/j.jacr.2015.07.011.
67. Russ G, Bonnema SJ, Erdogan MF, Durante C, Ngu R, Leenhardt L. European thyroid association guidelines for ultrasound malignancy risk stratification of thyroid nodules in adults: the EU-TIRADS. Eur Thyroid J. 2017;6(5):225–37. https://doi.org/10.1159/000478927.
68. Grani G, Lamartina L, Ascoli V, et al. Reducing the number of unnecessary thyroid biopsies while improving diagnostic accuracy: toward the "right" TIRADS. J Clin Endocrinol Metab. 2019;104(1):95–102. https://doi.org/10.1210/jc.2018-01674.
69. Grani G, Lamartina L, Cantisani V, Maranghi M, Lucia P, Durante C. Interobserver agreement of various thyroid imaging reporting and data systems. Endocr Connect. 2018;7(1):1–7. https://doi.org/10.1530/EC-17-0336.
70. Grani G, Lamartina L, Biffoni M, et al. Sonographically estimated risks of malignancy for thyroid nodules computed with five standard classification systems: changes over time and their relation to malignancy. Thyroid. 2018;28(9):1190–7. https://doi.org/10.1089/thy.2018.0178.
71. Ito Y, Higashiyama T, Takamura Y, et al. Risk factors for recurrence to the lymph node in papillary thyroid carcinoma patients without preoperatively detectable lateral node metastasis: validity of prophylactic modified radical neck dissection. World J Surg. 2007;31(11):2085–91. https://doi.org/10.1007/s00268-007-9224-y.
72. Langer JE, Mandel SJ. Sonographic imaging of cervical lymph nodes in patients with thyroid cancer. Neuroimaging Clin N Am. 2008;18(3):479, viii. https://doi.org/10.1016/j.nic.2008.03.007.
73. Hwang HS, Orloff LA. Efficacy of preoperative neck ultrasound in the detection of cervical lymph node metastasis from thyroid cancer. Laryngoscope. 2011;121(3):487–91. https://doi.org/10.1002/lary.21227.
74. Kim E, Park JS, Son KR, Kim JH, Jeon SJ, Na DG. Preoperative diagnosis of cervical metastatic lymph nodes in papillary thyroid carcinoma: comparison of ultrasound, computed tomography, and combined ultrasound with computed tomography. Thyroid. 2008;18(4):411–8. https://doi.org/10.1089/thy.2007.0269.
75. Leboulleux S, Girard E, Rose M, et al. Ultrasound criteria of malignancy for cervical lymph nodes in patients followed up for differentiated thyroid cancer. J Clin Endocrinol Metab. 2007;92(9):3590–4. https://doi.org/10.1210/jc.2007-0444.
76. Gimm O, Rath FW, Dralle H. Pattern of lymph node metastases in papillary thyroid carcinoma. Br J Surg. 1998;85(2):252–4. https://doi.org/10.1046/j.1365-2168.1998.00510.x.
77. Machens A, Hinze R, Thomusch O, Dralle H. Pattern of nodal metastasis for primary and reoperative thyroid cancer. World J Surg. 2002;26(1):22–8. https://doi.org/10.1007/s00268-001-0176-3.
78. Kuna SK, Bracic I, Tesic V, Kuna K, Herceg GH, Dodig D. Ultrasonographic differentiation of benign from malignant neck lymphadenopathy in thyroid

cancer. J Ultrasound Med. 2006;25(12):1531–40. https://doi.org/10.7863/jum.2006.25.12.1531.
79. Jiang ZZ, Huang YH, Shen HL, Liu XT. Clinical applications of superb microvascular imaging in the liver, breast, thyroid, skeletal muscle, and carotid plaques. J Ultrasound Med. 2019;38(11):2811–20. https://doi.org/10.1002/jum.15008.
80. Ahuja AT, Ying M, Ho SS, Metreweli C. Distribution of intranodal vessels in differentiating benign from metastatic neck nodes. Clin Radiol. 2001;56(3):197–201. https://doi.org/10.1053/crad.2000.0574.
81. Cibas ES, Ali SZ. The Bethesda system for reporting thyroid cytopathology. Thyroid. 2009;19(11):1159–65. https://doi.org/10.1089/thy.2009.0274.
82. Yang J, Schnadig V, Logrono R, Wasserman PG. Fine-needle aspiration of thyroid nodules: a study of 4703 patients with histologic and clinical correlations. Cancer. 2007;111(5):306–15. https://doi.org/10.1002/cncr.22955.
83. Roy R, Kouniavsky G, Venkat R, et al. The role of preoperative neck ultrasounds to assess lymph nodes in patients with suspicious or indeterminate thyroid nodules. J Surg Oncol. 2012;105(6):601–5. https://doi.org/10.1002/jso.22115.
84. Yeh MW, Bauer AJ, Bernet VA, et al. American Thyroid Association statement on preoperative imaging for thyroid cancer surgery. Thyroid. 2015;25(1):3–14. https://doi.org/10.1089/thy.2014.0096.
85. Hoang JK, Raduazo P, Yousem DM, Eastwood JD. What to do with incidental thyroid nodules on imaging? An approach for the radiologist. Semin Ultrasound CT MR. 2012;33(2):150–7. https://doi.org/10.1053/j.sult.2011.12.004.
86. Razek AA, Sadek AG, Kombar OR, Elmahdy TE, Nada N. Role of apparent diffusion coefficient values in differentiation between malignant and benign solitary thyroid nodules. AJNR Am J Neuroradiol. 2008;29(3):563–8. https://doi.org/10.3174/ajnr.A0849.
87. Van der Molen AJ, Thomsen HS, Morcos SK, Contrast Media Safety Committee, European Society of Urogenital Radiology (ESUR). Effect of iodinated contrast media on thyroid function in adults. Eur Radiol. 2004;14(5):902–7. https://doi.org/10.1007/s00330-004-2238-z.
88. Seo YL, Yoon DY, Lim KJ, et al. Locally advanced thyroid cancer: can CT help in prediction of extrathyroidal invasion to adjacent structures? AJR Am J Roentgenol. 2010;195(3):W240–4. https://doi.org/10.2214/AJR.09.3965.
89. Wang JC, Takashima S, Takayama F, et al. Tracheal invasion by thyroid carcinoma: prediction using MR imaging. AJR Am J Roentgenol. 2001;177(4):929–36. https://doi.org/10.2214/ajr.177.4.1770929.
90. Takashima S, Takayama F, Wang J, Kobayashi S, Kadoya M. Using MR imaging to predict invasion of the recurrent laryngeal nerve by thyroid carcinoma. AJR Am J Roentgenol. 2003;180(3):837–42. https://doi.org/10.2214/ajr.180.3.1800837.
91. Nam IC, Park JO, Joo YH, Cho KJ, Kim MS. Pattern and predictive factors of regional lymph node metastasis in papillary thyroid carcinoma: a prospective study. Head Neck. 2013;35(1):40–5. https://doi.org/10.1002/hed.22903.
92. Machens A, Holzhausen HJ, Dralle H. Skip metastases in thyroid cancer leaping the central lymph node compartment. Arch Surg. 2004;139(1):43–5. https://doi.org/10.1001/archsurg.139.1.43.
93. Kaplan SL, Mandel SJ, Muller R, Baloch ZW, Thaler ER, Loevner LA. The role of MR imaging in detecting nodal disease in thyroidectomy patients with rising thyroglobulin levels. AJNR Am J Neuroradiol. 2009;30(3):608–12. https://doi.org/10.3174/ajnr.A1405.
94. Schlüter B, Bohuslavizki KH, Beyer W, Plotkin M, Buchert R, Clausen M. Impact of FDG PET on patients with differentiated thyroid cancer who present with elevated thyroglobulin and negative 131I scan. J Nucl Med. 2001;42(1):71–6.
95. Som PM, Lawson W, Genden EM. The posttreatment neck: clinical and imaging considerations. In: Som PM, Curtin HD, editors. Head and neck imaging. 5th ed. St Louis, MO: Mosby; 2011. p. 2771–822.
96. Manikantan K, Khode S, Dwivedi RC, et al. Making sense of post-treatment surveillance in head and neck cancer: when and what of follow-up. Cancer Treat Rev. 2009;35(8):744–53. https://doi.org/10.1016/j.ctrv.2009.08.007.
97. Subramaniam RM, Truong M, Peller P, Sakai O, Mercier G. Fluorodeoxyglucose-positron-emission tomography imaging of head and neck squa- mous cell cancer. AJNR Am J Neuroradiol. 2010;31(4):598–604. https://doi.org/10.3174/ajnr.A1760.
98. de Bree R, van der Putten L, Brouwer J, Castelijns JA, Hoekstra OS, Leemans CR. Detection of locoregional recurrent head and neck cancer after (chemo) radiotherapy using modern imaging. Oral Oncol. 2009;45(4–5):386–93. https://doi.org/10.1016/j.oraloncology.2008.10.015.
99. Yao M, Smith RB, Graham MM, et al. The role of FDG PET in management of neck metastasis from head-and-neck cancer after definitive radiation treatment. Int J Radiat Oncol Biol Phys. 2005;63(4):991–9. https://doi.org/10.1016/j.ijrobp.2005.03.066.
100. Vandecaveye V, De Keyzer F, Nuyts S, et al. Detection of head and neck squamous cell carcinoma with diffusion weighted MRI after (chemo) radiotherapy: correlation between radiologic and histopathologic findings. Int J Radiat Oncol Biol Phys. 2007;67(4):960–71. https://doi.org/10.1016/j.ijrobp.2006.09.020.
101. Vandecaveye V, De Keyzer F, Dirix P, Lambrecht M, Nuyts S, Hermans R. Applications of diffusion-weighted magnetic resonance imaging in head and

neck squamous cell carcinoma. Neuroradiology. 2010;52(9):773–84. https://doi.org/10.1007/s00234-010-0743-0.

102. Genden EM, Rinaldo A, Suárez C, Wei WI, Bradley PJ, Ferlito A. Complications of free flap transfers for head and neck reconstruction following cancer resection. Oral Oncol. 2004;40(10):979–84. https://doi.org/10.1016/j.oraloncology.2004.01.012.
103. Lell M, Baum U, Greess H, et al. Head and neck tumors: imaging recurrent tumor and post-therapeutic changes with CT and MRI. Eur J Radiol. 2000;33(3):239–47. https://doi.org/10.1016/s0720-048x(99)00120-5.
104. Makimoto Y, Yamamoto S, Takano H, et al. Lymphadenopathy in the mesenteric pedicle of the free jejunal flap: reactive lymphadenopathy, not metastatic. J Comput Assist Tomogr. 2006;30(1):65–7. https://doi.org/10.1097/01.rct.0000177606.90817.cb.
105. Chong VF. Post treatment imaging in head and neck tumours. Cancer Imaging. 2005;5(1):8–10. Published 2005 Apr 6. https://doi.org/10.1102/1470-7330.2005.0003.
106. Mukherji SK, Wolf GT. Evaluation of head and neck squamous cell carcinoma after treatment. AJNR Am J Neuroradiol. 2003;24(9):1743–6.
107. Hermans R. Posttreatment imaging in head and neck cancer. Eur J Radiol. 2008;66(3):501–11. https://doi.org/10.1016/j.ejrad.2008.01.0210.1186/1758-3284-3-14.

Approach Towards Oral Cavity Cancers

5

Devendra Arvind Chaukar, Arjun Gurmeet Singh, Adhara Chakraborty, and Gurukeerthi Balakrishna

5.1 Introduction

Oral cavity malignancies are one of the most common cancers of the head and neck region with an estimated incidence of 377,713 cases in 2020 [1]. India alone contributes to more than a third of this global burden followed by China and the United States [2]. Oral cancer is also more prevalent among men because of the heavier tobacco and alcohol consumption among them [3]. The global incidence has seen a rise across all age groups in the last decade, especially in young men [3]. Much information is now present to indicate a rise in mortality due to oral cancer in many parts of the world with some of the highest increases in countries of Central and Western Europe. Generally, a modest 5-year survival rate of 50% is seen among patients with oral cancer [4].

Majority of oral cancers are epithelial in origin with 90% comprising squamous cell carcinoma (SCC) [5]. Other tumours that are known to occur in the oral cavity include those from a salivary gland origin, bone and dental structures, and mesenchymal tumours of the soft tissue, nerves, etc. The oral cavity boundaries include the point of contact of the opposed lips anteriorly, the hard palate superiorly, the circumvallate papillae inferiorly and the anterior pillar of the tonsils laterally. Within this, the sites assessed include the wet mucosa of both lips, oral tongue, upper and lower alveolar ridges, retromolar trigone (RMT), floor of the mouth, buccal mucosa and hard palate. Anything beyond the cutaneous portion of the vermilion of the lip is considered a disease of the skin [6]. In the Indian subcontinent and parts of South Asia, the most common site affected is the gingivobuccal complex (GBC), i.e. at the sulcular junction of the buccal mucosa and alveolar gingiva. This is also the most common site of quid/smokeless tobacco placement in these users and occurs due to a direct-contact carcinogenic effect [7]. The mucosal epithelium harbours cells that are the origin of oral SCC. They can either occur de novo or in a background of pre-malignant changes such as those seen in oral submucosal fibrosis, erythroplakia, leukoplakia and less commonly oral lichen planus [8–10]. Once invasion of the basement membrane is established, they become locally aggressive infiltrating the underlying structures and rich lymphatics of the region. Due to this, all subsites of the oral cavity have a propensity of regional spread, with up to 45% of cases presenting with cervical metastasis at the time of diagnosis [11].

This chapter provides an overview regarding the principles of managing oral cavity cancers and the fundamentals of surgical resection highlighting the key steps in surgery.

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N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_5

5.2 Principles of Management

The management of oral cavity cancers follows the basic principles of treatment of most malignancies. Priority should always be towards locoregional control and prevention of distant metastasis. Another equally important factor that needs to be considered is the quality of life of the patients being subjected to a sometimes rigorous treatment schedule. Hence, a dilemma exists on the acceptable definition of operable tumours that can achieve safe oncologic margins along with acceptable functional and aesthetic morbidity. Early-stage cancers are usually managed by a single-modality therapy in the form of surgery or radiotherapy, whereas advanced cancers are treated by a combination therapy, involving surgery followed by adjuvant radiotherapy (RT) alone or in combination with chemotherapy (CTRT) [12]. When multiple modalities are available, the treatment schedule with the maximum chance of cure should be considered. When the different modalities show comparable cure rates, the treatment option providing the best functional outcome should be considered. The choice between radiation or surgical resection for early-stage cancers mainly depends on the site tumour. Cancers of the buccal mucosa, tongue and floor of mouth are usually considered for surgical resection as these tumours are easily accessible and can be excised without considerable functional and cosmetic morbidity, and radiotherapy can be reserved to intensify management if needed or as a salvage treatment option. Managing the primary tumour by radiotherapy alone, in the form of conventional RT, brachytherapy or surface mould, is only considered for small superficial lesions on the lip and hard palate where excision is associated with poor aesthetic and functional outcomes (Key Point 1). Chemotherapy alone is currently being used either in trial settings or as a part of palliative treatment [12].

Key Point 1

- Surgery for early and advanced oral cancer delivers best survival outcomes as it is quick and cost effective with minimal morbidity.
- Quality of life is equally important and needs to be considered when planning treatment.
- Radiotherapy is considered for superficial lesions in sites associated with poor aesthetic and functional outcomes. For example, brachytherapy is used for superficial palatal lesions (surface mould) and for small tumours (≤1.5 cm depth) that are away from bone (Figs. 5.1 and 5.2) [13].

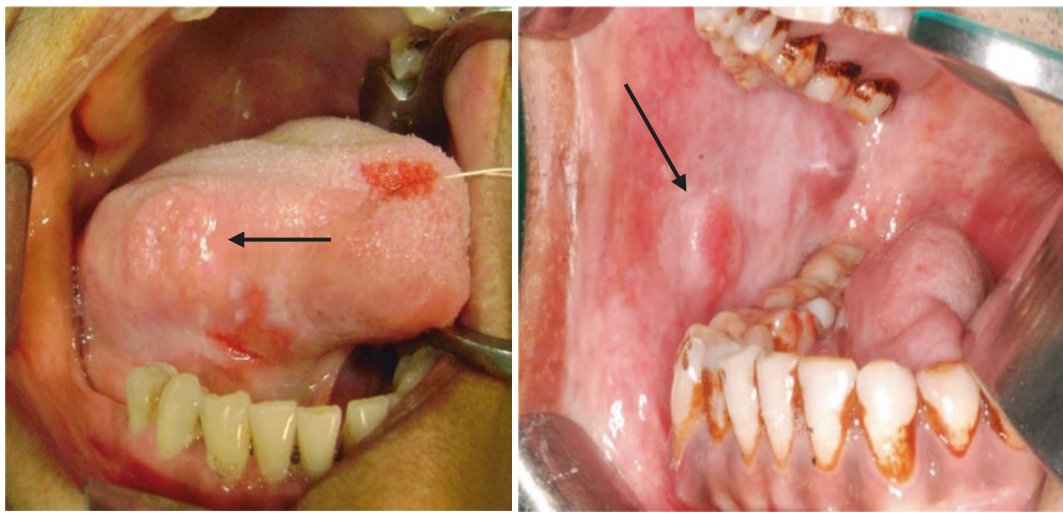


Fig. 5.1 Small tumours less than 1.5 cm in depth

Fig. 5.2 Small and superficial T1 tumours of lip and hard palate

5.2.1 Role of Neoadjuvant Chemotherapy

Neoadjuvant chemotherapy (NACT) was initially used to intensify treatment for oral cancers. The early randomized trials by Licitra and Zhong et al. demonstrated no improvement in overall survival or disease-free survival for operable oral cancers [14, 15]. A later meta-analysis demonstrated similar results but showed benefit in only patients with clinically N2 nodal status. Following this, Patil et al. used NACT in 721 borderline operable oral cancers. They defined borderline operable oral cancers as diseases where the extent would result in an inadequate or involved margin. They found that 43% had sufficient reduction in tumour size that made them operable and gave them a significant survival advantage [16]. Another setting that is gaining traction is the use of NACT for organ preservation of the oral cavity structures. Chaukar et al. demonstrated a 48% mandible preservation rate with no inadequate margins using NACT in operable oral cancers, and equal survival rates compared to the arm that did not receive NACT [17]. Currently, NACT is still being used in a trial setting, and more evidence is needed to substantiate its use in gaining survival advantage (Key Point 2).

Key Point 2 Indications for NACT Based on Current Evidence

Borderline operable disease

- Disease reaching up to the zygoma and/or soft-tissue swelling up to the zygoma
- Extensive soft-tissue involvement reaching up to the hyoid
- Extensive skin infiltration
- Involvement of the infratemporal fossa
- Extensive disease reaching vallecula

Organ preservation

- Paramandibular soft-tissue disease without bone erosion

5.3 Diagnostic Evaluation

A comprehensive history, physical examination and preoperative imaging are vital to form an appropriate diagnosis and treatment plan. The clinical staging of the AJCC classification takes into account all these parameters and helps in determining the extent of the primary tumour and cervical lymph node metastasis. The history of patient should comprise certain pointers that can help formulate the diagnosis. This includes questions regarding the presence of comorbidities and general condition, possible etiological agents and social habits focusing on the use of tobacco and alcohol, clinical progression of the disease and history of any prior cancer-related treatment. The estimate of clinical progression can be made by the duration of the disease, rate of progression and history relating to locoregional spread in the form of complaints such as trismus of recent onset, otalgia, dysarthria, odynophagia, facial numbness and severe weight loss.

The physical examination should be performed to accurately map the extent of the primary tumour and the presence of lymph node metastasis [18, 19]. A Hopkins rod or flexible endoscopy examination should be performed to rule out the presence of synchronous malignancies in the oropharyngeal, laryngeal and hypopharyngeal regions of the head and neck. Involvement of skin and bone is assessed by palpation and imaging. Induration or puckering palpable in the skin, along with *peau d'orange* appearance, should be suspicious of skin involvement (Fig. 5.3). The assessment of paramandibular disease is determined through palpation. This can be supplemented with additional imaging. The examination can be carried under topical or local anaesthesia. General anaesthesia is preferred if the patient is in intolerable pain, lesions that are difficult to assess such extension into the tonsil, lateral and posterior pharyngeal wall, base of tongue, vallecula and proximity to the hyoid bone.

All clinical interpretations need to be confirmed with an accurate representative biopsy. Histopathological diagnosis not only confirms the clinical diagnosis, but also helps in distinguishing the grade and variant of SCC predicting the nature of disease [14]. Punch biopsy of the mucosal regions of the oral cavity should be taken from the most representative part of the ulcer avoiding areas of necrosis. Widespread mucosal lesions entail a biopsy from multiple sites to ensure accurate assessment of the pathology [20–24].

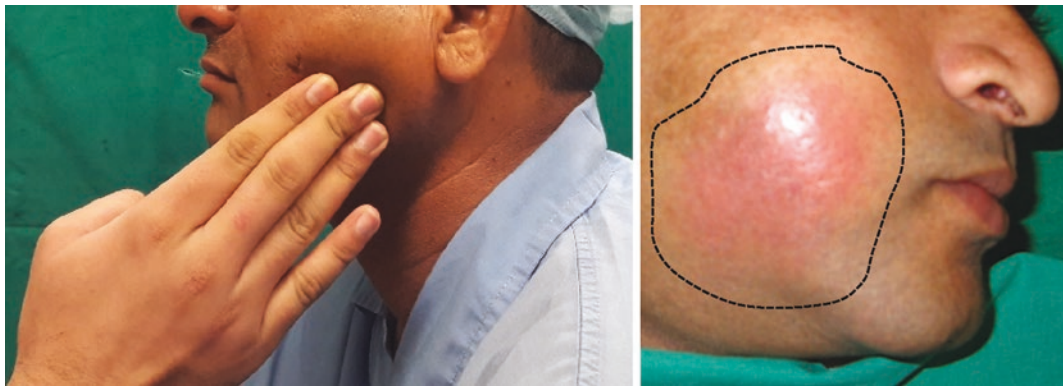


Fig. 5.3 Palpation of the skin to evaluate involvement and *peau d'orange* appearance

5.4 Principles of Imaging Techniques

The main aim of using imaging as a diagnostic tool is to study the spread of the tumour beyond the clinically discernible areas with respect to the involvement of the third dimension and adjoining spaces, i.e. masticator space, infratemporal fossa, and parapharyngeal and retropharyngeal space. The imaging modality to guide treatment plan is based on the site of the primary tumour involvement. The most common imaging modalities used are the contrast-enhanced (CE) CT scan and MRI. The role of the CECT has been described in demonstrating bone erosion of the mandible, maxilla or skull base [25]. A study comparing the different imaging modalities, namely the OPG, CECT, DentaScan and SPECT, to assess for mandibular involvement was undertaken, in which CT scan showed the highest accuracy [26].

CEMRI has been known to have superior soft-tissue delineation as compared to CECT, especially in lesions of the oral tongue, oropharynx and floor of mouth. The main factors that need to be studied in an MRI include the invasion of the extrinsic muscles of the tongue, spread into the sublingual and submandibular space; lesions crossing beyond the midline raphe; and the posterior extent of the disease onto the tongue base. The extent of involvement of the neurovascular bundle in malignancies involving the substance of the tongue, bone marrow and floor of mouth is of vital importance [27]. The features that need to be studied in any preoperative imaging based on the site of involvement are summarized below (Key Points 3 and 4, Fig. 5.4).

Key Point 3 Principles of Imaging Oral Cavity Cancers

Site of involvement	Characteristics	Features to study	CECT	CEMRI	Treatment decisions
RMT, GBC, hard palate	Higher chances for bone involvement (14–72%) [28, 29]	ITF involvement—supranotch or infranotch disease [30] Bone involvement—cortical erosion vs. extension into medullary canal Perineural spread Gross ENE	High specificity for detecting bone erosion (87–90%) [31] Detecting perineural spread and extension of nerve involvement, possible extension to foramen [31] Extent of marrow involvement	High sensitivity and negative predictive value and low sensitivity Inferior as compared to CECT for Buccal mucosal, RMT and GBC [31] Considered in cases where CT shows gross marrow involvement to accurately assess spread and perineural spread	Main decision regarding marginal vs. segmental mandibulectomy Predicting routes of tumour entry and possible spread [26] Segmental mandibulectomy—extent of bone resection if disease invading deeply into mandible having gross paramandibular disease [26, 32] Supranotch disease—poorer outcomes with increased chances of recurrences [29, 33]. Unresectable disease if PTF and lateral pterygoid plate involved

Site of involvement	Characteristics	Features to study	CECT	CEMRI	Treatment decisions
Tongue and floor of mouth	Spread of posteriorly located lesions to the tonsil and the base of tongue and vallecula Floor-of-mouth lesions abutting the mandible have a propensity for cortical erosion of the mandible Proximity of locally invasive cancers with the hyoid bone	Extent of the tumour and infiltration across the tongue musculature Proximity of the tumour to the mandible and possible involvement Involvement of the neurovascular bundle Deep infiltration and proximity with the hyoid	Preferred to assess for cortical erosion in floor-of-mouth cancers [34–36]	Superior to CECT Can be considered to assess suspicious marrow invasion in locally advanced tongue/floor-of-mouth carcinomas. However, possibility of overestimation of disease due to associated inflammation or periodontal disease [37]	Extent of resection—to consider reconstruction options if resection crossing midline, or there is breach of floor of mouth Lesions crossing midline—need to address the contralateral neck [38] Composite resection with a marginal or segmental mandibulectomy depending on the lesion abutting/involving the mandibular cortex Lesion in proximity to the hyoid bone—to consider options for neoadjuvant chemotherapy [16, 39] Extensive NV bundle involvement—to consider compartmental resection [40, 41]

5.5 Assessment of Depth of Invasion

The assessment of depth of invasion (DOI) has now become the standard as per the recommendations of the eighth AJCC staging. The role of MRI in assessing the depth of invasion of tumour has been reported extensively across literature. Most studies have accepted the use of MRI in assessing the depth of invasion in early oral tongue cancers. This use of MRI in assessing the depth of invasion has also been regarded as a prognostic marker for oral cancers reporting poor overall survival and disease-free survival with the DOI more than 8 and 11 mm, respectively [42]. The role of ultrasound-guided assessment in assessing tumour depths has also been highlighted with its ability to distinguish tumour interface with the surrounding tongue musculature leading to comparable accuracy between radiological and pathological reporting of depth of invasion. A recent meta-analysis has shown similar accuracy comparing MRI and ultrasound in assessing tongue cancers [43]. However, the presence of inter-observer variability and operator dependence makes the use of ultrasound less preferable as compared to the MRI. Based on the depth of invasion, it is essential to achieve an adequate three-dimensional margin with an adequate base. This is important for buccal mucosa and tongue cancers where a soft-tissue cuff of at least 5–10 mm is needed around the tumour (Fig. 5.5, Key Point 5).

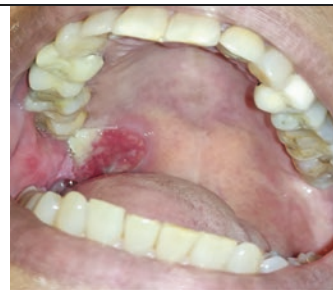
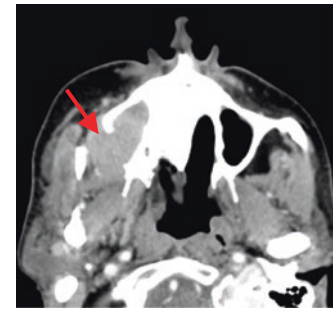
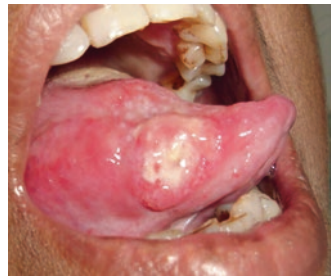
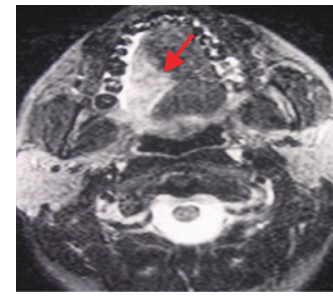
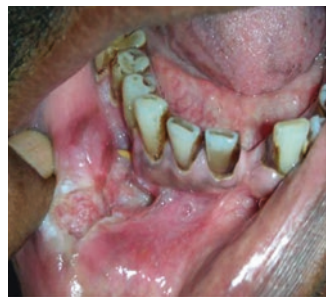
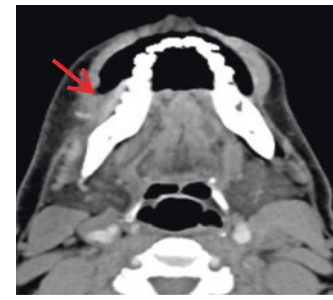
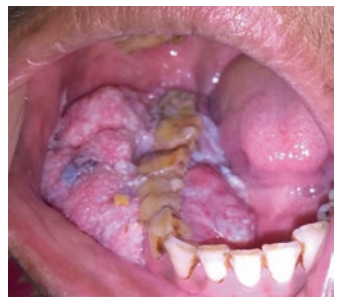
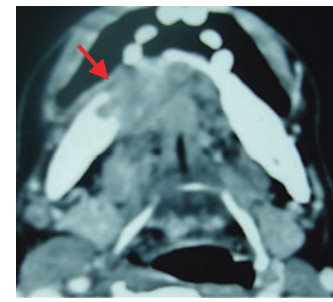
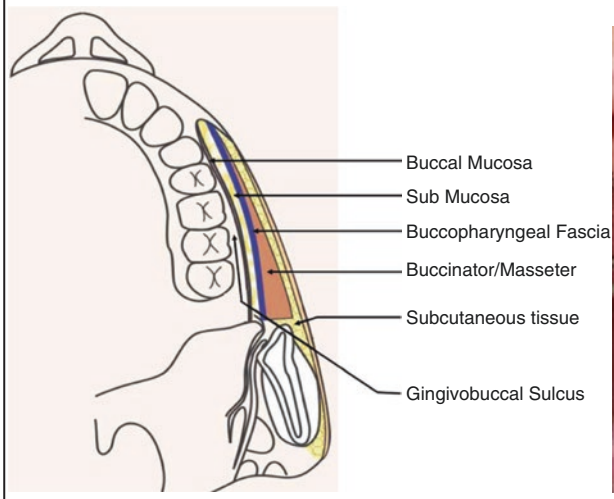
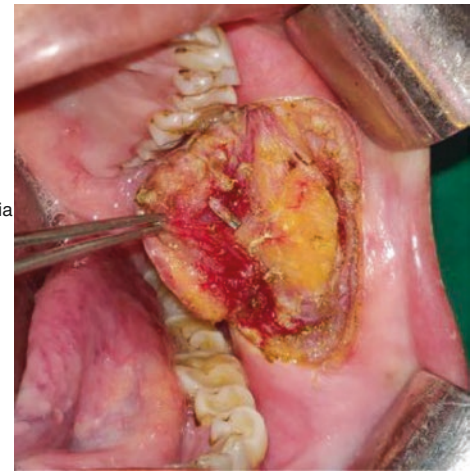
Key point 4 Common scenarios and imaging needed	
Clinical scenario	Imaging done to assess
1.  RMT: To assess for ITF invovlemnt—CECT/CEMRI	
2.  Tongue: To assess for depth of lesion—CEMRI	
3.  Lesion juxtaposed to bone: To assess for paramandibular disease and bone involvement—CECT	
4.  Mandible: To assess for extent of bone erosion and inferior alveolar canal invasion—CECT To assess for extent of marrow invasion and perineural spread—CEMRI	

Fig. 5.4 Subsites of oral tongue carcinoma and imaging findings of structural involvement

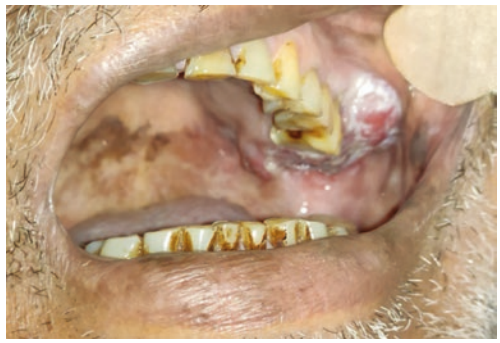
Key point 5

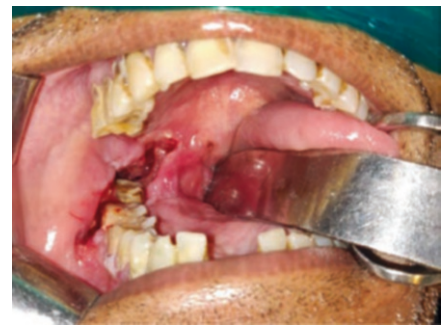
- 80% of the margin failure is at the base or deep margins
- Base for buccal mucosa is buccinator/masseter and then skin
- Based on the depth of resection
    - D1 – Mucosal and submucosal not reaching buccinators
    - D2 – Extending to the buccinators, but not breaching its continuity
    - D3 – Breaching buccinator





- Lesion breaching buccinators will mandate skin excision in most cases
- Base for alveolar lesions is underlying bone





- Base for tongue is deep musculature

Fig. 5.5 Critical points for consideration for margin resection

5.6 Imaging for Cervical Metastasis

The evaluation of regional spread is vital in the preoperative assessment of oral cancers. The presence of lymph node metastasis reduces the survival by 50%, and the presence of extranodal extension reduces it further by half. The extent of neck dissection depends on the site of the primary and the level of the positive lymph node [44]. The most likely site of lymph node drainage for oral cavity cancers is at levels I, II and III [45]. The presence of multiple cervical lymph nodes, presence of extranodal extension and encasement of soft tissue and vasculature of the neck significantly affect survival rates [46]. The

presence of above-mentioned features also forms an indication for adjuvant chemotherapy [47–49]. The imaging of choice to assess regional lymphadenopathy is a CECT due to its high specificity [50]. After the recent randomized trial that has shown a significant survival advantage when neck dissection is performed, imaging the neck purely to determine the nodal status has lost its significance.

5.7 Imaging for Distant Metastasis

The most common site for distant metastasis for oral carcinomas is the lung. Therefore, in majority of the cases, the preoperative workup of the patient should be accompanied with a plain CT thorax. The incidence of distant metastasis increases when patients present with large bulky nodal disease, multiple bilateral neck nodes and level III/IV lymph node involvement [12, 29]. A PET-CECT is considered as the imaging modality of choice for the detection of distant metastasis for most cancers [51]. However, for oral cancers, no significant difference has been observed in detecting distant metastasis between a plain CT thorax and a PET-CECT [51]. Therefore, the use of PET-CECT can be limited to recurrent oral cavity cancers or patients with suspected synchronous malignancies [52].

5.8 Approaches to Surgical Resection

5.8.1 Principles of Resection

Surgery is considered as the primary treatment modality for early and locally advanced oral cancers. Trials in the past have shown superior outcomes of surgical intervention as compared to primary radiotherapy in terms of overall survival and disease-free survival. One of the earliest randomized trials attempted to compare the survival outcomes in patients undergoing surgery followed by post-operative radiotherapy versus primary radiotherapy for oral cavity carcinomas. The trial was closed within less than 2 years of accrual due to marked difference in the overall survival favouring combination therapy of surgery with adjuvant therapy [52].

The surgical approach towards tumours of the oral cavity depends on the location of the tumour, depth of invasion and proximity of the lesion to bone, i.e. the buccal or lingual surface of the mandible, upper alveolus and hard palate. Furthermore, attention needs to be drawn to the size and depth of infiltration along with the presence of any other malignant or premalignant lesions in the oral cavity. The presence of any other suspicious lesion which has an area of intervening normal mucosa must be biopsied to confirm diagnosis. This will rule out the presence of a synchronous malignancy, which may affect the surgical plan. Other associated factors that need to be taken into consideration include the presence of trismus due to either pain, inflammation, masticator space involvement, prior surgery or chemoradiation.

5.8.2 Extent of Resection and Margins

The primary tumour management entails wide excision with adequate margins. The current accepted standard involves a minimum 5 mm margin to be considered during resection of the primary tumour [53]. The assessment of margins can be either specimen driven or defect driven. The specimen-driven approach has been reported to increase the rate of adequate resections and is considered superior to the defect-driven approach. However, intraoperatively, a margin of a minimum of 1 cm is considered adequate taking into account some degree of mucosal shrinkage after tissue resection and pathological processing [54]. Several studies have questioned the use of frozen section for intraoperative margin assessment, its benefit and cost-effectiveness [55]; however, its use can be considered in select situations such as recurrent tumours or those subjected to surgery after neoadjuvant chemotherapy where the clinico-radiological assessment of the margin status might be questionable.

5.8.2.1 Access-Incision Planning

Various incisions have been described based on the required access and extent of the primary tumour. When the skin is not involved, it is important to design the incision in a way that preserves vascularity of the native skin flap and provide adequate access at the same time. The incision is based on the proximity of the tumour with the oral commissure. The key principle is to preserve the vasculature around the oral commissure and lips (Fig. 5.6, Key Point 6).

If the skin resection is planned, the area to be resected is first marked keeping adequate margins around the involved area (Fig. 5.7). This is then connected to the neck incision by a perpendicular line. To gain further access to the oral cavity, the same principles highlighted in Fig. 5.6. Key Point 7 should be followed.

5.8.3 Surgical Techniques

5.8.3.1 Anaesthesia Considerations

General anaesthesia is preferred for oral cancer resection procedures. A nasotracheal intubation using a north pole-facing endotracheal tube is used so that the oral cavity is freely accessible. In case the mouth opening is restricted, a fibre-optic-assisted intubation or tracheostomy is performed. If the surgery entails resection of any part of the swallowing mechanism, an elective tracheostomy is performed. The patient is positioned supine with minimal neck extension, if required, for the primary resection. Nasogastric feeding tube is inserted and confirmed under direct visualization.

Approach	Indications
Peroral approach	Good mouth opening, anteriorly placed T1–T2 lesions
Lower cheek flap	Posteriorly placed lesions, lesions involving the RMT, gross paramandibular disease
Upper cheek flap	Tumours of the hard palate, upper GBS, upper alveolus
Pull-through visor approach	Anterior 2/3rd tongue lesions, lesions involving the entire dorsum of tongue, posteriorly located lesions (lesions at post 1/3rd of tongue, lesions involving BOT)
Mandibulotomy	Posteriorly located oropharyngeal and oral cavity lesions (requiring access for lateral soft-tissue margin and base), inaccessible lesions due to trismus

5.8.4 Early Tongue Carcinoma (T1 and T2 Tumours or T3/T4 Tumours That Are Completely Visualized)

5.8.4.1 Peroral Wide Local Excision

Once the patient is adequately anaesthetized, a mouth gag is inserted, and a visual and palpable examination confirms the extent of lesion. A traction stitch is taken at the planned anterior margin edge about 1 cm from the tumour followed by another stitch adjacent to it through the uninvolved substance of the tongue. Adequate mucosal margins are marked around the clinically discernible and palpable tumour (Fig. 5.8).

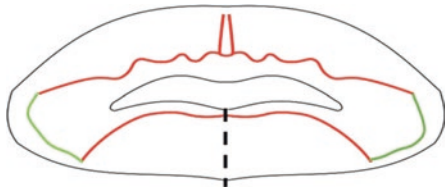
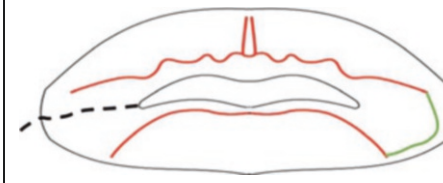
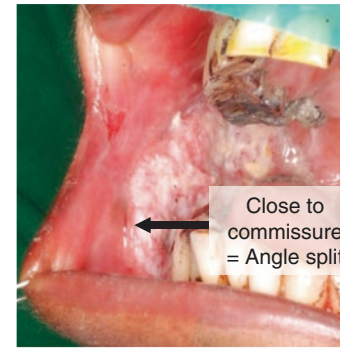
These markings are then deepened to include the tongue musculature always keeping in mind to palpate the adequacy of soft tissue resected for the third dimension, i.e. the base. As the resection continues posteriorly, the intramuscular branches or the terminal portion of lingual vascular bundle might be encountered deep to the sublingual gland. These vessels are meticulously ligated to achieve appropriate haemostasis (Fig. 5.9).

Once the specimen is removed, the mucosal and soft-tissue margins are assessed for adequacy (Fig. 5.10). Appropriate reconstruction is carried out based on the size of the defect and the functional requirement.

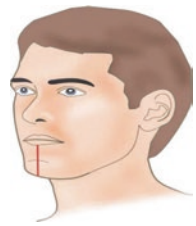
5.8.5 Advanced Tongue Carcinoma (T3 and T4 or Posteriorly Based T1 and T2 Tumours)

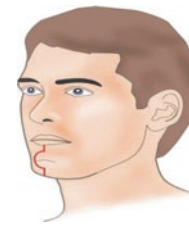
Once the patient is adequately anaesthetized, a mouth gag is inserted, and a visual and palpable examination confirms the extent of lesion. Nasogastric feeding tube is then inserted and confirmed under direct visualization. To achieve

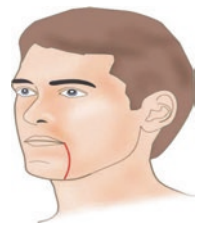
Key Point 6 Midline Lip Versus Angle Split Incision

Midline lip split	**Angle Split**
 Midline Lip Split	 Angle Split
• When the tumour is present posteriorly and the facial vessels around the oral commissure can be preserved, a midline lip split is preferred.	• When the tumour or margin involves the commissure and its vessels, angle split is preferred.
Away from commissure = Midline split	
• The two halves of the lower lip obtain their blood supply from the upper lips through the communication at the commissures.	• The vascularity of the lower lip is preserved through the midline revascularization

Modifications of the above have been suggested to improve aesthetics:


Roux - Vertical


McGregor- Chin sparing


Robson – Angle split

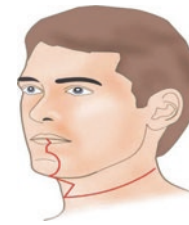
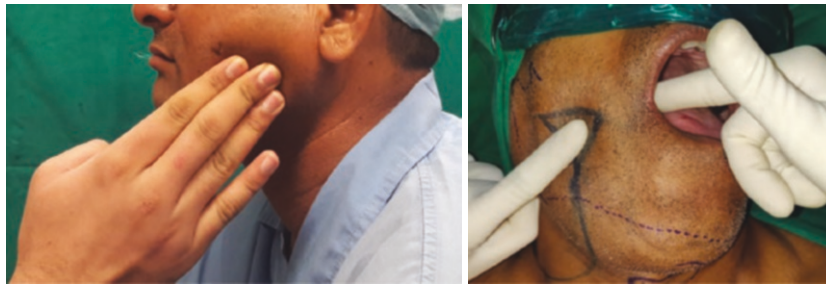

Rassekh – Modified zig zag

Fig. 5.6 Types of lip split incision

Key Point 7 When and how to resect skin?

When to resect skin?

- Look out for induration or puckering of skin by palpation
- Unhealthy inflamed skin not lifting from underlying tumour needs to be removed
- Tumour can be palpated through the skin



How to mark the skin?

- The skin should be marked prior to initiation of surgery
- Adequate margin of 1cm should be resected around the clinically discernible tumour
- A perpendicular is dropped from the lower edge so as to maintain adequate vascularity at the edge
- If the skin resection is less than 5-4cm, a cervical rotation flap can be planned

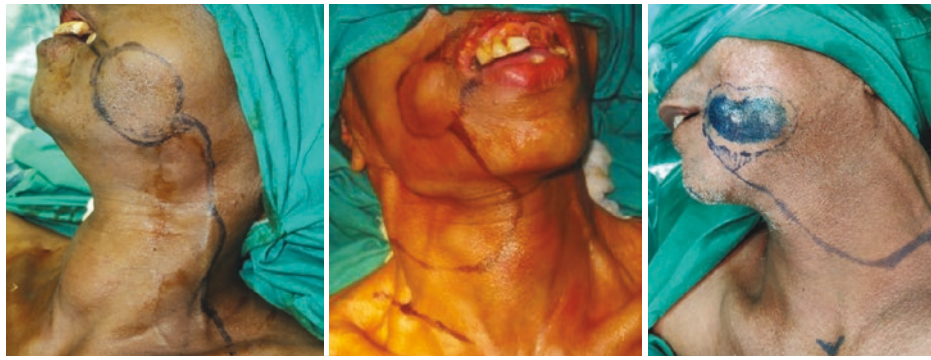


Fig. 5.7 Designing a skin incision to get adequate margin

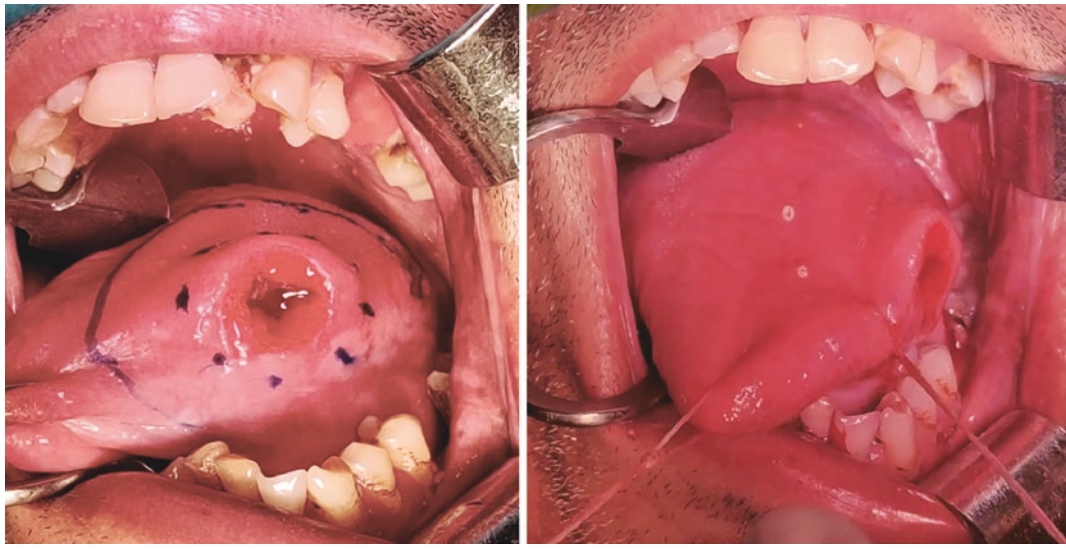


Fig. 5.8 Mucosal markings of the margin around the tumour

adequate margins, access to the posterior portion of the base tongue can be challenging in some T3 and T4 tumours. Few techniques have been described to aid in this situation that include:

1. Access osteotomy through mandibulotomy
2. Pull-through technique
3. Lateral pharyngotomy
4. Endoscope assisted

5.8.5.1 Access Osteotomy Through Mandibulotomy

This technique is usually performed for posteriorly based tumours involving the oropharyngeal area where accessing the posterior margin is difficult [56, 57]. There are various types of mandibulotomies described in literature; however, the paramedian type with mental nerve preservation is the most preferred. Certain factors need to be taken into consideration when planning a mandibulotomy like prevention of tooth injury and mental or inferior alveolar nerve damage. These are summarized as below [58] (Key Point 8).

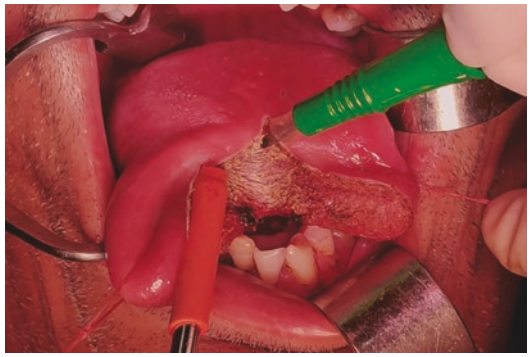


Fig. 5.9 Mucosal markings deepened to obtain adequate base

Key Point 8 Types of Mandibulotomies and Its Characteristics

Median	Osteotomy is between the central incisors Advantages: • Less risk of occlusal derangements • Good mechanical stability and exposure • Preservation of inferior alveolar nerve • Outside radiation portals Disadvantages • Division of genial muscles leading to delay in swallowing • Unaesthetic appearance if extraction of central incisor is needed

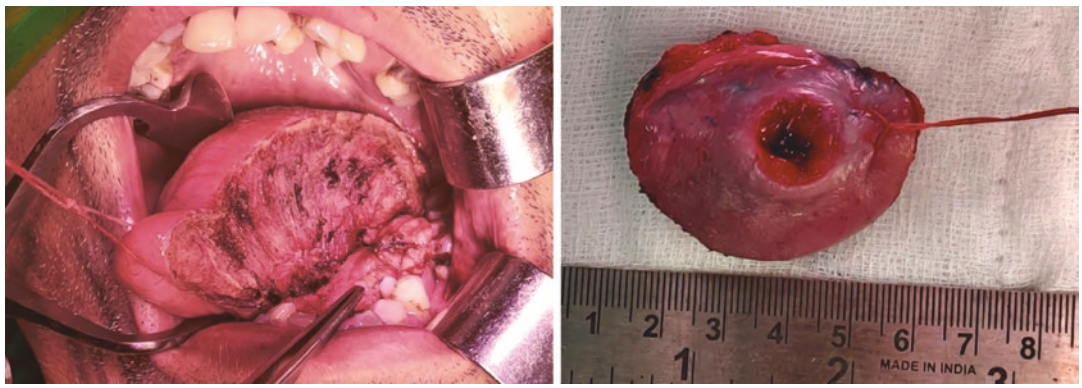


Fig. 5.10 Defect after resection and resected specimen

Paramedian	Osteotomy is between lateral and canine, most popular Advantages: • Might not need to extract teeth as canine root is tilted laterally • Good exposure • Mental nerve spared so lower lip innervation preserved Disadvantages: • Difficulty swallowing due to detachment of swallowing musculature • If adjuvant radiotherapy is planned, osteotomy site might be directly in the portals leading to poor healing

Lateral	Osteotomy through the body of the mandible, not currently in use Advantages: • Best access for posteriorly placed lesions Disadvantages: • Osteotomy site is under uneven muscular effects and might lead to delayed/non-union • Transection of inferior alveolar nerve causes devitalization of teeth and de-innervation of lower lip • If adjuvant radiotherapy is planned, osteotomy site will be directly in the portals leading to poor healing

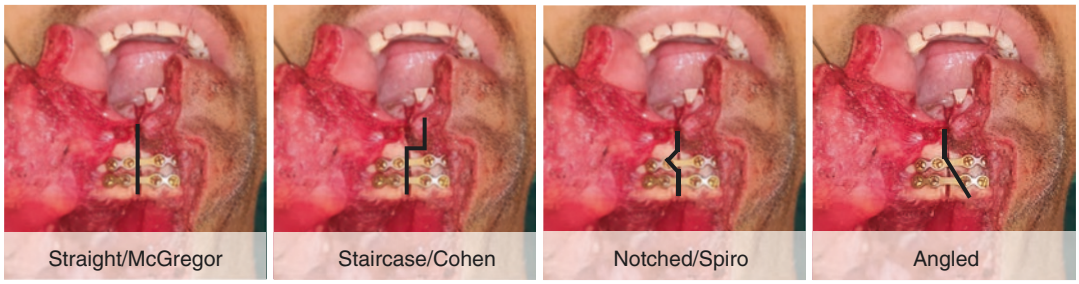


Fig. 5.11 Various designs of mandibulotomies

The osteotomy design of the mandibulotomy has various types. This can be divided into straight, stepped and notched [59, 61]. Of these, a stepped or notched mandibulotomy is usually preferred as it prevents the vertical movements of the mandible and facilitates fixation. Alternatively, a straight osteotomy shows more occlusal derangement, and the rearrangement of the fracture segments is difficult [59, 60] (Fig. 5.11).

5.8.5.2 Surgical Steps

A midline lip split is planned to gain access to the lateral surface of the mandible. Osteotomies can be planned either lateral, median or paramedian, with most commonly preferred being the lateral. These should be planned on the side of disease where the access is required. Once the lip is split, adequate mucosa and soft tissue of the gingivobuccal sulcus should be maintained on the mandible to aid in closure. Supra-periosteal flaps are raised so as to maintain adequate blood supply to the mandible. Once the site of osteotomy is confirmed, the periosteum is sharply dissected off the bone to expose the planned osteotomy line. Pre-plating is done by contouring the fixation plates across the planned osteotomy and drilling bur holes in their final position. The plates and corresponding screws are then set aside. The lingual mucoperiosteal flap is sharply raised across the planned osteotomy line.

Traction sutures are taken across the substance of the tongue. Once the osteotomy is performed, the floor of the mouth is incised close to the lingual plate and the tumour is accessed by pulling the oral tongue forward and outward. Adequate mucosal margins are marked around the tumour

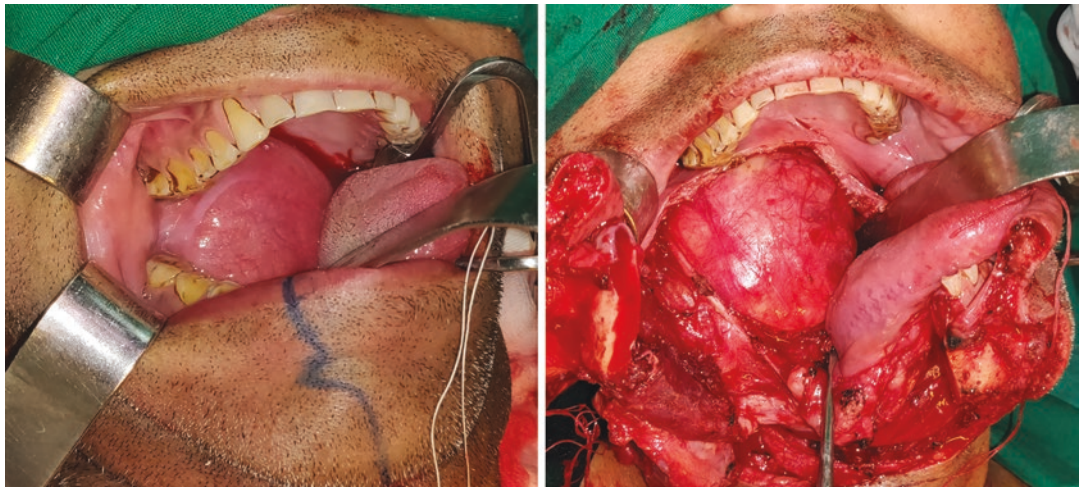


Fig. 5.12 Poor access for a posteriorly based lesion that improves once a mandibulotomy is performed

Fig. 5.13 Difficult-to-access bulky anterior lesions and posteriorly based lesion near the base tongue

with adequate visualization for the posterior margins (Fig. 5.12).

These markings are then deepened to include the tongue musculature always keeping in mind to palpate the adequacy of soft tissue resected for the base. Once the specimen is delivered and the reconstruction completed, fixation of the mandible is performed using the pre-contoured hardware, confirming that the occlusion is maintained.

5.8.5.3 Pull-Through Approach

This is usually done for bulky anterior tumours where posterior extent is difficult to access (Fig. 5.13).

The tongue is attached to the hyoid inferiorly, palate superiorly and mandible laterally and its own musculature makes up the bulk medially. For the resection of this compartment as a whole, these attachments need to be released.

5.8.5.4 Oral Component

A visor incision is planned to gain access for delivering the tongue in the neck. Traction sutures are taken across the substance of the tongue. A knife is used to sharply cut the periodontal attachments of the lingual aspect of gingiva across the extent of the tumour, usually from the ipsilateral

Fig. 5.14 Mucoperiosteal flap elevated from lingual alveolus

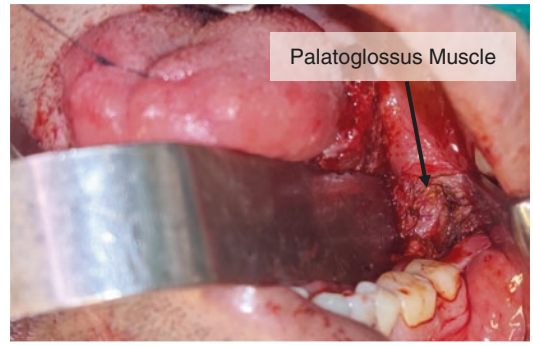


Fig. 5.15 Palatoglossus muscle visualized after mucosal incision

to the contralateral third molar region. Subperiosteal sharp dissection is performed to elevate the entire mucoperiosteal lingual gingiva from the lingual cortex, reaching up to mylohyoid line (Fig. 5.14).

Posteriorly mucosal incisions are continued on to ipsilateral tonsillolingual sulcus. Depending on the extent of disease, this incision continues to include the ipsilateral tonsil as a margin as well. Once this mucosal incision is deepened, the palatoglossus muscle is visualized medially and the medial pterygoid muscle laterally. The palatoglossus muscle is cut to release the palatal attachment and drop the tongue in the neck (Fig. 5.15).

On the contralateral side, the mucosal incision is continued on to the floor of the mouth and the dorsal surface of the uninvolved tongue. This incision is dictated by the extent of disease. If the extent requires a wider margin, a similar procedure is performed at the contralateral tonsillolingual sulcus as the ipsilateral side. The aim is to preserve as much of the oral or base tongue on the contralateral side as is oncologically feasible.

5.8.5.5 Neck Component

The neck dissection specimen is kept attached to the mandible at level Ib. Incision is given on the lower border of mandible corresponding to the intraoral mucosal incisions. Subperiosteal sharp dissection is continued elevating the periosteum off on the lingual surface of mandible laterally releasing the mylohyoid muscle from its origin. In the midline, the mandibular origin of both the anterior belly of digastric is released, followed by detaching the geniohyoid and genioglossus muscles from the genial tubercle. This will release the tongue from the mandible and result in a communication between the oral cavity and the neck. At the hyoid bone, the insertion of the tendon of the digastric, mylohyoid and hyoglossus is released. Once completed, the lingual neurovascular bundle is identified in close proximity to the lesser cornua of hyoid where it is ligated. Occasionally, the lingual artery might arise from a common faciolingual trunk and will need to be ligated in the tongue musculature. Proceeding laterally, the hypoglossal nerve is clipped and transected close to the external carotid so as to incorporate all contents of the tongue compartment. The posterior belly of digastric and styloglossus muscle is then cut cranially to include an adequate cuff of muscle with the specimen. At this time, the lingual nerve is encountered closer to the mucosa, which is also transacted. The tongue is then delivered into the neck to gain access to the posterior base tongue area. Once this is done, the ipsilateral mucosal incision is continued from the tonsillolingual sulcus onto the tongue base (Fig. 5.16).

As the mucosal incisions are deepened around the tumour, the tongue falls further into the neck

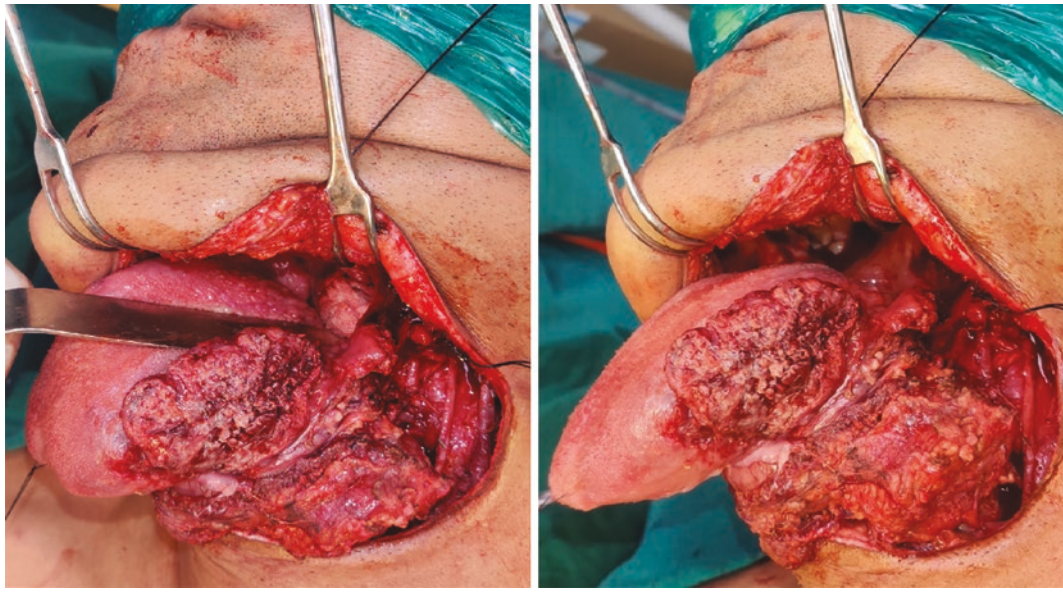


Fig. 5.16 Tongue being delivered in the neck to mark the posterior mucosal margins under adequate visualization

to continue the incision towards the contralateral uninvolved tongue.

These mucosal incisions are gradually deepened keeping in mind to palpate for the adequacy of soft-tissue margin around the tumour and avoiding inadvertent entry into the pre-epiglottic space. The mucosal incision is then continued onto the uninvolved portion of the base tongue to connect with the contralateral side. As the muscles are cut, the contralateral lingual neurovascular bundle and lingual nerve might be encountered that need to be ligated and transected, respectively. Once the specimen is removed, the mucosal and soft-tissue margins are assessed for adequacy, and appropriate reconstruction is carried out. The hyoid bone is hitched to the mandible to aid swallowing.

5.8.6 Early Buccal Mucosa (T1 and T2)

5.8.6.1 Peroral Wide Local Excision

Once the patient is adequately anaesthetized, a mouth gag is inserted and a visual and palpable examination confirms the extent of lesion. Adequate mucosal margins are marked anteriorly around the clinically discernible and palpable tumour. These markings are then deepened to include the buccinator musculature always keeping in mind to palpate the adequacy of soft tissue resected for the third dimension, i.e. the base. Once the buccinator is cut, the resection continues posteriorly in the subcutaneous plane, being observant for occasional hair follicles. Since the buccal mucosa is not very thick, infiltrative tumours, even if small in size, need to be resected along with a cuff of outer skin so that an adequate base can be obtained (Fig. 5.17).

The facial vessels are ligated both superiorly and inferiorly, and the length of the vessel should be included in the specimen to ensure adequacy of deep base if the skin is not planned to be removed. The mucosal incisions are continued posteriorly to reach the anterior border of masseter muscle. The Stenson's duct is ligated if it is part of the resection or margin. Postero-superiorly, the buccal fat pad can be preserved with its capsule if the tumour is superficial. Just before the final incisions are given to release the specimen,

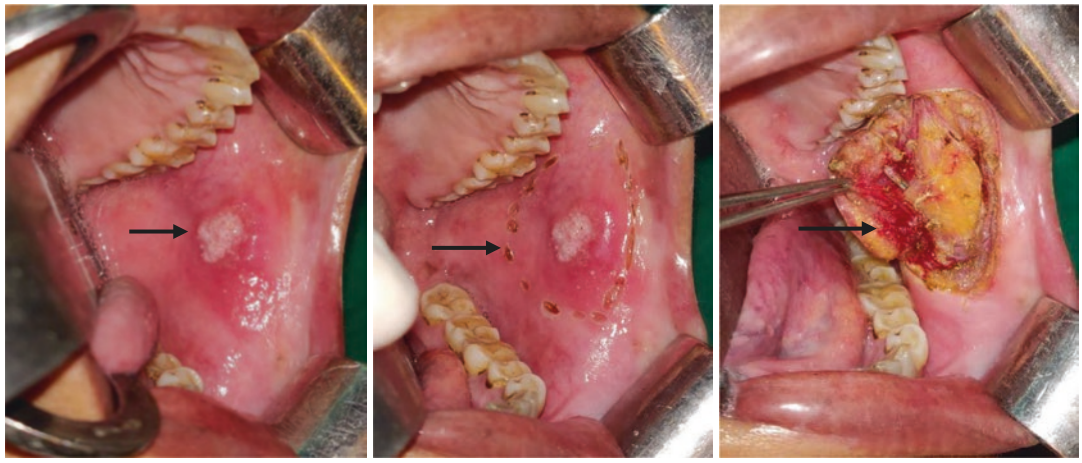


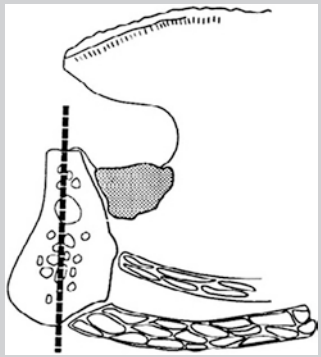
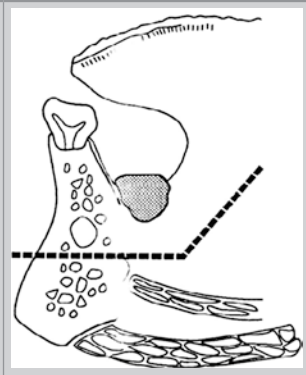
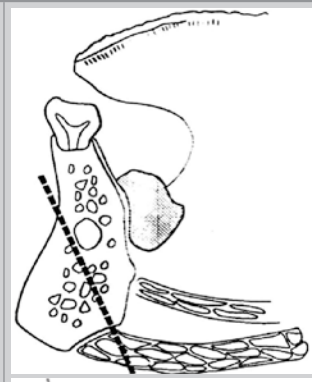
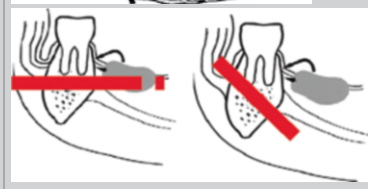
Fig. 5.17 Mucosal incisions deepened to include the underlying muscle as an adequate base in the specimen

orientation sutures are taken anteriorly and superiorly. Once the specimen is removed, the mucosal and soft-tissue margins are assessed for adequacy. Appropriate reconstruction is carried out based on the size of the defect and the functional requirement.

5.8.6.2 Wide Local Excision with Marginal Mandibulectomy

Tumours of the oral cavity involving or in close proximity to the mandible necessitate some form of mandibular resection. The extent of resection is decided by a combination of imaging, astute clinical judgment and a thorough knowledge of the pathophysiology of routes of tumour entry. For tumours juxtaposed with or superficially eroding the alveolus, marginal resection is an oncologically feasible option. To withstand the forces of mastication, a minimum residual height of 1 cm is required. It is contraindicated in the presence of gross bony erosion; in extensive soft-tissue disease, which precludes adequate soft-tissue margins; and in an edentulous and pipestem mandible where achieving a centimetre of residual bone is not possible. Prior radiotherapy is a relative contraindication as the periosteum loses its function as a protective barrier and tumour can enter the mandible at multiple points. The routes of tumour entry dictate the type of marginal resection to be performed. Brown et al. [62] demonstrated the point of abutment at the level of the attached and reflected mucosa to be the preferred point of entry for tumours of the floor of the mouth. Chaukar et al. in their study of buccal cancers reported the occlusal surface as the preferred method for buccal cancers [26] (Key Point 9).

Key Point 9 Types of Marginal Mandibulectomies

Vertical	Horizontal	Oblique
		
• Performed in a vertical plane in the intradental sockets • For floor-of-mouth or tongue cancers by removing the lingual plate • Removal of the buccal plate has been described in literature but is not performed as it leaves behind the weaker lingual plate, which is unable to withstand the forces of mastication • The soft-tissue attachments are mainly on the buccal side (better blood supply) and are sparse on the lingual side making it prone to injury	• Done for cancers of the buccal mucosa as tumours are closer to the occlusal surface permitting adequate soft-tissue and bony margins	 • point of abutment at the level of the attached and reflected mucosa mandates an oblique resection to achieve a good soft-tissue resection

5.8.6.2.1 Surgical Steps

Once the patient is adequately anaesthetized, a mouth gag is inserted, and a visual and palpable examination confirms the extent of lesion. Intraoral mucosal incisions are given keeping adequate margins from the tumour on the buccal aspect of the mandible (Fig. 5.18).

These cuts are deepened incising the buccinator muscle till subcutaneous tissue. Midline lip split incision is taken depending on the relationship of the tumour to the oral commissure as discussed in Key Point 6. Cheek flap is raised preserving adequate soft tissue over the tumour. Soft tissue over the mandible is incised to expose the proposed site of bone resection. Periosteum of the inferior rim is preserved to prevent the

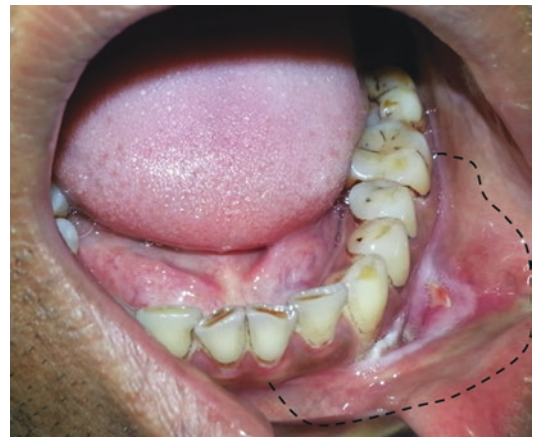


Fig. 5.18 Mucosal incision given around tumour from the anterior to the posterior planned site of osteotomy site on the buccal aspect of the mandible

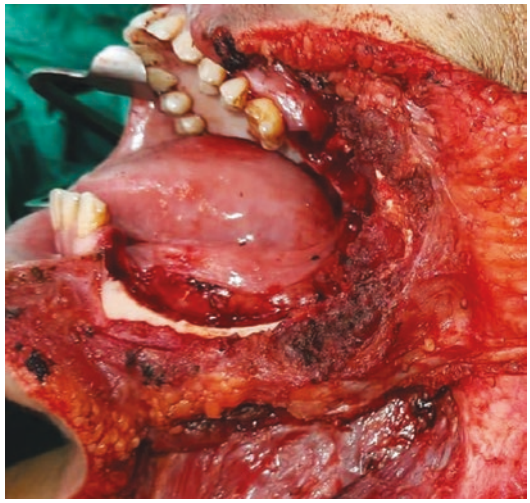


Fig. 5.19 Final resection bed after tumour removal. Periosteum and soft tissue should be maintained on the remaining mandible to maintain vascularity and avoid osteoradionecrosis if adjuvant radiotherapy is indicated

necrosis of the remaining bone. Teeth are extracted at the planned site of osteotomy, which is made at least 1 cm or two teeth away from the tumour. Anterior and posterior osteotomies are defined using powered instruments/reciprocating saw under continuous irrigation with saline to minimize thermal damage to the bony edges. These are connected across the body of the mandible maintaining a smooth curvilinear fashion, classically described as boat or canoe shape, avoiding any sharp angles. Height of the remaining mandible should be at least 1 cm to avoid the risk of stress fractures. It is important to engage both buccal and lingual cortices to obtain a uniform defect. The specimen is then swung laterally, and incision is given on the floor of the mouth keeping adequate margins. The lingual nerve will be encountered posteriorly and can be preserved if the disease is well away. Haemostasis is achieved by using bone wax or cauterizing the bleeding points over the cut surface of the bone (Fig. 5.19). Once the specimen is removed, the mucosal and soft-tissue margins are assessed for adequacy, and appropriate reconstruction is carried out.

5.8.7 Buccal Mucosa Composite Resection (T3 and T4)

Gross bony invasion or presence of paramandibular soft-tissue disease requires segmental resection of the bone. The extent and location of resection have a bearing on aesthetic and functional outcome. A simple classification proposed by Brown et al. [63] groups mandibular defects into four categories with increase in morbidity in terms of aesthetic and functional outcome from class I to IV. The extent of mandibular resection is guided by the extent of cortical erosion and/or medullary involvement in imaging and extent of soft-tissue disease [17].

5.8.8 Buccal Mucosa Composite Resection with Posterior Segmental Mandibulectomy

Once the patient is adequately anaesthetized, a mouth gag is inserted, and a visual and palpable examination confirms the extent of lesion. The planning for skin resection is done as previously discussed in Key Points 6 and 7. The area of the skin to be resected is marked after bimanually palpating the tumour, and a perpendicular incision is dropped from the lower skin edge connecting it to the neck crease incision. Intraoral mucosal incision is marked anteriorly keeping adequate margins around the tumour, extending to the planned osteotomy site. The incision extends posteriorly keeping adequate margins around the tumour to end short of the retromolar region. Teeth are extracted at the planned site of osteotomy on the mandible. The mucosal incisions are deepened to cut the buccinator and/or orbicularis oris till the subcutaneous tissue. The skin incision is then completed by bevelling away from the skin and communicated anteriorly with the oral cavity. At the lower border of mandible, platysma is sharply incised, and the cheek flap is raised keeping the buccinator and masseter on the specimen. The Stenson's duct is identified at the anterior border of masseter and ligated. The parotid gland is raised along with the

cheek flap without breaching its capsule till the posterior border of the mandible is reached. The stylomandibular ligament is then cut posteriorly. The masseter muscle is cut caudal to the zygomatic arch to expose the ramus of the mandible and the sigmoid notch. The rest of the muscle can be raised subperiosteally off the mandible to expose the entire condyle head and the coronoid process. With this, the capsule of the temporomandibular joint is separated from the specimen along with the insertion of the lateral pterygoid. Once this is done, the temporalis muscle is identified by the direction of its fibres, and its insertion is released from the coronoid process. The mandibular osteotomy is defined till the lower border of the mandible. Once the osteotomy is completed, the specimen is rotated downward and laterally to complete the mucosal incisions on the floor of the mouth. The specimen is gradually released deepening this lingual incision to include adequate cuff of mylohyoid muscle. The lingual nerve is encountered here and transected if the disease involves the retromolar trigone. This gives further access to complete the incision along the tonsillar pillar or tonsil and communicate it with the incision across the retromolar region (Fig. 5.20).

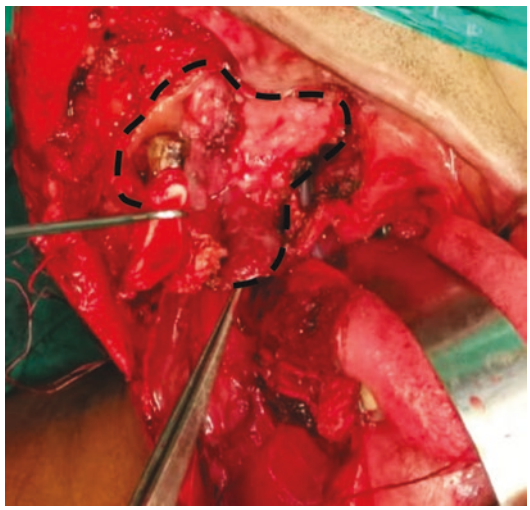


Fig. 5.20 Mucosal incision is continued along the tonsillar pillar or tonsil and communicate it with the incision across the retromolar region

As the mucosa is cut, the medial pterygoid muscle is identified due to the direction of the fibres and cut at an appropriate level keeping adequate cuff of medial soft-tissue base. As this muscle is cut, the mandibular nerve is identified and transected as cranially as possible. Lastly, the insertion of the lateral pterygoid muscle is released in a subperiosteal plane from the head and neck of the condyle by rotating the specimen counterclockwise. The maxillary artery and its branches can be encountered at this step and need to be ligated. Once the specimen is removed, the mucosal and soft-tissue margins are assessed for adequacy. Appropriate reconstruction is carried out based on the size of the defect and the functional requirement.

5.8.9 Modifications for Segmental Mandibulectomy

In case the disease is not extending posteriorly and infiltrating through the medullary canal, the posterior segmental of bone can be preserved to aid in reconstruction. The mucosal incision and extent of bone planning will be slightly different than the posterior segmental mandibulectomy.

- Teeth need to be extracted on both the anterior and posterior sites of osteotomy.
- Mucosal incisions are keeping adequate margins given around the tumour connecting these two osteotomy sites.
- The lateral soft tissue, or base, needs to be adequately assessed after raising the cheek flap.
- Once osteotomies are completed, the floor-of-mouth mucosal and soft-tissue incisions are given to deliver the specimen.

5.8.10 Modifications for Bite Composite Resection with/Without Infratemporal Fossa Contents

This is planned when the upper gingivobuccal sulcus or maxillary alveolus is involved. The

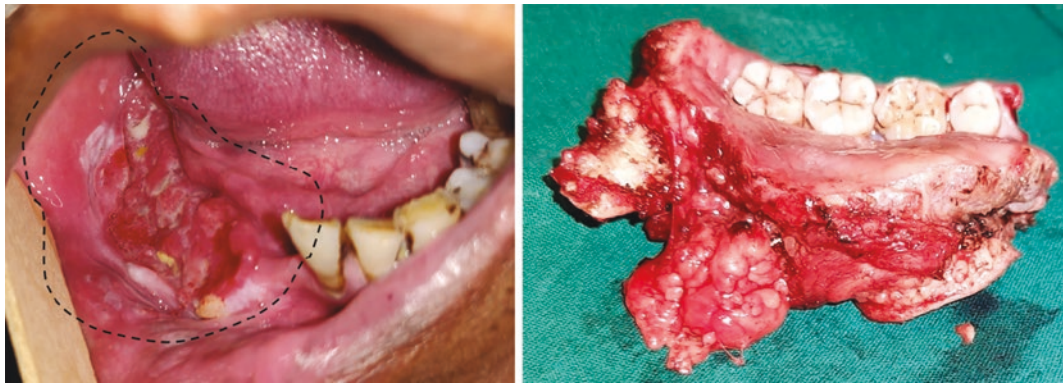


Fig. 5.21 Segmental mandibulectomy planned from the anterior to the posterior tooth extraction site

mucosal incision and extent of bone planning will be similar to the posterior segmental mandibulectomy and will include the upper alveolus (Figs. 5.21 and 5.22).

- Intraoral mucosal incisions are marked as per posterior segmental mandibulectomy, except that the posterior incision is carried to the site of osteotomy on the upper alveolus.
- Teeth are extracted at the planned site of osteotomy on the maxilla and mandible.
- The palatal mucosal cuts are taken extending from the site of extraction till the junction of hard and soft palate.
- The temporalis muscle is identified, its insertion is released from coronoid process and access to the posterolateral wall of the maxilla is obtained after the buccal fat pad is displaced inferiorly.
- The osteotomy is marked from the extraction socket, across the antero- and posterolateral maxillary walls till the pterygomaxillary fissure. The mandibular osteotomy is also defined till the lower border of the mandible.
- Once the mandibular, maxillary and palatal osteotomies are completed, the specimen is rotated downward and laterally to complete the mucosal incisions on the floor of the mouth.
- The specimen is gradually released deepening the lingual incision to include adequate cuff of mylohyoid muscle.
- This mucosal cut is continued posteriorly along the tonsillar pillar or tonsil and communicated upwards with the palatal incision (Fig. 5.16).

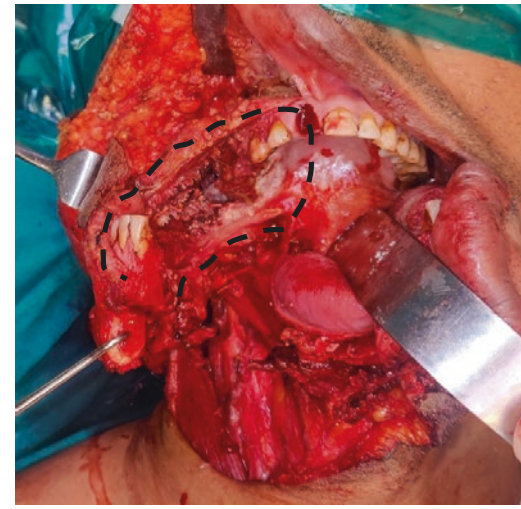


Fig. 5.22 Mucosal incision carried upward from the floor of the mouth towards the palate to include the maxillary alveolus in the specimen

- As the specimen is rotated further downward and laterally, the origin of the medial pterygoid muscle will need to be separated from the pterygoid plates and the insertional fibres of the lateral pterygoid muscle from the medial surface of the condylar head. The maxillary artery and its branches can be encountered here that need to be ligated. Alternatively, this vessel can be ligated at the posterior border of the neck of the condyle early on, adding to the haemostasis.
- Lastly, the specimen will hang on the mandibular nerve, which is transected as cranially as possible (Figs. 5.23 and 5.24).

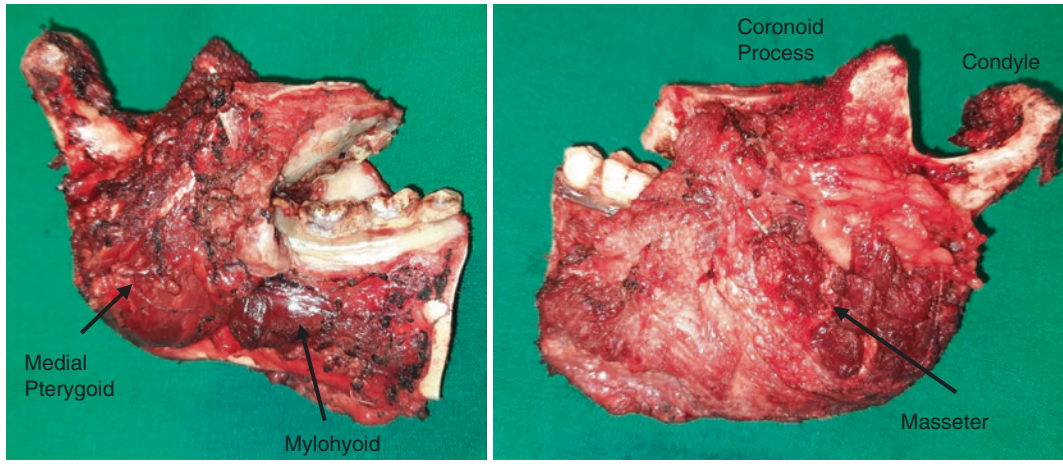


Fig. 5.23 Resection specimen of a bite composite resection

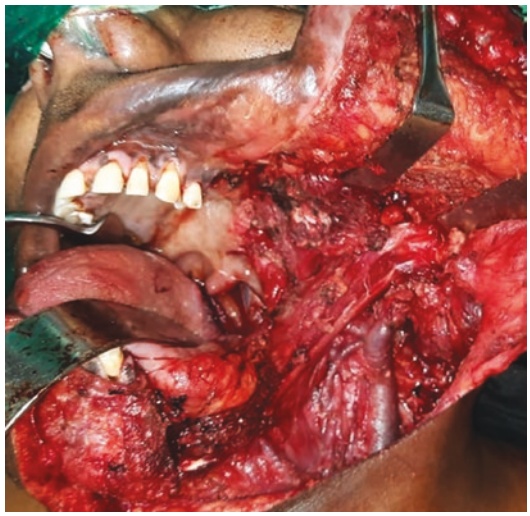


Fig. 5.24 Resection bed after tumour removal

In case the disease extent requires resection of the infratemporal fossa, the following modifications are required:

- The masseter muscle is cut at its attachment at the zygomatic arch, the glenoid fossa is identified and the temporalis muscle is cut as cranially as possible in the infratemporal fossa. It is important to follow the greater wing of sphenoid subperiosteally so that most of the contents can be included with the specimen. Harmonic or any other thermal instrument can be used for this step.
- The maxillary osteotomy is marked from the extraction socket, across the antero- and posterolateral maxillary walls and across the pterygomaxillary fissure to include the lower third of the pterygoid plates.
- After the mandible and maxillary osteotomies are performed, more access is gained to the infratemporal fossa and the remaining fibres of the temporalis are cut.
- Just after this, the mandibular nerve and vessels are identified at the foramen ovale, which are clipped and transected. Haemostasis can be achieved by packing the foramen with bone wax.
- Few fibres at the lateral pterygoid muscle origin need to be separated from the greater wing of sphenoid to deliver the specimen (Fig. 5.25).

Once the specimen is removed, the mucosal and soft-tissue margins are assessed for adequacy and appropriate reconstruction is carried out. Nasogastric feeding tube is then inserted and confirmed under direct visualization.

5.8.11 Hard Palate (T1–T2 Lesion)

5.8.11.1 Upper Alveolectomy

Once the patient is adequately anaesthetized, a mouth gag is inserted, and a visual and palpable examination confirms the extent of lesion. Teeth

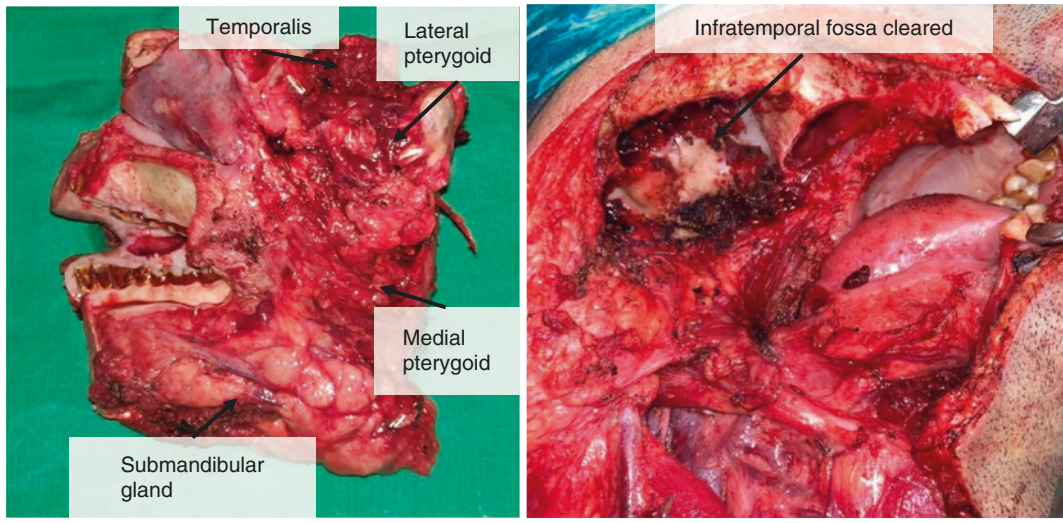


Fig. 5.25 Resection specimen and bed of a bite composite resection with infratemporal fossa clearance

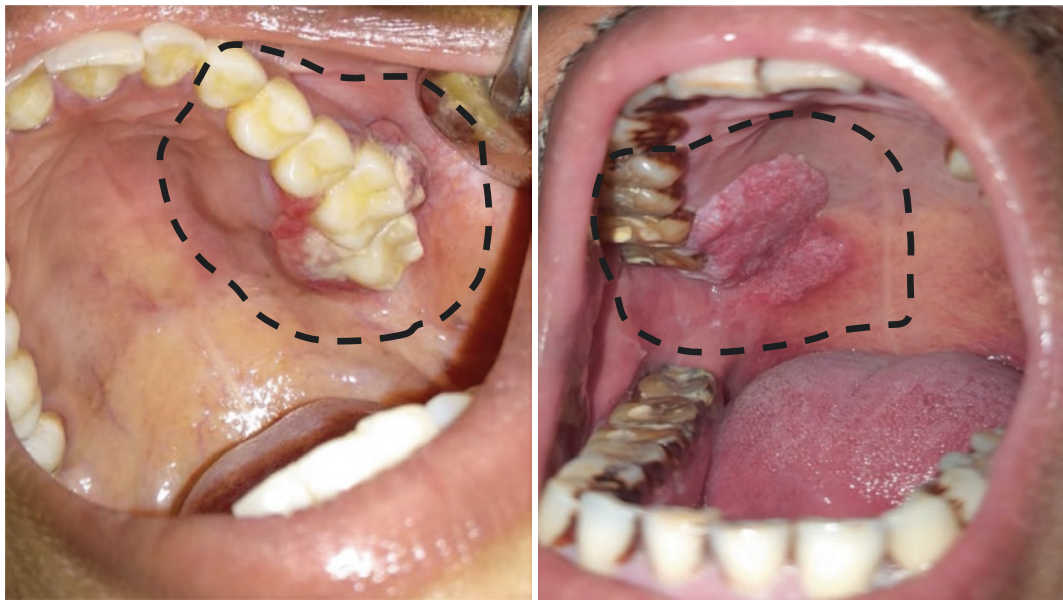


Fig. 5.26 Mucosal margins and extent of resection for an upper alveolus and hard palate lesion

are extracted at the site of planned osteotomies. Mucosal incisions are marked from these extraction sockets into the gingivobuccal sulcus keeping an adequate margin around the tumour. These are deepened to cut the buccinator, masseter and/or orbicularis oris till the subcutaneous fat. The resection then continues supero-medially keeping adequate soft tissue around the tumour to define the bone cuts on the antero- and posterolateral maxillary walls. The palatal mucosal incision is then given keeping adequate margin from the tumour (Fig. 5.26).

The osteotomies are performed on the palatal, medial and antero- and/or posterolateral wall of the maxilla. The specimen is delivered after releasing any mucosal attachments with the max-

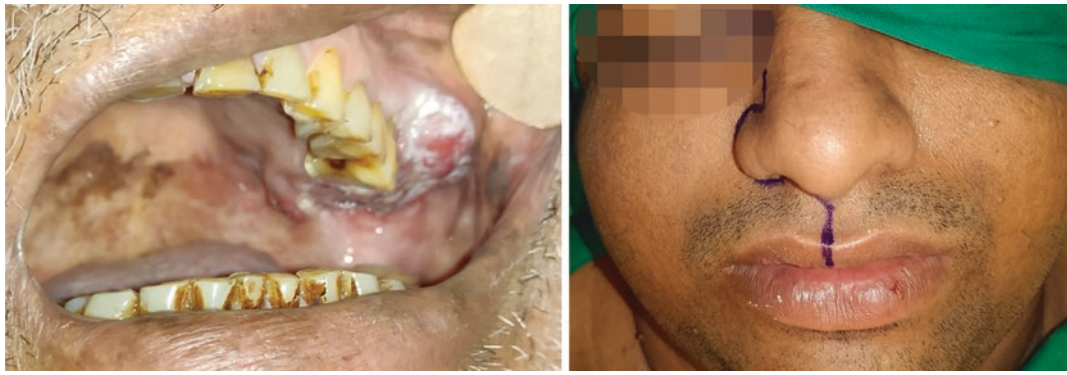


Fig. 5.27 Posteriorly based lesions might require a upper philtrum split without/with lateral rhinotomy extension for accessing the tumour

illary sinus and/or nasal cavity. Nasogastric feeding tube is then inserted and confirmed under direct visualization.

For posteriorly placed lesions, few modifications might be needed:

- For access, an upper philtrum split incision along with a lateral rhinotomy incision may be planned. The cheek flap is raised in the supraperiosteal plane until the planned osteotomy site (Fig. 5.27).
- The palatal incision is given till the junction of soft and hard palate, connecting it with the gingivobuccal incision across the retromolar trigone. The posterior limit of maxillary cut will be the maxillary tuberosity. As the incision continues posteriorly, the greater palatine vessels might need to be cauterized to achieve haemostasis.

Once the specimen is removed, the mucosal and soft-tissue margins are assessed for adequacy and appropriate reconstruction is carried out. Nasogastric feeding tube is then inserted and confirmed under direct visualization.

5.9 Broad Tips for Reconstruction

1. Every defect in oral cavity is three dimensional, has multiple functional tissue elements and is often odd shaped. All this should be respected in planning reconstruction.
2. Head is at one end of the body; free flaps are as important as pedicle and local in a reconstructive surgeon's armamentarium.
3. Free, pedicle and local flaps complement, supplement and complete each other, with the surgeon's preference for one over the other being the only impediment!
4. Lip and lid should be closed up to third defect, shared for next third and reconstructed for anything more.
5. Buccal mucosa defects need generous flap replacement, especially at RMT, with marginal mandibulectomy and with associated skin defect.
6. Any mandible defect with two bony ends available for fixation deserves a consideration for bony reconstruction. All bone defects come with a soft-tissue deficit which needs equal attention.
7. The tongue remnant determines the functional outcome after resection. All reconstruction should be aimed at facilitating its freedom to move.
8. Maxilla defects are heterogenous. Obturator, bone and soft-tissue reconstruction options should be weighed carefully before choice is made.
9. Mouth opening, dentition and mucosal fibrosis should be factored in before any reconstructive decision for the oral cavity.

10. Slight overcorrection of volume deficit is always preferred over undercorrection.
11. Time, radiation and gravity affect all reconstruction, and severity may vary from one tissue to another.
12. Most problems attributed to radiation have their genesis in some deficiencies in surgical planning and execution.

References

1. Ferlay J, Colombet M, Soerjomataram I, Parkin DM, Piñeros M, Znaor A, et al. Cancer statistics for the year 2020: an overview. Int J Cancer. 2021; https://doi.org/10.1002/ijc.33588.
2. Miranda-Filho A, Bray F. Global patterns and trends in cancers of the lip, tongue and mouth. Oral Oncol. 2020;102:104551.
3. Gupta N, Gupta R, Acharya AK, Patthi B, Goud V, Reddy S, et al. Changing trends in oral cancer-a global scenario. Nepal J Epidemiol. 2016;6(4):613.
4. Warnakulasuriya S. Global epidemiology of oral and oropharyngeal cancer. Oral Oncol. 2009;45(4–5):309–16.
5. Marur S, Forastiere AA. Head and neck cancer: changing epidemiology, diagnosis, and treatment. Mayo Clinic Proc. 2008;83(4):489–501.
6. Huang SH, O'Sullivan B. Overview of the 8th edition TNM classification for head and neck cancer. Curr Treat Options Oncol. 2017;18(7):1–13.
7. Dikshit R, Gupta PC, Ramasundarahettige C, Gajalakshmi V, Aleksandrowicz L, Badwe R, et al. Cancer mortality in India: a nationally representative survey. Lancet. 2012;379(9828):1807–16.
8. Bánóczy J. Follow-up studies in oral leukoplakia. J Maxillofac Surg. 1977;5:69–75.
9. Shafer WG, Waldron CA. Erythroplakia of the oral cavity. Cancer. 1975;36(3):1021–8.
10. Chaturvedi P, Vaishampayan SS, Nair S, Nair D, Agarwal J, Kane S, et al. Oral squamous cell carcinoma arising in background of oral submucous fibrosis: a clinicopathologically distinct disease. Head Neck. 2013;35(10):1404–9.
11. Ow TJ, Myers JN. Current management of advanced resectable oral cavity squamous cell carcinoma. Clin Exp Otorhinolaryngol. 2011;4(1):1.
12. National Comprehensive Cancer Network. NCCN clinical practice guidelines in oncology: breast cancer version 3. Fort Washington, PA: National Comprehensive Cancer Network; 2017.
13. Guibert M, David I, Vergez S, Rives M, Filleron T, Bonnet J, et al. Brachytherapy in lip carcinoma: long-term results. Int J Radiat Oncol Biol Phys. 2011;81(5):e839–43.
14. Licitra L, Grandi C, Guzzo M, Mariani L, Vullo SL, Valvo F, Quattrone P, Valagussa P, Bonadonna G, Molinari R, Cantù G. Primary chemotherapy in resectable oral cavity squamous cell cancer: a randomized controlled trial. J Clin Oncol. 2003;21(2):327–33.
15. Zhong LP, Zhang CP, Ren GX, Guo W, William WN Jr, Sun J, Zhu HG, Tu WY, Li J, Cai YL, Wang LZ. Randomized phase III trial of induction chemotherapy with docetaxel, cisplatin, and fluorouracil followed by surgery versus up-front surgery in locally advanced resectable oral squamous cell carcinoma. J Clin Oncol. 2013;31(6):744.
16. Patil VM, Prabhash K, Noronha V, Joshi A, Muddu V, Dhumal S, Arya S, Juvekar S, Chaturvedi P, Chaukar D, Pai P. Neoadjuvant chemotherapy followed by surgery in very locally advanced technically unresectable oral cavity cancers. Oral Oncol. 2014;50(10):1000–4.
17. Chaukar D, Pai PS, Chaturvedi P, Pantvaidya G, Deshmukh A, Nair D, Thiagarajan S, D'Cruz A, Prabash K, Noronha V, Patil VM. A prospective phase II open-label randomized controlled trial to compare mandibular preservation in upfront surgery to neoadjuvant chemotherapy followed by surgery in operable oral cavity cancer. J Clin Oncol. https://doi.org/10.1200/JCO.21.00179
18. Rodriguez-Bruno K, Ali MJ, Wang SJ. Role of panendoscopy to identify synchronous second primary malignancies in patients with oral cavity and oropharyngeal squamous cell carcinoma. Head Neck. 2011;33(7):949–53.
19. González-García R, Naval-Gías L, Román-Romero L, Sastre-Pérez J, Rodríguez-Campo FJ. Local recurrences and second primary tumors from squamous cell carcinoma of the oral cavity: a retrospective analytic study of 500 patients. Head Neck J Sci Spec Head Neck. 2009;31(9):1168–80.
20. Oliver R, Sloan P, Pemberton M. Oral biopsies: methods and applications. Br Dent J. 2004;196(6):329–33.
21. Bankfalvi A, Piffko J. Prognostic and predictive factors in oral cancer: the role of the invasive tumour front. J Oral Pathol Med Rev Artic. 2000;29(7):291–8.
22. Rosebush MS, Mark Anderson K, Rawal SY, Mincer HH, Rawal YB. The oral biopsy: indications, techniques and special considerations. J Tenn Dent Assoc. 2010;90(2):17.
23. Wang Y, Fang K, Jung S, Zheng J, Hao S. Excisional biopsy with margin control for oral cancers. Head Neck. 2010;32(11):1528–33.
24. D'Cruz AK, Siddachari RC, Walvekar RR, Pantvaidya GH, Chaukar DA, Deshpande MS, et al. Elective neck dissection for the management of the N0 neck in early cancer of the oral tongue: need for a randomized controlled trial. Head Neck J Sci Spec Head Neck. 2009;31(5):618–24.
25. Arya S, Chaukar D, Pai P. Imaging in oral cancers. Indian J Radiol Imaging. 2012;22(3):195.
26. Chaukar D, Dandekar M, Kane S, Arya S, Purandare N, Rangarajan V, et al. Invasion of the mandible in gingivobuccal complex cancers: Histopathological

analysis of routes of tumour entry and correlation with preoperative assessment. Oral Oncol. 2018;86:181–7.
27. Dhar H, Vaish R, D'Cruz AK. Management of locally advanced oral cancers. Oral Oncol. 2020;105:104662.
28. Lane AP, Buckmire RA, Mukherji SK, Pillsbury HC III, Meredith SD. Use of computed tomography in the assessment of mandibular invasion in carcinoma of the retromolar trigone. Otolaryngol Neck Surg. 2000;122(5):673–7.
29. Liao CT, Lee LY, Huang SF, Chen IH, Kang CJ, Lin CY, Fan KH, Wang HM, Ng SH, Yen TC. Outcome analysis of patients with oral cavity cancer and extracapsular spread in neck lymph nodes. Int J Radiat Oncol Biol Phys. 2011;81(4):930–7.
30. DeAngelis A, Breik O, Angel C, Goh C, Iseli T, Nastri A, et al. Can radiological examination of mandibular bone invasion accurately predict the need for mandibular resection in oral squamous cell carcinoma? Int J Oral Maxillofac Surg. 2019;48(5):576–83.
31. Mahajan A, Ahuja A, Sable N, Stambuk HE. Imaging in oral cancers: a comprehensive review. Oral Oncol. 2020;104:104658.
32. Dubner S, Heller KS. Local control of squamous cell carcinoma following marginal and segmental mandibulectomy. Head Neck. 1993;15(1):29–32.
33. Mohiyuddin SA, Harsha P, Maruvala S, Sumanth K, Suresh T, Manjunath G, et al. Outcome of compartment resection of locally advanced oral cancers extending to infratemporal fossa: a tertiary rural hospital experience. Eur Arch Otorhinolaryngol. 2018;275(11):2843–50.
34. Sigal R, Zagdanski AM, Schwaab G, Bosq J, Auperin A, Laplanche A, Francke JP, Eschwege F, Luboinski B, Vanel D. CT and MR imaging of squamous cell carcinoma of the tongue and floor of the mouth. Radiographics. 1996;16(4):787–810.
35. Moreira MA, Lessa LS, Bortoli FR, Lopes A, Xavier EP, Ceretta RA, Sônego FG, Tomasi CD, Pires PD, Ceretta LB, Perry ID. Meta-analysis of magnetic resonance imaging accuracy for diagnosis of oral cancer. PLoS One. 2017;12(5):e0177462.
36. Yasumoto M, Shibuya H, Takeda M, Korenaga T. Squamous cell carcinoma of the oral cavity: MR findings and value of T1-versus T2-weighted fast spin-echo images. AJR Am J Roentgenol. 1995;164(4):981–7.
37. de Souza Brandão Neto J, Aires FT, Dedivitis RA, Matos LL, Cernea CR. Comparison between magnetic resonance and computed tomography in detecting mandibular invasion in oral cancer: a systematic review and diagnostic meta-analysis: MRI x CT in mandibular invasion. Oral Oncol. 2018;78:114–8.
38. Singh B, Nair S, Nair D, Patil A, Chaturvedi P, D'Cruz AK. Ipsilateral neck nodal status as predictor of contralateral nodal metastasis in carcinoma of tongue crossing the midline. Head Neck. 2013;35(5):649–52.
39. Thiagarajan S, Dhar H, Bhattacharjee A, Fatehi KS, Shah SB, Chaukar D, Nair D, Deshmukh A, Prabhash K, Joshi A, Patil V. Patterns of failure and outcomes in cT4 oral squamous cell carcinoma (OSCC) undergoing upfront surgery in comparison to neo-adjuvant chemotherapy (NACT) followed by surgery: a matched pair analysis. Oral Oncol. 2020;100:104455.
40. Piazza C, Grammatica A, Montalto N, Paderno A, Del Bon F, Nicolai P. Compartmental surgery for oral tongue and floor of the mouth cancer: oncologic outcomes. Head Neck. 2019;41(1):110–5.
41. Calabrese L, Bruschini R, Giugliano G, Ostuni A, Maffini F, Massaro MA, Santoro L, Navach V, Preda L, Alterio D, Ansarin M. Compartmental tongue surgery: long term oncologic results in the treatment of tongue cancer. Oral Oncol. 2011;47(3):174–9.
42. Mao MH, Wang S, Feng ZE, Li JZ, Li H, Qin LZ, Han ZX. Accuracy of magnetic resonance imaging in evaluating the depth of invasion of tongue cancer. A prospective cohort study. Oral Oncol. 2019;91:79–84.
43. Marchi F, Filauro M, Iandelli A, Carobbio AL, Mazzola F, Santori G, Parrinello G, Canevari FR, Piazza C, Peretti G. Magnetic resonance vs. intraoral ultrasonography in the preoperative assessment of oral squamous cell carcinoma: a systematic review and meta-analysis. Front Oncol. 2020;9:1571.
44. Pantvaidya G, Rao K, D'Cruz A. Management of the neck in oral cancers. Oral Oncol. 2020;100:104476.
45. Shah JP. Patterns of cervical lymph node metastasis from squamous carcinomas of the upper aerodigestive tract. Am J Surg. 1990;160(4):405–9.
46. Agarwal JP, Kane S, Ghosh-Laskar S, Pilar A, Manik V, Oza N, Wagle P, Gupta T, Budrukkar A, Murthy V, Swain M. Extranodal extension in resected oral cavity squamous cell carcinoma: more to it than meets the eye. Laryngoscope. 2019;129(5):1130–6.
47. Bernier J, Domenge C, Ozsahin M, Matuszewska K, Lefèbvre JL, Greiner RH, Giralt J, Maingon P, Rolland F, Bolla M, Cognetti F. Postoperative irradiation with or without concomitant chemotherapy for locally advanced head and neck cancer. N Engl J Med. 2004;350(19):1945–52.
48. Cooper JS, Pajak TF, Forastiere AA, Jacobs J, Campbell BH, Saxman SB, Kish JA, Kim HE, Cmelak AJ, Rotman M, Machtay M. Postoperative concurrent radiotherapy and chemotherapy for high-risk squamous-cell carcinoma of the head and neck. N Engl J Med. 2004;350(19):1937–44.
49. Chen MM, Colevas AD, Megwalu U, Divi V. Survival benefit of post-operative chemotherapy for intermediate-risk advanced stage head and neck cancer differs with patient age. Oral Oncol. 2018;84:71–5.
50. Liao LJ, Lo WC, Hsu WL, Wang CT, Lai MS. Detection of cervical lymph node metastasis in head and neck cancer patients with clinically N0 neck—a meta-analysis comparing different imaging modalities. BMC Cancer. 2012;12(1):1–7.
51. Pfister DG, Spencer S, Adelstein D, Adkins D, Anzai Y, Brizel DM, Bruce JY, Busse PM, Caudell JJ, Cmelak AJ, Colevas AD. Head and neck cancers, version 2.2020, NCCN clinical practice guidelines in oncology. J Natl Compr Cancer Netw. 2020;18(7):873–98.
52. Robertson AG, Soutar DS, Paul J, Webster M, Leonard AG, Moore KP, McManners J, Yosef HM, Canney P,

Errington RD, Hammersley N. Early closure of a randomized trial: surgery and postoperative radiotherapy versus radiotherapy in the management of intra-oral tumours. Clin Oncol. 1998;10(3):155–60.
53. Anderson CR, Sisson K, Moncrieff M. A meta-analysis of margin size and local recurrence in oral squamous cell carcinoma. Oral Oncol. 2015;51(5):464–9.
54. Mistry RC, Qureshi SS, Kumaran C. Post-resection mucosal margin shrinkage in oral cancer: quantification and significance. J Surg Oncol. 2005;91(2):131–3.
55. Bulbul MG, Tarabichi O, Sethi RK, Parikh AS, Varvares MA. Does clearance of positive margins improve local control in oral cavity cancer? A meta-analysis. Otolaryngol Head Neck Surg. 2019;161(2):235–44.
56. Bozzetti A, Biglioli F, Gianni AB, Brusati R. Mandibulotomy for access to benign deep lobe parotid tumors with parapharyngeal extension: report of four cases. J Oral Maxillofac Surg. 1998;56(2):272–6.
57. Lee HS, Tae K, Shim BT, Kwon SW, Ahn KS. Mandibulotomy for the approach to the oral cavity, oropharynx and skull base. Korean J Otolaryngol Head Neck Surg. 1997;40(10):1390–7.
58. Pan WL, Hao SP, Lin YS, Chang KP, Su JL. The anatomical basis for mandibulotomy: midline versus paramidline. Laryngoscope. 2003;113(2):377–80.
59. Spiro RH, Gerold FP, Strong EW. Mandibular "swing" approach for oral and oropharyngeal tumors. Head Neck Surg. 1981;3(5):371–8.
60. McGregor IA, MacDonald DG. Mandibular osteotomy in the surgical approach to the oral cavity. Head Neck Surg. 1983;5(5):457–62.
61. Cohen JI, Marentette LJ, Maisel RH. The mandibular swing stabilization of the midline mandibular osteotomy. Laryngoscope. 1988;98(10):1139–42.
62. Brown JS, Lowe D, Kalavrezos N, D'Souza J, Magennis P, Woolgar J. Patterns of invasion and routes of tumor entry into the mandible by oral squamous cell carcinoma. Head Neck. 2002;24(4):370–83.
63. Brown JS, Barry C, Ho M, Shaw R. A new classification for mandibular defects after oncological resection. Lancet Oncol. 2016;17(1):e23–30.

6 Oropharyngeal and Hypopharyngeal Tumours and Their Treatment

Jeyasakthy Saniasiaya and Norhafiza Mat Lazim

6.1 Benign Oropharyngeal Tumours

6.1.1 Lingual Thyroid

Lingual thyroid, an abnormal ectopic thyroid tissue, is commonly found within the base of the tongue. Lingual thyroid was initially reported by Hickman in 1869 [1]. Apart from tongue base, lingual thyroid can be located at the floor of the mouth [2]. It is noteworthy that lingual thyroid has been reported as the sole functioning thyroid tissue in nearly 75% of individuals [3], which necessitates thorough investigation and management. Lingual thyroid occurs ensuing failure of thyroid gland during embryogenesis to descend from ventral floor to its original location, which is over the thyroid cartilage. Lingual thyroid is said to arise from thyroglossal duct epithelium, which is unobliterated.

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6.1.2 Epidemiology

Female predominance has been reported with a female-to-male ratio of 7:1 [3]. Lingual thyroid is mostly seen amongst females when the plasma thyroid-stimulating hormone (TSH) level increases in body causing hypertrophy of the thyroid tissue, especially during puberty, pregnancy or menopause [4]. Ectopic thyroid can be found in more than one location in the body. It has been reported that 70% of patients with lingual thyroid are hypothyroid [5] and nearly 10% of patients may suffer cretinism. Incidence of lingual thyroid, albeit unknown, has been reported around the third decade of life [5]. Ectopic thyroid tissue is traditionally located within lingual, sublingual, thyroglossal, laryngotracheal and lateral cervical region. Albeit rare, other sites of involvement include submandibular, prelaryngeal, tracheal, oesophageal and substernal [3].

6.1.3 Clinical Presentation

Clinical presentation may vary and ranges from dysphagia, odynophagia, foreign-body sensation, bleeding, choking, dysphonia and snoring to upper airway obstruction. A small group of patients may remain asymptomatic until late adolescence. Additionally, acute symptoms may manifest locally in relation to the size of the lingual thyroid [6]. Clinically, lingual thyroid located at the base

N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_6

of the tongue appears as smooth-surfaced lobulated mass with bluish to reddish colour.

6.1.4 Histology

Lingual thyroid histologically resembles normal thyroid parenchyma. It is noteworthy that within the ectopic thyroid tissue, other benign as well as malignant conditions may arise such as thyroid adenoma, hyperplasia, inflammation and carcinoma [5].

6.1.5 Imaging

Neck ultrasonography is an important imaging modality, especially to detect thyroid tissue at the thyroid gland region. Technetium-99 (99mTC) is the gold standard to diagnose lingual thyroid as it demonstrates radionuclide activity at the base of the tongue and not at the thyroid gland level.

6.1.6 Blood Investigation

Thyroid function test is prudent as hypothyroidism is present in approximately 70% of patients with lingual thyroid.

6.1.7 Treatment

Treatment for lingual thyroid includes both surgical and medical treatment.

6.1.8 Surgical Treatment

Surgical treatment comprises excising the lingual thyroid or autotransplantation of lingual thyroid into the muscle. Surgical approach varies and depends on the location of the lingual thyroid including transoral, transhyoid and lateral pharyngotomy. Although surgical excision is ideal, it is important that radionuclide scan is performed to confirm the presence of functioning thyroid tissue at the thyroid gland level. If the lingual thyroid is found to be the only functioning thyroid, the lingual thyroid can be autotransplanted into the neck post-excision [7].

6.1.9 Non-surgical Treatment

Non-surgical treatment includes hormonal therapy as well as radionuclide ablation. Levothyroxine is used to suppress thyroid-stimulating hormone to correct hypothyroidism as well as to prevent the ectopic tissue to increase in size while preventing local symptoms [6]. Interestingly, usage of levothyroxine in paediatric age group has revealed symptom improvement in addition to reduction of the size of lingual thyroid [8]. Radioactive iodine ablation is another alternative amongst patients who are found unsuitable for surgical excision.

6.2 Pleomorphic Adenoma

Pleomorphic adenoma (PA) is the most prevalent non-cancerous tumour of the salivary gland. PA constitutes epithelial and myoepithelial cells arranged in various patterns. It is noteworthy that minor salivary gland is vastly located within the oropharyngeal region.

Minor salivary gland PA comprises only 10% [9]. Minor salivary gland tumours traditionally appear from the palate, upper lips, gums, cheek, floor of mouth, pharynx and even trachea. Palate is the predominant site of PA amongst the minor salivary gland tumour followed by upper lip.

Patients' presenting symptoms depend on the site and size of oropharynx involvement. Patients may occasionally remain asymptomatic and may be discovered incidentally. The most common symptom of oropharynx PA is non-ulcerative submucosal mass followed by dysphonia, dyspnoea, hoarseness [10] and rarely sleep apnoea [11].

6.2.1 Diagnosis

Computed tomography is ideal in assessing the nature of the mass, site and size as well as for surgical planning.

6.2.2 Biopsy and Histology

Incisional biopsy is a preferred method to obtain diagnosis, which can be performed in the clinic setting or in operating theatre if the mass is not reachable. PA comprises epithelial, myoepithelial and fibromyxoid tissue. PA arising from the minor salivary gland demonstrates superior cellular element with lesser mesenchymal element [12].

6.2.3 Treatment

Surgery is the gold standard modality of choice. Surgical approach depends on the size, locality as well as structures located in the vicinity. As the oropharyngeal region is narrow, it is prudent for the surgeons to choose the right approach for optimal resection. Amongst the approaches available include transoral, transhyoid, transcervical, transpharyngeal, transmandibular as well as combined approaches. Additionally, with the advent of instrumentations, endoscopic as well as robotic assisted surgery is being rapidly used, especially in tongue base tumours [13]. Enucleation is not advised following risk of recurrence [14]. Recurrence rate of approximately 6% has been reported in minor salivary gland PA [15].

6.2.4 Case Illustration 1

This is a case of a Myanmar lady, 30 years old, presented with a history of neck swelling associated with odynophagia and voice change (Fig. 6.1). There is no history of loss of appetite or loss of weight. Other history was insignificant. Clinical examination revealed a left parotid swelling measuring 8.0 cm × 6.0 cm, firm in consistency, mobile and non-tender, with well-defined border.

Intraoral examination showed extensive medialization of the lateral pharyngeal wall and soft palate (Fig. 6.2). The opening of Stenson's duct is normal, with no discharge or calculi debris seen. Other ENT examinations are unremarkable. CT scan of neck is performed, and it revealed a heterogenous mass of both superficial and deep lobe of the parotid glands. Oropharyngeal mass caused partial oropharyngeal obstruction. FNAC of the parotid suggests that it is a benign tumour which corresponds to the clinical diagnosis of pleomorphic adenoma.

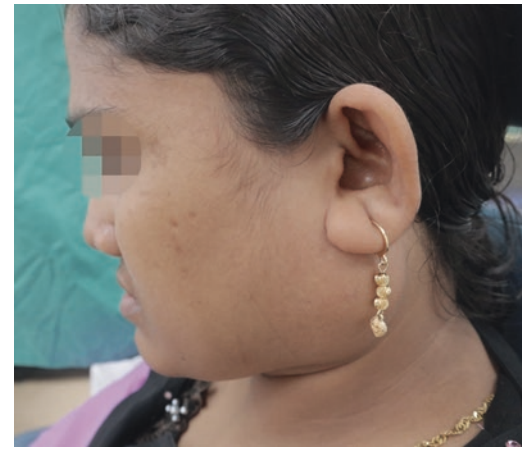

Fig. 6.1 Neck examination shows a diffuse left neck mass, around the parotid area and extending inferiorly to the level of angle of mandible. The mass has pushed the ear lobule anterosuperiorly. The displacement of ear lobule is a significant finding of mass that originates from the parotid glands

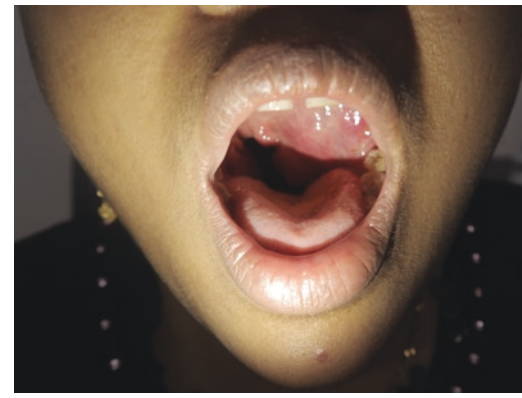

Fig. 6.2 Oral cavity examination showed the medialization of left soft palate and lateral pharyngeal wall

She was planned for total parotidectomy with preservation of the facial nerve, owing to the benign nature of the tumour. In case of malignant tumour, if the evidence of facial nerve palsy is observed preoperatively, and intraoperatively the facial nerve is adherent to the mass, then the facial nerve needs to be resected to achieve better oncologic outcomes.

Fig. 6.3 The facial nerve leads to facial nerve function monitoring during parotidectomy. This is vital as the facial nerve runs between the superficial lobes and deep lobes of parotid glands. The facial nerve monitor allows the identification of the nerve and thus avoids injury to the facial nerve. Otherwise, the patient will suffer from facial asymmetry due to the facial nerve injury

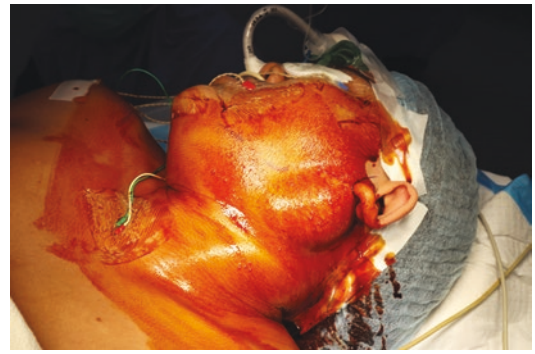

Fig. 6.4 The patient is intubated via a nasal intubation tube, which is seen in situ. The parotid mass is visualized clearly below the left-ear lobule. Facial nerve needles have been secured on the patient's face. Blue needle is for orbicularis oculi, and red needle is for orbicularis oris

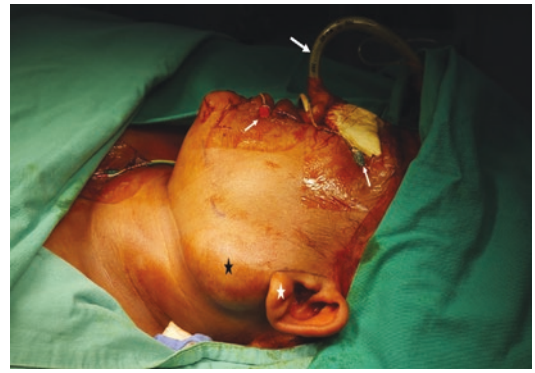

Fig. 6.5 The patient is intubated via a nasal intubation tube, which is seen in situ. The parotid mass is visualized (black star), and the displacement of ear lobule anterosuperiorly is seen (white star). The nerve needles are secured (small arrows)

Intraoperatively, the facial nerve monitor is applied (Fig. 6.3). This consists of four-channel electrodes, where the pin needle is inserted into frontalis, orbicularis oculi, orbicularis oris and mentalis. The short muscle relaxant is used to facilitate contraction of the muscle during dissection of the parotid tissues, neighbouring the facial nerve trunk and its branches.

The skin is cleaned with a diluted povidone iodine solution (Fig. 6.4), and the draping is done. Importantly, the draping should be done on the other half of the face, exposing the eye corner and oral commissure for the observation of contraction during dissection (Fig. 6.5). This will give clues if the nerve trunk or its branches are nearby. Thus, the surgeon needs to be more careful with the dissection.

The skin incision should be marked accordingly, which includes the mass (Fig. 6.6), the angle of mandible, the midline neck and the outline of SCM muscle. The modified Blair skin incision is done. Importantly, the inferior limb of this incision should be extended more inferiorly to facilitate dissection for deep lobe removal. Ideally, in selected cases, mandibulotomy is required to provide access to the deep lobe. In most cases, if the deep lobe tumour is small-to-moderate size, mandibulotomy is not required. With good dissection and correct techniques, deep lobe tumour can be removed successfully.

Surgical steps are similar with superficial parotidectomy, which is covered in Chap. 8 of this book. For deep lobe approach, it is important to do deep dissection medial to the digastric muscles, to access the parapharyngeal space. Extra precaution needs to be exercised to avoid injury to hypoglossal nerve, which is located just near to the muscle, but more anteriorly. The facial nerve and its branches need to be skeletonized, isolated and retracted superolaterally. Continuous dissection will expose the mass, which most of the time is well encapsulated. Blunt dissection around this mass will facilitate tumour removal.

Post-operatively, the patient had marginal mandibular nerve paresis with other branches intact. The patient was prescribed intravenous dexamethasone for 3 days and was discharged at 5 days post-operatively. The Redivac drain is

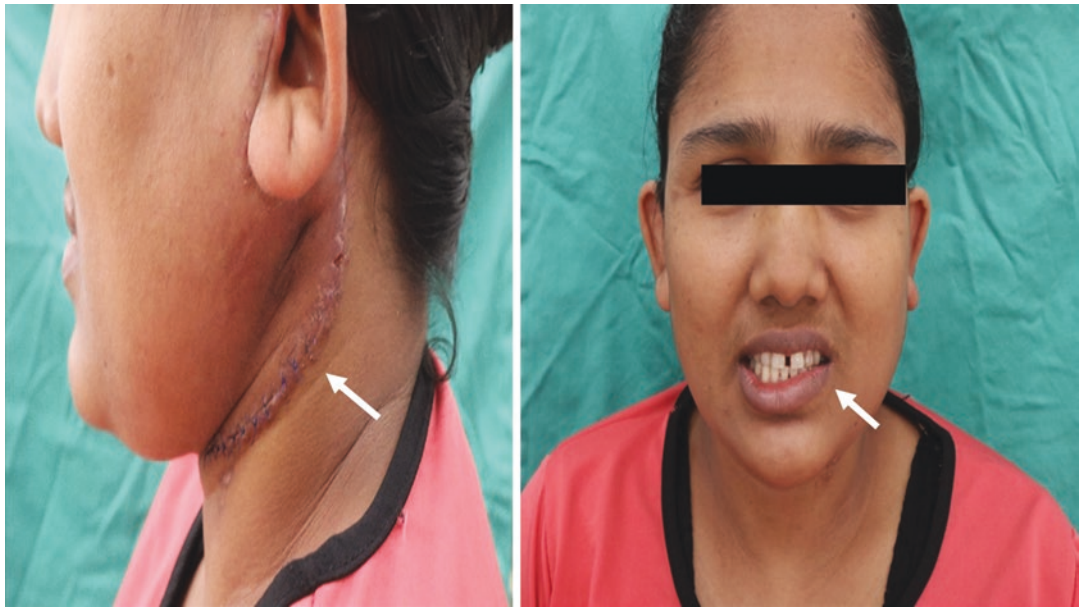

Fig. 6.6 The post-operative wound has dried out; some small suture is still visible in blue. The left marginal mandibular nerve paresis is evident

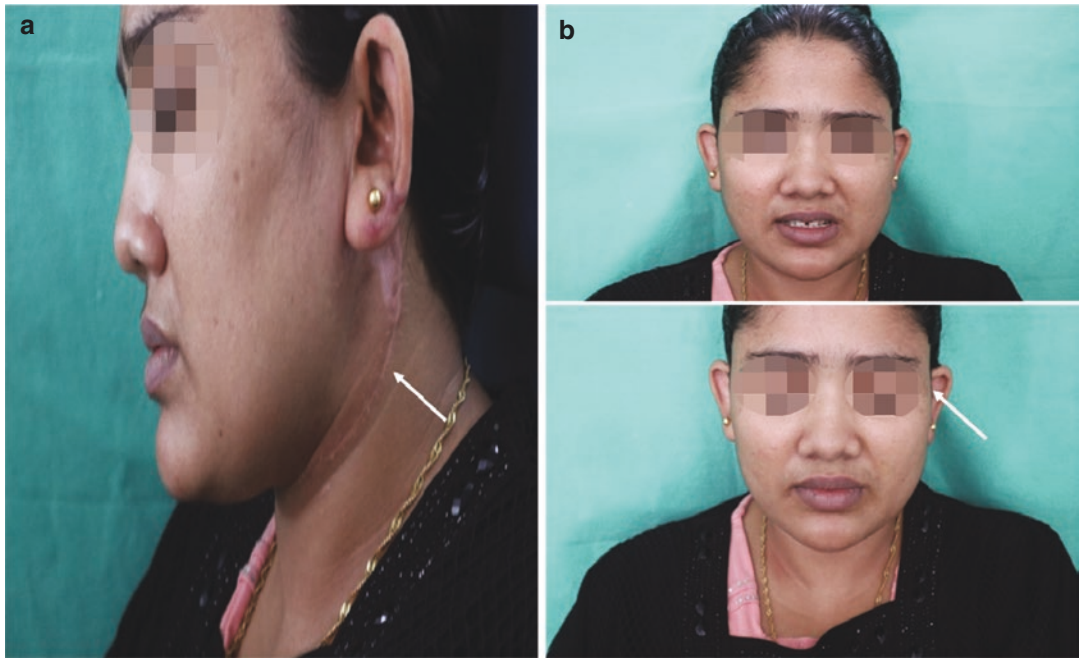

Fig. 6.7 The post-operative wound completely healed (**a**). The facial nerve function has recovered, wherein the patient was able to close the eye fully and had oral commissure symmetry (**b**)

removed if drainage is less than 20 cc over 24 h. At a follow-up at 2 weeks post-operatively, the wound has healed and the marginal mandibular nerve paresis has improved (Fig. 6.6).

At 3-month follow-up, the nerve has improved to near normal. The patient hand good eye closure and symmetry of oral commissure during smiling. There is no loss of depression of lower lips (Fig. 6.7).

6.3 Papilloma

Papilloma is a benign epithelial mass which comprises fingerlike projections involving squamous epithelium. Squamous papilloma is an exophytic mass which involves soft palate, tonsils [16] or uvula.

6.3.1 Epidemiology

Oropharyngeal papilloma is common amongst adults [17]. Female predominance is noted with a male-to-female ratio of 1:1.5 [16]. Mean age of patients with oropharyngeal papilloma is 33 years of age [16]. The most common location is palate and tongue [18]. Oral papilloma is associated with human papillomaviruses 6 and 11 in almost 50% of cases [19].

6.3.2 Clinical Presentation

Oral papilloma may present with varying symptoms depending on its location and size. Most common symptoms include dysphagia and foreign-body sensation [20]. However, amongst immunosuppression patients, papillomas may be larger and multifocal and appear more aggressive [21]. Yet, it is noteworthy that the majority of patients remain asymptomatic.

6.3.3 Histology

Papilloma histologically appears as fingerlike projections of squamous epithelium with evidence of hyperkeratosis and parakeratosis [22]. The fibrovascular core is covered by stratified squamous epithelium.

6.3.4 Treatment

Surgical excision of papilloma is regarded the gold standard. Recurrence is rare.

6.4 Oropharyngeal Squamous Cell Carcinoma

Squamous cell carcinoma (SCC) is the most prevalent oropharyngeal malignancy (Figs. 6.8, 6.9 and 6.10), which comprises 90% of malignancy within the oropharyngeal region [23]. The numbers of cases of oropharyngeal squamous cell carcinoma (OSCC) have burgeoned over the past decade, especially amongst the Western countries [24]. Despite the reported decreasing trend within the overall head and neck malignancy, human papillomavirus (HPV)-related OSCC has been steadily increasing [25, 26]. It is interesting that the prevalence of OSCC is increasing both in male and female [27]. HPV-related OSCC has demonstrated a distinct manifestation as compared to the traditional

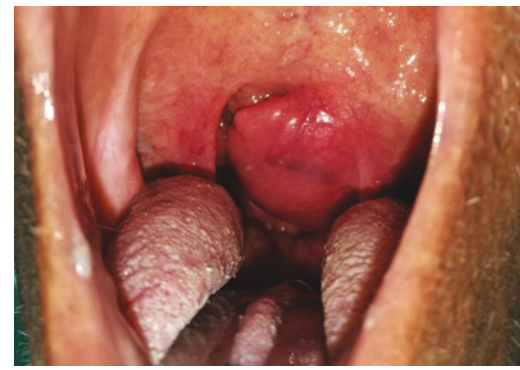

Fig. 6.8 Unilateral tonsillar enlargement whereby the left tonsil is filling the entire oropharyngeal region

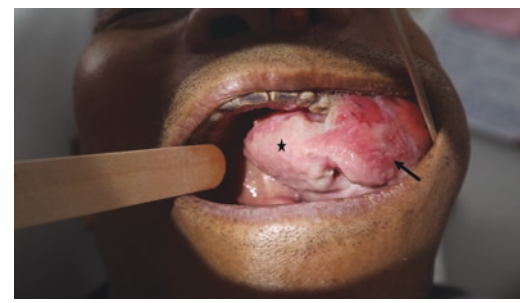

Fig. 6.9 The palatal malignant mass (star) has extended laterally to involve the dentition and gingivobuccal sulcus (arrow) and also invaded to the oropharyngeal area

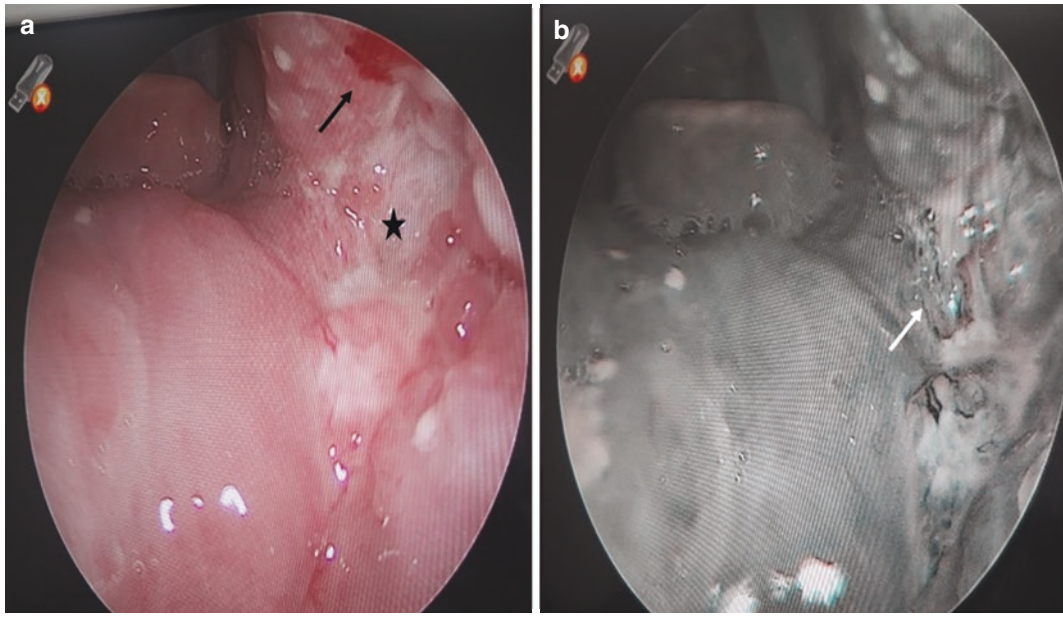

Fig. 6.10 (**a**) The friable tissue at left retromolar trigone area is suspicious of malignancy. (**b**) The narrowband image-enhanced endoscopy showed the changes in the vessel pattern that signify malignancy

Table 6.1 Subtypes of squamous cell carcinoma

Subtypes	Description
Verrucous SCC	Verrucous carcinoma has better prognosis than traditional OSCC. It appears as dull projections and invaginations of well-differentiated squamous epithelium. Additionally, prominent surface keratinization with occasional abnormal mitoses is seen. Verrucous carcinoma is able to invade stroma with well-defined pushing border.
Basaloid SCC	Basaloid SCC comprises rounded nests with smooth borders, and peripheral palisading, basophilic myxoid or mucoid material along with gland-like foci are present. Nuclear pleomorphism, high mitotic activity, apoptosis and necrosis are seen. Basaloid SCC is claimed to have worse prognosis than the traditional OSCC.
Papillary SCC	Papillary SCC demonstrates papillary growth pattern along with thin fibrovascular core blanketed by cancerous epithelial cells. Surface of epithelium can be of two types: High-grade keratinizing epithelial dysplasia or immature and basaloid epithelial cells with no evidence of maturation or keratinization. Papillary SCC has a better prognosis compared to traditional OSCC.
Spindle SCC	Spindle SCC appears as an exophytic mass with ulcerated surface with remnants of dysplastic squamous epithelium with areas of transition from squamous cells to malignant spindled or pleomorphic tumour cells with hypercellularity, necrosis and abnormal mitosis. The prognosis of this tumour is similar to traditional OSCC.
Adenosquamous SCC	Adenosquamous carcinoma demonstrates characteristics of squamous and glandular differentiation. This subtype is rare in oropharynx. Prognosis is worse than traditional OSCC.
Lymphoepithelial SCC	Lymphoepithelial carcinoma is morphologically similar to non-keratinizing nasopharyngeal carcinoma, undifferentiated type. However, unlike the nasopharyngeal carcinoma, it is not related to Epstein-Barr virus. It comprises large cells with round-to-oval vesicular nuclei, and scanty eosinophilic and amphophilic cytoplasm.

OSCC. HPV-related OSCC afflicts younger patients, white females, non-smokers and promiscuous behaviour [28–30]. Non-HPV-related OSCC on the other hand afflicts elderly male notably amongst heavy smokers and high alcohol consumers [31, 32]. Subtypes of OSCC (Table 6.1) include verrucous carcinoma, basaloid SCC, papillary SCC, spindle cell SCC, adenosquamous SCC and lymphoepithelial carcinoma [33].

6.4.1 Risk Factors

Smoking or tobacco consumption and alcohol are considered by far the highest risk factors to develop OSCC.

1. Smoking

   The International Agency for Research on Cancer (IARC) groups tobacco smoking as group 1 carcinogen for both oral cavity and oropharynx [34]. Relative risk for OSCC based on a meta-analysis is 6.76 amongst current tobacco smokers compared to non-smokers [35]. It is noteworthy that smoking-associated risk is dose dependent, and it is based on total or cumulative cigarette usage. The risk for OSCC reduces over time amongst patients who stop smoking and may even reach to a non-smoker status after 10 years [36].
2. Alcohol

   Heavy alcohol consumption is associated with high risk of developing oropharynx malignancies, especially when consumed >60 g or 4 drinks per day or more than 4–7 drinks per week [37]. Besides that, alcohol is reported as an independent risk factor. Relative risk for head and neck SCC is 1.3 for 10 g of ethanol per day compared with 13.0 for 125 g of ethanol per day, whereby superior risk is noted for OSCC as compared to oral cavity SCC [38].
3. HPV

   HPV has been discovered as a major aetiologic risk factor for numerous head and neck cancers, notably OSCC. HPV-16 accounts as the most common subtype in nearly 95% of the HPV-related OSCC [39]. HPV-related OSCC has been reported to be more common amongst people who are younger, white and of higher socioeconomic status as well as in those with increased lifetime sexual or oral sexual partners.

Other additional risk factors include oral microbiome, nutritional deficiencies, poor immune status, environmental pollutants, occupational exposure as well as genetic factors.

6.4.2 Clinical Presentation

OSCC traditionally manifests as an ulcerative non-healing tumour or appears as an irregular mucosal change frequently in the tonsils and base of tongue (Figs. 6.11 and 6.12) [40]. OSCC is known for its ability to remain asymptomatic for a long period as well as metastasis propensity. Non-healing extraction socket is also a telltale sign of OSCC. Presence of persistent neck mass, sore throat and dysphagia are the most common complaints. However, it is worth noting that pre-

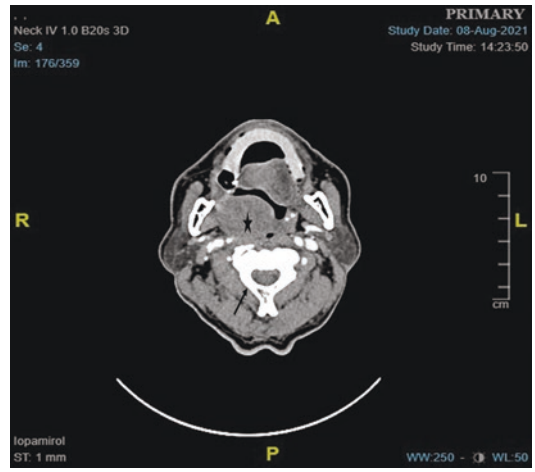

Fig. 6.11 The oropharyngeal mass (star) is visualized with some obstruction of the oropharyngeal airway. Patient may complain of dysphagia and voice change

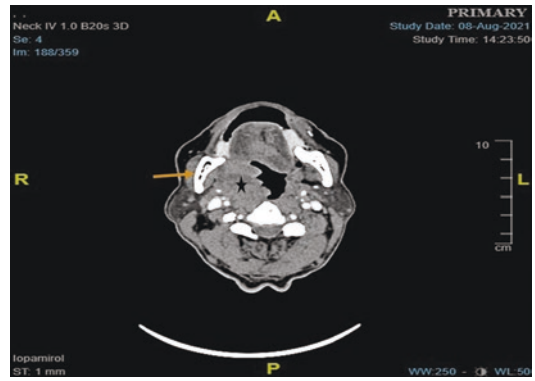

Fig. 6.12 The irregular border of the oropharyngeal mass (star). The mass has occluded the airway to 50%. The mass is very close to the mandible (arrow)

sentation may differ according to the HPV status of the mass. Among HPV-related OSCC, neck mass is the most common presentation (51%), followed by sore throat (28%) and dysphagia (10%). It is worth noting that humongous metastatic node may emerge with a tiny primary tumour.

Neck swelling was reported to be more common amongst the HPV-related OSCC as compared to the non-HPV-related OSCC, whereby sore throat was more common in the latter group of patients.

Patients with OSCC are reported to present with symptoms until tumour becomes large enough (>2 cm) and invades other structures [41], as patients usually remain asymptomatic when the primary tumour is <2 cm [42]. As primary tumour of OSCC enlarges, it leads to dysphagia, odynophagia, sore throat, pain, referred otalgia and obstructive symptoms, especially when the tumour is obstructing the airway as well as constitutional symptoms [43].

6.4.3 Diagnosis

Endoscopic examination under general anaesthesia enables assessment of the primary tumour size along with its extension, for biopsy in a controlled setting to obtain histological diagnosis as well as to detect the presence of secondary tumour or synchronous lesion.

6.4.4 Histology

HPV-related OSCC appears to be non-keratinizing with basaloid features reiterating tonsillar crypt epithelium [44]. HPV status is determined using several methods including reverse transcriptase polymerase chain reaction for high-risk HPV E6 and E7 mRNA, DNA or RNA in situ hybridization test as well as p16 immunohistochemistry [45]. p16 has become a favoured biomarker for HPV status and is utilized mainly for oropharyngeal carcinoma as well as non-keratinizing tumours [46]. Additionally, the College of American Pathologists favours usage of p16 immunohistochemistry or in situ hybridization to predict oropharyngeal origin when investigating the metastatic node of known primary.

6.4.5 Imaging

Imaging is necessary as a diagnostic modality to assess staging, extension of tumour, presence of synchronous tumour, metastatic and regional lymph node spread, as well as recurrence or residual disease (Figs. 6.11 and 6.12). Chest radiograph is a valuable diagnostic modality to assess metastasis, and lung is the most prevalent location for the spread of OSCC as well as a possible site for second primary. Additionally, chest radiograph is an important part of preoperative evaluation to identify the presence of pulmonary or airway disease.

Ultrasound is used as a diagnostic tool for guiding fine needle aspiration cytology/biopsy as well as to detect the presence of occult primary tumour sites in patients with metastatic cervical lymph node [47, 48].

Contrasted computed tomography is crucial to delineate the tumour size, extension, staging, and bone or cartilage involvement. CT enables rapid image acquisition as well as excellent resolution of bony involvement. It is worth noting that the presence of cystic metastatic lymph node has been associated with HPV-related OSCC [49]. Magnetic resonance imaging (MRI) is the preferred modality to evaluate soft-tissue, perineural, intravascular and marrow involvement [50].

Positron emission tomography (PET)/CT is effective to evaluate the site of the occult tumour as it has superior sensitivity and specificity in comparison to the traditional CT. Additionally, PET/CT is deemed superior to assess the effectiveness of treatment. PET/CT has been reported to be an excellent modality when performed 12 weeks post-chemoradiation to assess response following treatment. Surveillance imaging should be carried out at an optimal timing which is vital. Surveillance PET/CT, if carried out at earlier stages, may lead to false positives and false negatives [51, 52]. A retrospective study performed

revealed that PET/CT carried out 2 months post-treatment provides accurate results [53], although to date there is yet any consensus on the ideal timing for imaging to assess post-treatment outcome [54, 55].

6.4.6 Staging

Staging for oropharyngeal carcinoma is based on the TNM staging of carcinomas originating in the oropharynx. TNM staging pertains to SCC as well as other epithelial malignancies originating in the oropharynx. The most recent TNM staging system is the 8th edition of the American Joint Committee on Cancer (AJCC).

6.4.7 Treatment

Multidisciplinary discussion should include oto-rhinolaryngologists, oncologists, dieticians, nurses and speech pathologists as well as social workers. Despite the variation noted across the causative factors, clinical behaviour, outcome of treatment as well as molecular pattern of HPV-positive compared to HPV-negative tumours, the choice of treatments remains similar [56]. Treatment is based on tumour, node and metastasis (TNM) staging, patient's age, general conditions, patient's preference as well as facilities available at the medical centre [57]. Generally, single mode of treatment is advocated at the early stage of disease, whereas advanced stage of the OSCC is treated with dual-modality treatment [58].

6.4.8 Early Stage

Early-stage tumour can be treated either surgically or via radiation therapy. Early-stage OSCC can be treated surgically via either open or transoral/endoscopic approach with a margin of 1–2 cm. Neck dissection is carried out when there is evidence of neck disease or in an N0 neck as occult cervical neck disease has been reported to be nearly 30–40% in OSCC.

6.4.9 Advanced Stage

Multimodality treatment is traditionally carried out in advanced OSCC (stages III and IV). Combined mode of treatment comprises surgical resection in the initial stage with subsequent adjuvant radiotherapy or chemoradiotherapy [59]. Surgery addresses both primary sites as cervical node. In a clinically negative node, elective neck dissection should be performed. Generally, the functional as well as curative outcome of both surgery and chemoradiation is difficult to predict [60]. Surgical techniques which are performed include open resection, transoral robotic surgery as well as transoral laser microsurgery. Regardless of the surgical techniques, the surgical principle is the same: removal of tumour with at least 1–2 cm margins. Extensive resection requires reconstruction.

6.4.10 Non-surgical Treatment

Radiation therapy can be given primarily or combined with chemotherapy or post-surgical resection. Radiation therapy has been reported to show promising results notably at the earlier stage of the disease. Five-year loco-regional control rate has been reported to be 98% with the overall survival rate of 90% [61]. Following surgery, radiation therapy is prescribed in patients in advanced stage of disease, nodal involvement, close margin, perineural invasion as well as lymphovascular invasion [62]. Also, chemotherapy, when combined with radiation therapy in post-surgery patients with extranodal extension and/or in patients with positive margins, has demonstrated promising results [59].

Standard radiation dose to treat OSCC with gross tumour is 66–70 Gy in 33–35 daily fractions over a period of 6.5–7 weeks. As for radiation therapy post-surgery, the dose is 60 Gy in 30 fractions over 6 weeks. In patients with positive extranodal extension or close or positive margin, the dose comprises an additional 3–6 Gy. In an unoperated neck, dosage of 50–54 Gy is used. Radiation therapy is traditionally given within a 6-week period to reduce the chances of repopulation [62].

Since its introduction in the early 2000s, intensity-modulated radiotherapy (IMRT) has been a favoured form of radiation therapy, which permits the oncologist to manipulate the radiation dose to increase accuracy to the targeted region while reducing radiation to the neighbouring vital structures. IMRT has been extensively used with excellent outcomes of chemoradiation OSCC [58]. Recent study on survival outcome with primary IMRT of which 90% had locally advanced disease who received concurrent chemotherapy showed a 3-year overall survival rate of 77.2%. GORTEC group reported the first OSCC-specific trial, whereby 266 patients in this study were randomized to concurrent chemoradiotherapy or radiotherapy alone [63]. The 3-year overall survival rate was 51% in the chemoradiotherapy group in comparison to 31% in the radiotherapy group. This regime has become a standard therapy for loco-regionally advanced disease of OSCC [64].

1. Chemotherapy

   It is noteworthy that the current treatment regime of curative treatment of the loco-regionally advanced HPV-related p16-positive as well as non-HPV-related p16-negative OSCC is concurrent chemoradiotherapy with IMRT plus cisplatin, a platinum-based chemotherapy agent given every 3 weeks [65]. In patients with locally advanced stage III–IV SCC of the oral cavity, oropharynx, larynx or hypopharynx, standard fraction rate of radiotherapy with cisplatin at 100 mg/m^2 × 3 or accelerated fractionation and a concomitant boost with cisplatin at 100 mg/m^2 × 2 demonstrated similar overall survival rate [66].
2. Immunotherapy

   Usage of immune checkpoint inhibitors, notably nivolumab, pembrolizumab, durvalumab, atezolizumab and avelumab, as an adjunct therapy for head and neck malignancies has shown promising results. Pembrolizumab and nivolumab are FDA approved amongst patients with recurrent and metastatic disease. It is worth noting that these drugs principally target programmed cell death protein 1 (PD-1)/PD-L1 axis, and oropharynx has been regarded as a known immune-privileged site.

   Cetuximab, a monoclonal antibody against human epidermal growth factor receptor, has demonstrated promising results amongst patients with advanced head and neck SCC [67]. Cetuximab has demonstrated lower toxicity as compared to the standard chemotherapy agents such as paclitaxel, cisplatin and methotrexate.

6.4.11 Case Illustration 1

A 45-year-old Chinese lady initially presented with tonsillar mass and was diagnosed with adenoid cystic carcinoma. She underwent bilateral tonsillectomy and had adjuvant radiation in 2012. On subsequent follow-up, oral cavity and oropharyngeal examination revealed a residual mass at the inferior pole of right tonsils (Fig. 6.13). The biopsy of the mass confirmed recurrent ACC. Subsequently, CT scan was performed, which showed mass at the right parapharyngeal space region. She was counselled for excision of the recurrent tumour and neck dissection but refused. In the following years of follow-up, the

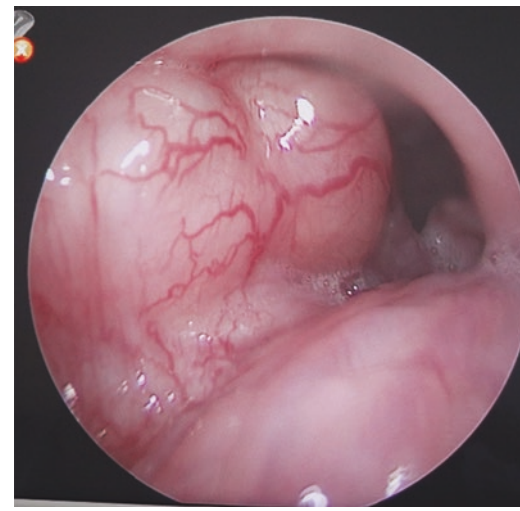

Fig. 6.13 Oral cavity examination showed a vascularized mass at right tonsillar region. This is a recurrent adenoid cystic carcinoma as the patient had bilateral tonsillectomy previously

mass increased in size with prominent vascularity seen. Repeated CT scan was performed, which showed that the mass has increased in size. The patient however refused for further treatment.

6.4.12 Case Illustration 2

A 30-year-old Malay lady presented with a history of globus, odynophagia and voice change. Clinical examination revealed a unilateral tonsillar hypertrophy (Figs. 6.14 and 6.15). Cervical palpation revealed a small neck node at left level II region. Other systems' examination is unremarkable. FNAC of neck nodes shows lymphoproliferative changes. The diagnostic tonsillectomy was performed and suggestive leukaemic infiltration. Further investigations showed that she had lymphoblastic leukaemia. Subsequently, she was referred to haemato-oncology for chemotherapy treatment.

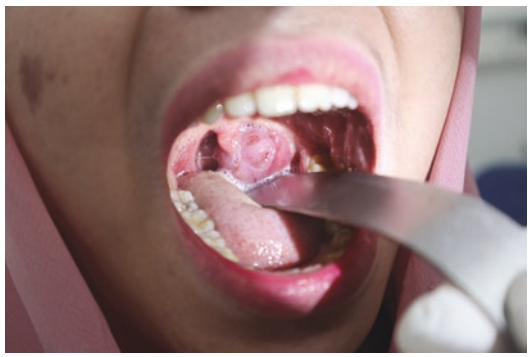

Fig. 6.14 Oral cavity examination showed grade 4 left tonsillar enlargement with minimal ulcerative mucosa. The ulcerative mucosa is a sign of sinister pathology like malignancy. A common tonsillar hypertrophy has intact mucosa

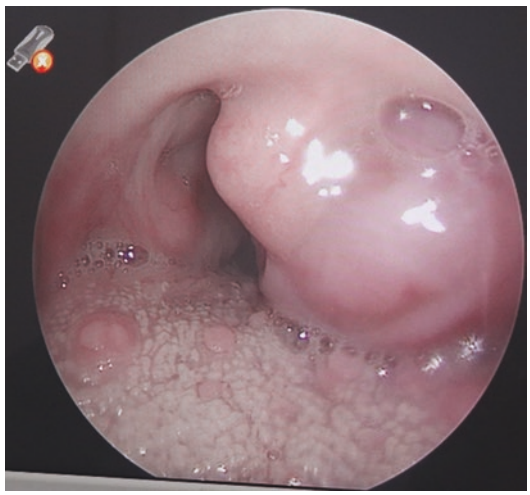

Fig. 6.15 Left oropharyngeal mass

6.5 Benign Hypopharyngeal Tumours

6.5.1 Fibrolipoma

Fibrolipoma is a pedunculated benign tumour. It is amongst two most common benign hypopharyngeal tumours including leiomyoma [68]. Fibrolipomas are encapsulated, smooth and pedunculated. Male predominance was reported [69]. Clinical presentations are commonly dysphagia, discomfort, irritation and cough [69]. Albeit rare, if lipoma enlarges, it may obstruct the airway and cause hoarseness, asphyxia and even death [70]. Having said that, clinical manifestations rely chiefly on the location and size of the mass.

Computed tomography is able to diagnose the mass although magnetic resonance imaging (MRI) is usually favoured [69]. MRI is deemed superior owing to its multiplanar imaging potential, which enables precise delineation of the soft-tissue mass apart from the avoidance of ionizing radiation exposure.

Surgical resection via suspension laryngoscope and carbon dioxide laser is the ideal choice of treatment. Although malignant transformation of solitary lipoma has not been reported, malignant transformation of multiple lipomata of the larynx as well as pharynx has been reported [71].

6.6 Hypopharyngeal Squamous Cell Carcinoma

Hypopharyngeal carcinoma comprises malignant tumours occurring at the hypopharynx subsites: pyriform sinus, postcricoid or posterior pharyngeal wall. Over 95% of hypopharyngeal carci-

noma arises from the epithelial mucosal lining of the hypopharynx leading to squamous cell carcinoma (SCC). Hypopharynx carcinoma comprises 7% of all malignancy of the aerodigestive tract. Hypopharynx SCC involves 5% of all head and neck cancers [72]. The most common site of malignancy is pyriform sinus, with posterior pharyngeal wall and postcricoid being the least common [73]. Pyriform sinus SCC represents 70% of cases [72–74].

6.6.1 Epidemiology

Overall male predominance is found in hypopharynx carcinoma [75] predominantly amongst patients with a history of heavy usage of alcohol and smoking [76]. Long-term exposure results in progressive cellular dysregulation by alteration of tumour suppressor gene such as TP53, amplification of proto-oncogenes such as cyclin D1 as well as damage to regulatory factors including transforming growth-beta (TGF-beta) and retinoic acid receptors. Additionally, transformation from normal mucosa to malignancy is related to genetic anomaly. Yet, women predominance is found amongst postcricoid SCC following Plummer-Vinson syndrome. Interestingly, postcricoid SCC amongst female patients is unrelated to alcohol consumption or smoking [76]. It is noteworthy that hypopharyngeal carcinoma is associated with an overall poor prognosis with an overall 5-year survival rate of 30–35% [77, 78]. National cancer database (NCDB) revealed epidemiologic data of hypopharyngeal cancer averages at 63 years of age, of which 75% are male patients involving over 70% of Caucasians [79].

6.6.2 Risk Factor

Heavy smoking and alcohol consumption have been predominantly linked to head and neck cancers. Other predominant causative factors are poor nutrition, Plummer-Vinson syndrome (especially in females) and gastroesophageal reflux disease. Effect of human papillomavirus in the pathogenesis of hypopharyngeal cancer remains a debate to date [80]. Asbestos is found to be an independent causative factor leading to the occurrence of hypopharyngeal cancer [81]. Genetic factors as a risk factor are still under research. Presence of heritable polymorphisms of expression of enzymes that activate tobacco-related proto-oncogenes such as aryl hydrocarbon hydroxylase and detoxifying carcinogens such as glutathione S-transferase is linked with head and neck malignancy. Detection of polymorphisms in alcohol dehydrogenase genes increases the risk of oral and pharyngeal malignancy associated with alcohol.

6.6.3 Clinical Presentation

It is noteworthy that patients with hypopharyngeal carcinoma have traditionally shown delayed presentation with loco-regional or distant metastasis, hence accounting for a poor prognosis [82]. Patients typically remain asymptomatic until the mass grows large, extending into the laryngeal region or following cervical nodal metastasis [83]. Early clinical manifestations may be non-typical and mimic benign conditions such as laryngopharyngeal reflux. Dysphagia is the most common presentation followed by sore throat, hoarseness or globus sensation [78]. Referred otalgia is another presentation of hypopharyngeal cancer. Following the extensive lymphatic network of the hypopharynx, early cervical nodal metastasis has been reported [78]. Approximately 6% of patients exhibit metastasis upon presentation, and the number increases as the disease progresses as metastasis is said to be present up to 60% during the disease course [79].

6.6.4 Diagnosis

A meticulous history taking is imperative followed by physical examination with a thorough head and neck assessment. Additionally, underlying medical illness or comorbidities, presence of unexplained weight loss, nutrition status and performance status of the patient are deemed necessary. Flexible fibre-optic laryngoscopy is

mandatory to assess the site, size and extension of the tumour; presence of synchronous lesion; and vocal cord mobility. Yet, the patient needs to be under direct laryngoscopy and oesophagoscopy to assess the tumour spread, length, involvement of oesophagus mucosa and presence of synchronous lesion as well as for biopsy to determine the pathological diagnosis. Presence of narrowband imaging (NBI) with or without autofluorescence enables a clearer delineation of the tumour compared to the standard white-light endoscopy [84, 85]. It is noteworthy that synchronous tumours are present in 1–6% of patients newly diagnosed with head and neck SCC [86].

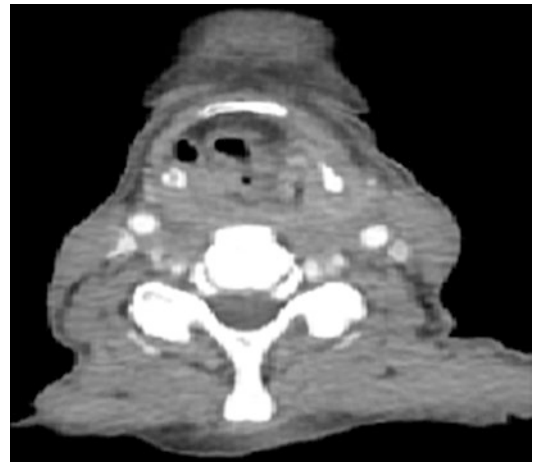

Fig. 6.16 Hypopharyngeal tumoural mass

6.6.5 Blood Investigations

Blood investigations are necessary to evaluate the presence of anaemia notably iron deficiency anaemia due to its association with Plummer-Vinson syndrome. Additionally, presence of macrocytic anaemia directs towards alcohol abuse. Thrombocytopenia and hypoalbuminemia, on the other hand, suggest nutritional deficiency. It is mandatory to assess the thyroid function as the patient may need to be assessed for hypothyroidism as radiation may lead to this condition in nearly 40% of individuals, which may be worst in patients with underlying hypothyroidism.

6.6.6 Imaging

Imaging is a mandatory part of tumour assessment. It is noteworthy that imaging should be done prior to biopsy as to avoid false positives, which overestimates the tumour following post-biopsy oedema. Chest radiograph is mandatory as a preoperative assessment in addition to assessing for the presence of lung metastasis. Barium swallow is carried out to delineate the inferior border of the lesion and to look for the presence of involvement of oesophageal inlet.

Computed tomography (CT) with contrast is essential for staging of the tumour, to assess the size, extension and presence of cervical and distant metastasis in addition to the presence of secondary or synchronous tumour (Fig. 6.16). Thickness slice for CT should be 0.625–1.25 mm, and the reformatted is to be no greater than 2.5 mm. It is imperative that CT scan needs to be carried out upon quiet respiration with patients instructed not to swallow [87].

Magnetic resonance imaging (MRI) is superior to delineate the soft-tissue involvement [87]. Multiplanar MRI enables a three-dimensional assessment of the tumour as well as assessment of the prevertebral involvement. CT or MRI has been the recommended imaging for hypopharynx by the Royal College of Radiologists, 2014 [88]. MRI requires an axial, sagittal and coronal T1W and T2W sequence with contrast enhancement as well as fat suppression to visualize soft-tissue and cartilage invasion [87]. PET is deemed ideal amongst patients with locally advanced disease and nodal involvement to evaluate unknown primary site involvement and to evaluate the outcome of therapy. PET/CT is ideal in advanced cases of hypopharyngeal carcinoma, in residual or recurrent cases [87].

6.6.7 Endoscopic Examination Under General Anaesthesia

Endoscopic examination under general anaesthesia enables thorough assessment of the primary tumour along with its extension, for biopsy in a

controlled setting to obtain histological diagnosis as well as to detect the presence of secondary tumour or synchronous lesion. It is mandatory to perform oesophagoscopy as involvement of oesophagus is discovered frequently due to its close proximity of the hypopharynx especially postcricoid malignancy.

6.6.8 Histology

Overexpression of epidermal growth factor receptor (EGFR) has been reported in approximately 100% of head and neck malignancies.

6.6.9 Staging

Staging for hypopharyngeal carcinoma is based on TNM staging of carcinomas originating in the hypopharynx. TNM staging system applies to squamous cell carcinoma as well as other epithelial malignancies originating in the hypopharynx. The most recent TNM staging system is the 8th edition of the American Joint Committee on Cancer.

6.6.9.1 Primary Tumour (T)

- **TX**: primary tumour cannot be assessed
- **Tis**: carcinoma in situ
- **T1**:
  - Tumour limited to one subsite of hypopharynx (left or right pyriform sinuses, posterior hypopharyngeal wall, or postcricoid region) and/or
  - Tumour ≤2 cm in greatest dimension
- **T2**:
  - Tumour extends into adjacent subsite of hypopharynx or adjacent site (larynx, oropharynx) and/or
  - Tumour >2 and ≤4 cm without fixation of hemilarynx
- **T3**:
  - Tumour >4 cm or
  - Clinical fixation of hemilarynx or
  - Extension to oesophageal mucosa
- **T4**: moderately advanced and very advanced local disease
  - **T4a**: moderately advanced local disease in which tumour invades one or more of the following:
    Thyroid cartilage
    Cricoid cartilage
    Hyoid bone
    Thyroid gland
    Oesophageal muscle
    Central compartment soft tissue (prelaryngeal strap muscles and subcutaneous fat)
  - **T4b**: very advanced local disease in which tumour encases carotid artery or invades one or more of the following:
    Mediastinal structures
    Prevertebral fascia

6.6.9.2 Regional Lymph Node (N)

Regional nodal status is defined the same as for most other cancers of the head and neck. See the main article, cervical lymph node (staging).

6.6.9.3 Distant Metastasis (M)

The terms pM0 and MX are not valid TNM categories. The following categories may be used:

- **cM0**: no evidence of metastases
- **cM1**: distant metastasis
- **pM1**: distant metastasis, microscopically confirmed

6.6.9.4 Stage Groups

The prognostic stage groups are defined the same as for most other cancers of the head and neck:

- **Stage 0**
  - Tis, N0, M0
- **Stage I**
  - T1, N0, M0
- **Stage II**
  - T2, N0, M0
- **Stage III**
  - T3, N0, M0
  - [T1, T2, T3], N1, M0

- **Stage IVA**
  - T4a, [N0, N1], M0
  - [T1, T2, T3, T4a], N2, M0
- **Stage IVB**
  - [Any T], N3, M0
  - T4b, [Any N], M0
- **Stage IVC**
  - [Any T], [Any N], M1

6.6.10 Treatment

Treatment option is based on the staging of the tumour, age, patients' performance status, facility availability in the medical centre as well as patients' preference. Ideally, a multidisciplinary meeting should be carried out involving the surgical and radiation oncologists, speech and language therapists as well as patients and their family prior to commencement of treatment. Favoured treatment options available include surgery, radiotherapy or chemotherapy. Single-mode therapy is advocated for early-stage, localized tumour (T1 and T2 N0), whereas multimodality treatment is opted for the advanced stage of disease.

6.6.10.1 Surgical

Myriad surgical techniques as well as approaches are available today including both transoral and open techniques depending on the tumour extension and structures involved [89]. Transoral surgical approach is associated with superior ability in localized smaller tumour, whereby complete surgical resections can be achieved successfully with negative margin.

1. Early-stage tumour

   Early stage is managed either surgically or via radiation therapy [90]. Surgical approaches include transoral resection or partial open laryngopharyngectomy with or without reconstruction. Occult nodal metastasis is reported to be present in nearly 30–40% of hypopharyngeal carcinoma patients. Hence, neck dissection should be carried out in all cases electively during the surgical resection of the primary tumour.

2. Late stage of tumour

   Nearly 80% of patients with hypopharyngeal carcinoma patients are at stage III and IV during their first visit. It is noteworthy that more than 60% of patients have demonstrated submucosal extension [91], with histological studies reporting 1–2 cm of submucosal extension warranting minimal resection margin of 1.5 cm superiorly, 3 cm inferiorly and 2 cm laterally [87]. Approximately 80% of macroscopical submucosal extensions are demonstrated in patients with previous radiotherapy [87].

3. Recurrent disease

   Salvage surgery carried out in patients with recurrence post-radiation has reported a lower success rate, with larynx preservation rarely possible [74]. Additionally, patients with recurrence post failed radiation therapy require greater resection margin causing difficulty for reconstruction.

6.6.10.2 Non-surgical: Chemotherapy and Radiotherapy

Radiotherapy has been utilized as organ-sparing modality as compared to surgery in treating early-stage hypopharyngeal SCC. Locally advanced hypopharyngeal SCC can be treated with radiotherapy when combined with systemic therapy. Post-operative radiotherapy or chemoradiotherapy demonstrated improved loco-regional disease control as well as overall survival rate even with the presence of positive margin or extra-capsular nodal extension or extra-capsular nodal disease [92]. Prospective trials have revealed equal rate of local control and survival when surgery and adjuvant treatment are compared with primary non-surgical therapy in advanced cancers. It is noteworthy that there is scarcity of trials including randomized controlled trials involving primary tumour of hypopharyngeal carcinoma. Hence, most of the referred clinical trials have been for laryngeal cancer.

Addition of concomitant systemic therapy, notably cisplatin, has demonstrated moderate improvement of the overall survival rate. Combination therapy in the advanced stage of hypopharyngeal carcinoma has been reiterated.

Yet, in elderly patients aged 71 years and above, the benefit of systemic therapy has been deemed doubtful [93, 94].

As for induction chemotherapy, several large trials have been performed which revealed its potential as an organ preservation modality, which has been shown to be in par with the survival outcome of surgery in laryngeal cancer. Induction chemotherapy has demonstrated the possibility to reduce distant metastasis [95]. Primary radiotherapy with subsequent salvage surgery showed poorer survival rate in comparison to primary surgery followed by post-operative radiotherapy, especially in advanced stage [74]. Whereas the outcome of primary radiotherapy [95, 96] in patients with early-stage hypopharyngeal carcinoma is comparable to primary total-laryngectomy or larynx-conserving surgery [97–99].

In a phase III trial of hypopharyngeal carcinoma patients, induction chemotherapy followed by radiotherapy as compared to primary surgery followed by radiotherapy revealed no difference in local or regional recurrence as well as 5-year disease-free survival rate [100]. In the induction chemotherapy group, disease-free survival rate was 25%, and it was 27% in the primary surgery group. Additionally, survival rate of patients with a functional larynx amongst the chemoradiation group was 35% [101]. Based on a recent Surveillance, Epidemiology, and End Results (SEER) program study regarding survival outcome amongst hypopharyngeal cancer patients, non-surgical organ preservation study was favoured for hypopharyngeal carcinoma management [77].

Intensity-modulated radiation therapy enables precisely targeted therapy to minimize the risk of radiation to the vital structures located at the vicinity, for example the parotid gland. Intensity-modulated radiation therapy enables target volume delineation, which has demonstrated local control as well as functional outcomes.

Targeted therapy is rapidly developing in the management of head and neck carcinoma. Immunotherapy, especially the one with targeted therapies against programmed death ligand pathway [PD-1, PD-L1], is currently under investigation for various tumour types [102]. Randomized clinical trials of these targeted therapies known as immune checkpoint inhibitors including pembrolizumab and nivolumab have demonstrated improvement in head and neck cancers and are currently approved in recurrent as well as metastatic head and neck cancers [103, 104]. p53 and ERCCI, a host of molecular targets of interest to head and neck cancer including hypopharyngeal cancer, have been associated with providing response to treatment, notably chemotherapy and laryngeal preservation [105].

References

1. Hickman W. Congenital tumour of the base of the tongue passing down the epiglottis on the larynx and causing death by suffocation sixteen hours after death (sic.). Trans Pathol Soc Lond. 1869;20:160.
2. Douglas P, Baker A. Lingual thyroid. Br J Oral Maxillofac Surg. 1994;32:123–4.
3. Beil CM, Keberle M. Oral and oropharyngeal tumours. Eur J Radiol. 2008;66:448–59.
4. Farrell ML, Forer M. Lingual thyroid. Aust N Z J Surg. 1994;64:135–8.
5. Thomas G, Hoilat R, Daniels JS, Kalagie W. Ectopic lingual thyroid: a case report. Int J Oral Maxillofac Surg. 2003;32:219–21.
6. Kumar SLK, Kurien NM, Jacob MM, et al. Lingual thyroid. Ann Maxillofac Surg. 2015;5(1):104–7.
7. Jones P. Autotransplantation in lingual ectopia of the thyroid gland: review of literature and report of successful case. Arch Dis Child. 1961;36:164–70.
8. Kumar V, Nagandhar Y, Prakash B, Chattopadhyay A, Vepakomma D. Lingual thyroid gland: clinical evaluation and management. Indian J Pediatr. 2004;71:e62–4.
9. Grewal DS, Pusalkar AG, Pathak AM. Pedunculated pleomorphic adenoma of the tongue base manifesting with dyspnoea—a case report. J Laryngol Otol. 1984;98(4):425–7.
10. Maruyama A, Tsunoda A, Takahashi M, et al. Nasopharyngeal pleomorphic adenoma presenting as otitis media with effusion: case report and literature review. Am J Otolaryngol. 2014;35:73–6.
11. Uz U, Celik O. Pleomorphic adenoma of the posterior surface of the soft palate causing sleep disturbance: a case report. Am J Case Rep. 2017;18:1266–70.
12. Nascimento LA, Vilela TGP. Pleomorphic adenoma of the tongue base: case report and review. Int Arch Otorhinolaryngol. 2014;18:328–31.
13. Eveson JW, Kusafuka K. Pleomorphic adenoma. In: Barnes L, Eveson JW, Reichart P, Sidransky D, editors. World Health Organization classification of tumours. Lyon: IARC Press; 2005. p. l254–8.

14. Vlaykov A, Vicheva D. Nasal pleomorphic adenoma—a case report. Int J Sci Res. 2015;4:77–9.
15. Berry S, Tay H, Puentes CP. Pleomorphic adenoma of the base of the tongue. Ear Nose Throat J. 2004;83:646–8.
16. Ramisetty SD, Rajsekhar B, Vijay Srinivas G, et al. Unusual length of pedicle: pedunculated squamous papilloma of uvula causing unusual dysphagia of long duration in a child of 10 years. Case Rep Dent. 2014;2014:313506.
17. Wadhera R, Kalra V, Gulati SP, et al. A big solitary oropharyngeal papilloma in a child. Egypt J Ear Nose Throat Allied Sci. 2012;13(3):131–2.
18. Al-Khateeb TH. Benign oral masses in a northern Jordanian population-retrospective study. Open Denstistry J. 2009;3:147–53.
19. Snietura M, Lamch R, Kopec A, et al. Oral and oropharyngeal papillomas are not associated with high-risk human papillomavirus infection. Eur Arch Otorhinolaryngol. 2017;274(9):3477–83.
20. Goodstein Khan A, Pinczewski J, et al. Symptomatic squamous papilloma of the uvula: report of a case series and review of the literature. Case Rep Otolaryngol. 2012;2:329289.
21. Kwak E, Choi YH, Park W, et al. Oral papillomatosis in immunocompromised patients: a case series of kidney transplant recipients and myelodysplastic syndrome. J Oral Maxillofac Surg. 2018;76(1):128–33.
22. Abbey LM, Sawyer DR. The clinical and histopathologic features of a series of 464 oral squamous cell papillomas. Oral Surg Oral Med Oral Pathol. 1980;49(5):419–28.
23. Chi AC, Day TA, Neville BW. Oral cavity and oropharyngeal squamous cell carcinoma-an update. CA Cancer J Clin. 2015;65:401–21.
24. Caturvedi AK, Anderson WF, Lortet-Tieulent J, et al. Worldwide trends in incidence rates of oral cavity and oropharyngeal cancers. J Clin Oncol. 2013;31(36):4550–9.
25. Gillison ML, Koch WM, Capone RB, et al. Evidence for a causal association between human papillomavirus and a subset of head and neck cancers. J Natl Cancer Inst. 2000;92(9):709–20.
26. Mork J, Lie AK, Glattre E, et al. Human papillomavirus infection as a risk factor for squamous-cell carcinoma of the head and neck. N Engl J Med. 2001;344(15):1125–31.
27. Simard EP, Torre LA, Jemal A. International trends in head and neck cancer incidence rates: differences by country, sex and anatomic site. Oral Oncol. 2014;50(5):387–403.
28. D'Souza G, Agrawal Y, Halpern J, Bodison S, Gillison ML. Oral sexual behaviors associated with prevalent oral human papillomavirus infection. J Infect Dis. 2009;199(9):1263–9.
29. Gillison ML, D'Souza G, Westra W, et al. Distinct risk factor profiles for human papillomavirus type 16-positive and human papillomavirus type 16-negative head and neck cancers. J Natl Cancer Inst. 2008;100(6):407–20.
30. Smith EM, Ritchie JM, Summersgill KF, et al. Age, sexual behavior and human papillomavirus infection in oral cavity and oropharyngeal cancers. Int J Cancer. 2004;108(5):766–72.
31. Gillison ML, Zhang Q, Jordan R, et al. Tobacco smoking and increased risk of death and progression for patients with p16-positive and p16-negative oropharyngeal cancer. J Clin Oncol. 2012;30(17):2102–11.
32. Tramacere I, Negri E, Bagnardi V, et al. A meta-analysis of alcohol drinking and oral and pharyngeal cancers, part 1: overall results and dose-risk relation. Oral Oncol. 2010;46(7):497–503.
33. Slootweg PJ, Bishop JA. Oral and oropharyngeal cancer: pathology and genetics, Encyclopedia cancer. 3rd ed. Berlin: Springer; 2019.
34. International Agency for Research on Cancer (IARC). IARC monographs on the evaluation of carcinogenic risks to humans. List of classifications by cancer site. monographs.iarc.fr/ENG/Classification/index.php. Accessed 3 Jun 2015.
35. Gandini S, Botteri E, Iodice S, et al. Tobacco smoking and cancer: a meta-analysis. Int J Cancer. 2008;122:155–64.
36. International Agency for Research on Cancer (IARC). IARC monographs on the evaluation of carcinogenic risk in humans, Tobacco smoke and involuntary smoking, vol. 83. Lyon: IARC Press; 2004.
37. International Agency for Research on Cancer (IARC). Section 2.2. Cancer of the oral cavity and pharynx. In: IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, editor. IARC monographs on the evaluation of carcinogenic risks to humans, Alcohol consumption and ethylcarbamate, vol. 96. Lyon: IARC Press; 2010. p. 237–329.
38. Turati F, Garavello W, Tramacere I, et al. A meta-analysis of alcohol drinking and oral and pharyngeal cancers: results from subgroup analyses. Alcohol Alcohol. 2013;48:107–18.
39. Mirghani H, Amen F, Moreau F, Lacau St Guily J. Do high-risk human papillomaviruses cause oral cavity squamous cell carcinoma? Oral Oncol. 2015;51:229–36.
40. Sood AJ, McIlwain W, O'Connell B, Nguyen S, Houlton JJ, Day T. The association between T-stage and clinical nodal metastasis in HPV-positive oropharyngeal cancer. Am J Otolaryngol. 2014;35:463–8.
41. Guggenheimer J, Verbin RS, Johnson JT, Horkowitz CA, Myers EN. Factors delaying the diagnosis of oral and oropharyngeal carcinomas. Cancer. 1989;64(4):932–5.
42. Mashberg A, Meyers H. Anatomical site and size of 222 early asymptomatic oral squamous cell carcinomas: a continuing prospective study of oral cancer. II. Cancer. 1976;37(5):2149–57.
43. McIlwain WR, Sood AJ, Nguyen SA, Day TA. Initial symptoms in patients with HPV-positive and HPV-negative oropharyngeal cancer. JAMA Otolaryngol Head Neck Surg. 2014;140:441–7.

44. Lewis JS Jr, Khan RA, Masand RP, et al. Recognition of nonkeratinizing morphology in oropharyngeal squamous cell carcinoma—prospective cohort and interobserver variability study. Histopathology. 2012;60:427–36.
45. Bishop JA, Lewis JS Jr, Rocco JW, Faquin WC. HPV-related squamous cell carcinoma of the head and neck: an update on testing in routine pathology practice. Semin Diagn Pathol. https://doi.org/10.1053/j.semdp.2015.02.013 [published online ahead of print 4 Feb 2015].
46. El-Naggar AK, Westra WH. p16 expression as a surrogate marker for HPV-related oropharyngeal carcinoma: a guide for interpretative relevance and consistency. Head Neck. 2012;34:459–61.
47. Mydlarz WK, Liu J, Blanco R, Fakhry C. Transcervical ultrasound identifies primary tumor site of unknown primary head and neck squamous cell carcinoma. Otolaryngol Head Neck Surg. 2014;151:1090–2.
48. Fakhry C, Agrawal N, Califano J, et al. The use of ultrasound in the search for the primary site of unknown primary head and neck squamous cell cancers. Oral Oncol. 2014;50:640–5.
49. Goldenberg D, Begum S, Westra WH, et al. Cystic lymph node metastasis in patients with head and neck cancer: an HPV-associated phenomenon. Head Neck. 2008;30:898–903.
50. Law CP, Chandra RV, Hoang JK, Phal PM. Imaging the oral cavity: key concepts for the radiologist. Br J Radiol. 2011;84:944–57.
51. Rabalais AG, Walvekar R, Nuss D, et al. Positron emission tomography-computed tomography surveillance for the node positive neck after chemoradiotherapy. Laryngoscope. 2009;119:1120–4.
52. Ryan WR, Fee WE Jr, Le QT, Pinto HA. Positron-emission tomography for surveillance of head and neck cancer. Laryngoscope. 2005;115:645–50.
53. Leung AS, Rath TJ, Hughes MA, Kim S, Branstetter BF 4th. Optimal timing of first post-treatment FDG-PET/CT in head and neck squamous cell carcinoma. Head Neck. https://doi.org/10.1002/hed.24112 [published online ahead of print 27 Apr 2015].
54. Isles MG, McConkey C, Mehanna HM. A systematic review and meta-analysis of the role of positron emission tomography in the follow up of head and neck squamous cell carcinoma following radiotherapy or chemoradiotherapy. Clin Otolaryngol. 2008;33:210–22.
55. Ho AS, Tsao GJ, Chen FW, et al. Impact of positron emission tomography/computed tomography surveillance at 12 and 24 months for detecting head and neck cancer recurrence. Cancer. 2013;119:1349–56.
56. Iyer NG, Dogan S, Palmer F, et al. Detailed analysis of clinicopathologic factors demonstrate distinct difference outcome and prognostic factors between surgically treated HPV-positive and negative oropharyngeal cancer. Ann Surg Oncol. 2015;22(13):4411–21.
57. Shah JP, Patel SG, Singh B. Jatin Shah's head and neck surgery and oncology. 4th ed. Philadelphia, PA: Elsevier/Mosby; 2012.
58. Hay A, Nixon IJ. Recent advances in the understanding and management of oropharyngeal cancer. F1000Res. 2018;7:1362.
59. Cooper JS, Pajak TF, Forastiere AA, et al. Postoperative concurrent radiotherapy and chemotherapy for high-risk squamous-cell carcinoma of the head and neck. N Engl J Med. 2004;350:1937–44.
60. More YI, Tsue TT, Girod DA, et al. Functional swallowing outcomes following transoral robotic surgery vs primary chemoradiotherapy in patients with advanced-stage oropharynx and supraglottis cancers. JAMA Otolaryngol Head Neck Surg. 2013;139:43–8.
61. Garden AS, Kies MS, Morrison WH, et al. Outcomes and patterns of care of patients with locally advanced oropharyngeal carcinoma treated in the early 21st century. Radiat Oncol. 2013;8(1):21.
62. Ang KK, Trotti A, Brown BW, et al. Randomized trial addressing risk features and time factors of surgery plus radiotherapy in advanced head-and-neck cancer. Int J Radiat Oncol Biol Phys. 2001;51(3):571–8.
63. Calais G, Alfonsi M, Bardet E, et al. Randomised trial of radiation therapy versus concomitant chemotherapy and radiation therapy for advanced oropharyngeal carcinoma. J Natl Cancer Inst. 1999;91(24):2081–6.
64. Pignon JP, Bourhis J, Domenge C, et al. Chemotherapy added to locoregional treatment for head and neck squamous-cell carcinoma: three meta-analyses of updated individual data. MACH-NC Collaborative Group. Meta-analysis of chemotherapy on head and neck cancer. Lancet. 2000;355(9208):949–55.
65. Blanchard P, Baujat B, Holostenco V, Bourredjem A, Baey C, Bourhis J, et al. Meta-analysis of chemotherapy in head and neck cancer (MACH-NC): a comprehensive analysis by tumour site. Radiother Oncol. 2011;100:33–40.
66. Parvathaneni U, Lavertu P, Gibson MK, Glastonbury CM. Advances in diagnosis and multidisciplinary management of oropharyngeal squamous cell carcinoma: state of art. RSNA. 2019;39(7):1–14.
67. Vermorken JB, Mesia R, Rivera F, et al. Platinum-based chemotherapy plus cetuximab in head and neck cancer. N Engl J Med. 2008;359(11):1116–27.
68. Choi J, Cho J, Joo Y, et al. A hypopharyngeal ductal cysts masquerading as a laryngopharyngeal reflux disease. Clin Exp Otorhinolaryngol. 2014;7(1):76–8.
69. Jungehulsing M, Fischbach R, Pototschnig C, et al. Rare benign tumours: laryngeal and hypopharyngeal lipoma. Ann Otol Laryngol. 2000;109:301–5.
70. Fyfe B, Mittleman RE. Hypopharyngeal lipoma as a cause for sudden asphyxia death. Am J Forensic Med Pathol. 1991;12:82–4.

71. Kapur TR. Recurrent lipomata of the larynx and the pharynx with late malignant changes. J Laryngol Otol. 1968;82:761–8.
72. Patel R, Goldstein D, Brown D, et al. Circumferential pharyngeal reconstruction: history, critical analysis of techniques, and current therapeutic recommendations. Head Neck. 2010;32:109–20.
73. Pignon JP, Bourhis J, Domenge C, Designe L. Chemotherapy added to locoregional treatment for head and neck squamous-cell carcinoma: three meta-analyses of updated individual data. MACH-NC Collaborative Group. Meta-analysis of chemotherapy on head and neck cancer. Lancet. 2000;355(9208):949–55.
74. Godballe C, Jorgensen K, Hansen O, et al. Hypopharyngeal cancer: results of treatment based on radiation therapy and salvage surgery. Laryngoscope. 2002;112:834–8.
75. Ho C, Ng W, Lam K, et al. Radial clearance in resection of hypopharyngeal cancer: an independent prognostic factor. Head Neck. 2002;24:181–90.
76. Archibald S, Young JEM. A pharyngo-cervical esophageal reconstruction. Clin Plast Surg. 2005;32:339–46.
77. Newman JR, Connolly TM, Illing EA, Kilgore ML, Locher JL, Carroll WR. Survival trends in hypopharyngeal cancer: a population-based review. Laryngoscope. 2015;125(3):624–9.
78. Hall SF, Groome PA, Irish J, O'Sullivan B. The natural history of patients with squamous cell carcinoma of the hypopharynx. Laryngoscope. 2008;118(8):1362–71.
79. Eckel HE, Staar S, Volling P, Sittel C, Damm M, Jungehuelsing M. Surgical treatment for hypopharynx carcinoma: feasibility mortality and results. Otolaryngol Head Neck Surg. 2001;124(5):561–9.
80. Lee JK, Lee KH, Kim SA, Lee DH. p16 as a prognostic factor for the response to induction chemotherapy in advanced hypopharyngeal squamous cell carcinoma. Oncol Lett. 2018;15:6571–7.
81. Marchand JL, Duce D, Leclerc A, et al. Laryngeal and hypopharyngeal cancer and occupational exposure to asbestos and man-made vitreous fibers: results of a case-control study. Am J Ind Med. 2000;37(6):581–9.
82. Chu P, Chang S. Reconstruction of the hypopharynx after surgical treatment of squamous cell carcinoma. J Chin Med Assoc. 2009;72:351–5.
83. Garneau JC, Bakst RL, Miles BA. Hypopharyngeal cancer: a state of art review. Oral Oncol. 2018;86:244–50.
84. Watanabe A, Taniguchi M, Tsujie H, et al. The value of narrow band imaging endoscope for early head and neck cancers. Otolaryngol Head Neck Surg. 2008;138:446–51.
85. Nonaka S, Saito Y. Endoscopic diagnosis of pharyngeal carcinoma by NBI. Endoscopy. 2008;40:347–51.
86. Jones AS, Morar P, Phillips DE, et al. Second primary tumours in patients with head and neck squamous cell carcinoma. Cancer. 1995;75:1343–53.
87. Pracy P, Loughran S, Good J, et al. Hypopharyngeal cancer: United Kingdom National Multidisciplinary guidelines. J Laryngol Otol. 2016;130:S104–10.
88. Olliff J, Richards P, Connor S, Wong WL, Beale T, Madani G. Head and neck cancers. In: Nicholson T, editor. Recommendations for cross-sectional imaging in cancer management. London: The Royal College of Radiologists; 2014. p. 3–19.
89. Bradley PJ. Cancer of the hypopharynx. Oper Tech Otolaryngol. 2005;16:55–66.
90. Martin A, Jackel MC, Christiansen H, Mahmoodzada M, Kron M, Steiner W. Organ preserving transoral laser microsurgery for cancer of the hypopharynx. Laryngoscope. 2008;118:398–402.
91. Ho CM, Ng WF, Lam KH, Wei WJ, Yuen AP. Submucosal tumor extension in hypopharyngeal cancer. Arch Otolaryngol Head Neck Surg. 1997;123:959–65.
92. Bernier J, Cooper JS, Pajak TF, et al. Defining risk levels in locally advanced head and neck cancers: a comparative analysis of concurrent postoperative radiation plus chemotherapy trials of the EORTC (#22931) and RTOG (# 9501). Head Neck. 2005;27:843–50.
93. Blanchard P, Baujat B, Holostenco V, et al. Meta-analysis of chemotherapy in head and neck cancer (MACH-NC): a comprehensive analysis by tumour site. Radiother Oncol. 2011;100(1):33–40.
94. Pignon JP, le Maitre A, Maillard E, Bourhis J, Group M-NC. Meta-analysis of chemotherapy in head and neck cancer (MACH-NC): an update on 93 randomised trials and 17,346 patients. Radiother Oncol. 2009;92:4–14.
95. Posner MR, Hershock DM, Blajman CR, Mickiewicz E, Winquist E, Gorbounova V, et al. Cisplatin and fluorouracil alone or with docetaxel in head and neck cancer. N Engl J Med. 2007;357:1705–15.
96. Foote RL. Radiotherapy alone for early-stage squamous cell carcinoma of the larynx and hypopharynx. Int J Radiat Oncol Biol Phys. 2007;69:S31–6.
97. Yoshimura RI, Kagami Y, Ito Y, et al. Outcomes in patients with early-stage hypopharyngeal cancer treated with radiotherapy. Int J Radiat Oncol Biol Phys. 2010;77:1017–23.
98. Nakamura K, Shioyama Y, Kawashima M, et al. Multi-institutional analysis of early squamous cell carcinoma of the hypopharynx treated with radical radiotherapy. Int J Radiat Oncol Biol Phys. 2006;65:1045–50.
99. Rabbani A, Amdur R, Mancuso A, et al. Definitive radiotherapy for T1-T2 squamous cell carcinoma of pyriform sinus. Int J Radiat Oncol Biol Phys. 2008;72:351–5.
100. Lefebvre JL, Andry G, Chevalier D, Luboinski B, Collette L, Traissac L, et al. Laryngeal preservation with induction chemotherapy for hypopharyngeal squamous cell carcinoma: 10-year results of EORTC trial 24891. Ann Oncol. 2012;23:2708–14.
101. Gourin CG, Terris DJ. Carcinoma of the hypopharynx. Surg Oncol Clin N Am. 2004;13:81–98.

102. Ono T, Azuma K, Kawahara A, et al. Association between PD-L1 expression combined with tumor-infiltrating lymphocytes and the prognosis of patients with advanced hypopharyngeal squamous cell carcinoma. Oncotarget. 2017;8(54):92699–714.
103. Chow LQM, Haddad R, Gupta S, et al. Antitumor activity of pembrolizumab in biomarker-unselected patients with recurrent and/or metastatic head and neck squamous cell carcinoma: results from the phase Ib KEYNOTE-012 expansion cohort. J Clin Oncol. 2016;34(32):3838–45.
104. Ferris RL, Blumenschein G, Fayette J, et al. Nivolumab for recurrent squamous-cell carcinoma of the head and neck. N Engl J Med. 2016;375(19):1856–67.
105. Hasegawa Y, Goto M, Hanai N, Ozawa T, Hirakawa H. Predictive biomarkers for combined chemotherapy with 5-fluorouracil and cisplatin in oro- and hypopharyngeal cancers. Mol Clin Oncol. 2017;8:378–86.

7 Surgical Management of Nasopharyngeal Carcinoma

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7.1 Introduction

Nasopharyngeal carcinoma (NPC) is an epithelial carcinoma that arises from nasopharyngeal mucosal lining and is commonly observed at the pharyngeal recess or known as fossa of Rosenmuller (FOR) [1]. It has a high prevalence in China and is a rare malignancy throughout other parts of the world. In Malaysia, NPC is the fourth most common cancer among the Malaysian population and the third common cancer among males with a high incidence of NPC among the native Bidayuh people of Sarawak, in Malaysia [2]. NPC has a bimodal distribution pattern where the first peak is in late adolescence/early adulthood at the age of 15–24 years, and second peak later in life at about 65–79 years [3].

The diagnosis of NPC includes clinical history, physical examination and biopsy. The most common presentation of NPC is neck mass that is commonly unilateral [4]. Other presenting symptoms of NPC include epistaxis, nasal obstruction, hearing impairment and tinnitus. In an advanced case, the symptoms include headache, diplopia, facial numbness, hypaesthesia, trismus, ptosis or hoarseness [5]. Physical examination of the nasopharynx is carried out in otorhinolaryngology (ORL) clinic. Tumour can be readily seen and biopsied from the nasopharynx.

The histological proof from the biopsy is crucial to confirm the diagnosis [6]. According to the latest histopathological classification of NPC by the World Health Organization (WHO) in 2005, NPC can be grouped into three histological subtypes: keratinizing squamous cell carcinoma,

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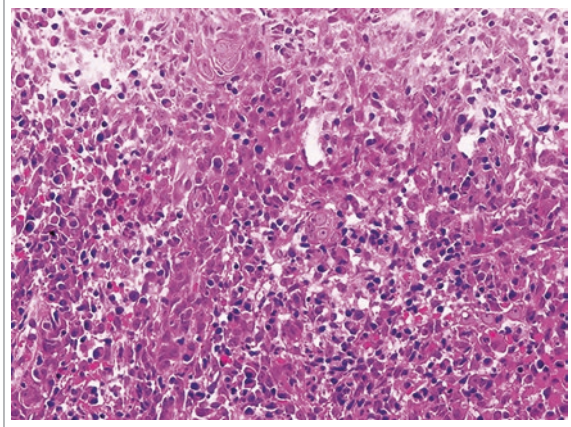
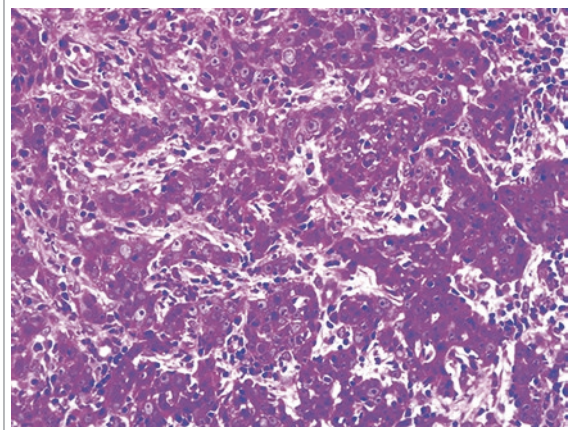
N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_7

non-keratinizing carcinoma and basaloid squamous cell carcinoma (Table 7.1) [7].

In newly diagnosed NPC, radiotherapy or concurrent chemoradiotherapy has been the standard treatment. The use of radiation allows the management of both the primary site and nodal metastasis, especially the retropharyngeal lymph nodes as the first echelon node in

Table 7.1 Histopathological types of NPC and their features

Histopathological type of NPC	Features
Keratinizing squamous cell carcinoma	This is applied to tumours showing obvious or prominent squamous differentiation at the light microscopic level. Intercellular bridges and/or varying degrees of keratinization are indicators of squamous differentiation. The tumour grows in irregular islands separated by desmoplastic stroma [8].  Keratinizing squamous cell carcinoma (H&E 400×)
Non-keratinizing squamous cell carcinoma • Differentiated type • Undifferentiated type	As implied by the name, the characteristics of squamous differentiation are ambiguous in this subtype. Malignant cells are arranged in a variety of ways, ranging from solid to trabecula to singly. The more prevalent undifferentiated subtype is characterized by large cells with round-to-oval vesicular nuclei, prominent central nucleoli and sparse eosinophilic cytoplasm. Indistinct cell borders result in a syncytial appearance. They coexist with a variable proportion of lymphoplasma cells, and the stroma lacks any desmoplastic response [8].  Non-keratinizing nasopharyngeal carcinoma, undifferentiated subtype (H&E 400×)
Basaloid squamous cell carcinoma	Basaloid squamous cell carcinoma is rare to occur in the nasopharynx. This type is characterized by the presence of basaloid malignant cells mixed in with squamous cell carcinoma cells [8].

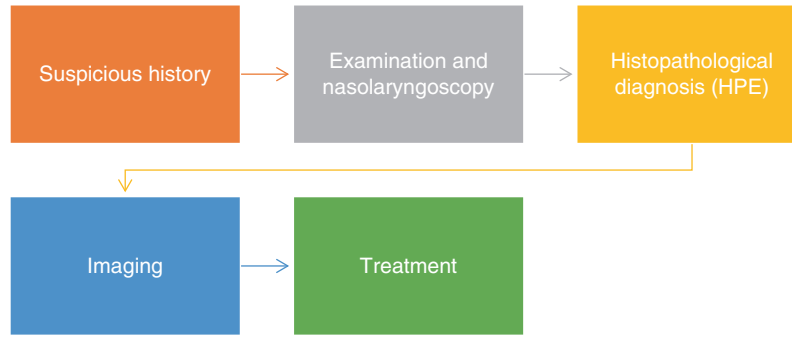


Fig. 7.1 General management outline of NPC

NPC. Radiotherapy is the loco-regional treatment for all stages of NPC, without distant metastasis [9]. General management flow of NPC is as in Fig. 7.1.

7.2 Salvage Neck Dissection

Salvage neck dissection is an approach of choice for neck residue or recurrent nasopharyngeal carcinoma after primary radiotherapy treatment (RT). NPC is easily metastasized to cervical lymph node, and the incidence of residual or recurrent NPC is 4.6–18% [1].

By definition, a recurrence of disease is when the cervical lymph nodes reappear 3 months after initial complete regression, while residual of disease is defined as a lymph node without complete regression by 3 months after primary therapy [10]. In current practice, the recurrence of regional NPC is confirmed by fine needle aspiration (FNA) cytology. Before receiving salvage treatment for regional failure, patients will receive complete physical examination, nasopharyngoscopy and biopsy of the suspicious nasopharyngeal lesions, repeat imaging and restaging of the tumour to exclude local disease and distant metastases.

According to Wang et al., level II is the most common site of nodal metastasis, followed by levels V, III, IV and I. From the study, the author also suggests that if there is no metastasis in level I and parotid region after careful examination, routine dissection of level I and parotid gland is not necessary [11]. In salvage neck dissection, the operation involves modified radical neck dissection, radical neck dissection or extended radical neck dissection (which may include parotidectomy, skin, phrenic nerve, vagus nerve, submaxillary and hypoglossal nerve).

7.2.1 Roles of Flaps in Salvage Neck Dissection

There are few options for flap reconstructions in salvage neck dissection. These include anterior-lateral thigh (ALT) free flap and pedicled pectoralis major myocutaneous flap (PMMF) to repair large facial defects more than 4.0 cm in diameter. However, microsurgical free flap reconstruction is a challenging procedure in a patient who received post-operative irradiation because the treatment depletes the area of potential recipient neck vessels for microvascular anastomosis [12]. According to a study by [13], the free flap reconstruction is feasible and safe in patients with prior irradiation as the failure rate was 6.3% in the prior irradiation and neck dissection group, 4.8% in the neck dissection group and 5.2% in the irradiation group compared to 2.1% in the non-irradiation and neck dissection group.

In the case series of Lin et al., they preferred ALT flap due to it being a reliable perforator flap with constant anatomy based on the descending branch of the lateral circumflex femoral artery, long vascular pedicle that is suitable for microvascular anastomosis to the transcervical recipient vessels and availability of large and long flap that can be harvested without any complications [12]. Song et al. had reported the good outcome of all the flaps, which involved PMMFs, free

forearm flap, free fibular bone flap and pedicled tongue flap, that were used in their salvage surgery in NPC cases. The NPC cases were originally treated with radiotherapy and subsequently developed neck recurrence or second primary tumour in the radiated area [14]. In the study, the PMMF was created in spindle or crescent shape as required by the donor site and was tunnelled under the medial one-third of the clavicle, and the flap was transferred to the cervical area and sutured to the cervical defect.

7.3 External Access for Nasopharyngectomy: Lip Split, Maxillary Swing, Midfacial Degloving

The advent of endoscopic transnasal approaches has made open approaches to the nasopharynx less popular. However, it is not entirely obsolete, especially in the circumstances where an endoscopic approach is deemed unable to adequately clear the tumour or in centres with facilities where dedicated skull base team is limited. This chapter aims to give an idea on the selection criteria, advantages and disadvantages and the brief surgical steps.

The nasopharynx is bordered anteriorly by posterior nasal apertures and nasal septum, posteriorly by the buccopharyngeal fascia which lies anterior to the longus capitis muscle, superiorly by the pharyngeal mucosa overlying the basisphenoid and inferiorly by the oropharynx at the level of soft palate. The lateral limit is formed by the opening of the Eustachian tube (ET). Thus, the goal of resection is to include the cartilaginous ET medial to the medial pterygoid muscle.

Numerous approaches have been described, and we would like to classify them as below:

1. Transoral-transpalatine approach
2. Transmandibular-transcervical approach
3. Anterolateral: Maxillary swing approach
4. Lateral: Infratemporal approach type C
5. Combined approach: Subtemporal-preauricular infratemporal fossa approach and facial translocation

7.3.1 Patient Selection and Preoperative consideration

Open nasopharyngectomy unavoidably renders significant morbidity to a patient both functionally and aesthetically. It is only reasonable to be performed should the procedure change the course of disease either by total eradication of tumour or by reducing the bulk. Detailed knowledge of the complex anatomy of the nasopharynx and precise understanding of the vital structures like skull base and internal carotid artery (ICA) are therefore indispensable before embarking on this procedure.

Computed tomography and magnetic resonance imaging are complementary in assessing the tumour volume and local and intracranial-intradural extension, to evaluate the ICA and the potential damage to it. Angiography and balloon occlusion test are needed if resection of ICA is deemed necessary. A pre-procedure tracheostomy is necessary in almost all the open approaches including the transoral approach. This is to avoid airway compromise due to oedema in the immediate post-operative period. Most patients will require alternative feeding method in the post-operative period. Therefore, they need to be counselled on nasogastric tube feeding or even PEG tube feeding if resection is anticipated to be extensive, which will significantly delay the oral feeding. If a transpalatal approach is used, preoperative designing and planning for an acrylic palatal splint or obturator need to be considered.

An honest discussion on the risks of the surgery with the patient cannot be overemphasized. This includes potential residual tumour, subsequent

adjuvant chemoradiotherapy, fatal injury to ICA, haemorrhage from the pterygoid plexus and cerebrospinal fluid leak. In patients undergoing nasopharyngectomy as a salvage procedure after radiotherapy, it is utmost importance to carefully explain the risk of osteoradionecrosis not only at the mandible but more dangerously over the sphenoid body. Other risks are injury to the tooth, palatal numbness and velopharyngeal insufficiencies.

Intraoperatively, local anaesthesia to the skin and mucosa can be given with 1% lidocaine with 1:100,000 adrenaline. Patient is positioned in the standard supine position with neck extension. Drains are required when the neck is accessed. Prophylactic antibiotics can be administered to reduce the risk of infection. Intraoperative steroid (IV dexamethasone) will aid in reducing airway oedema. Ventilation is best considered using a tracheostomy as mentioned above.

Image-guided navigation has become almost a must in recent days.

7.3.2 Transoral-Transpalatine Approach (Fig. 7.2)

This is an approach for malignant tumours with limited clivus and craniocervical junction extension and size measuring less than 2 cm. This approach is contraindicated for tumours larger than 2 cm and with intracranial-intradural involvement, exten-

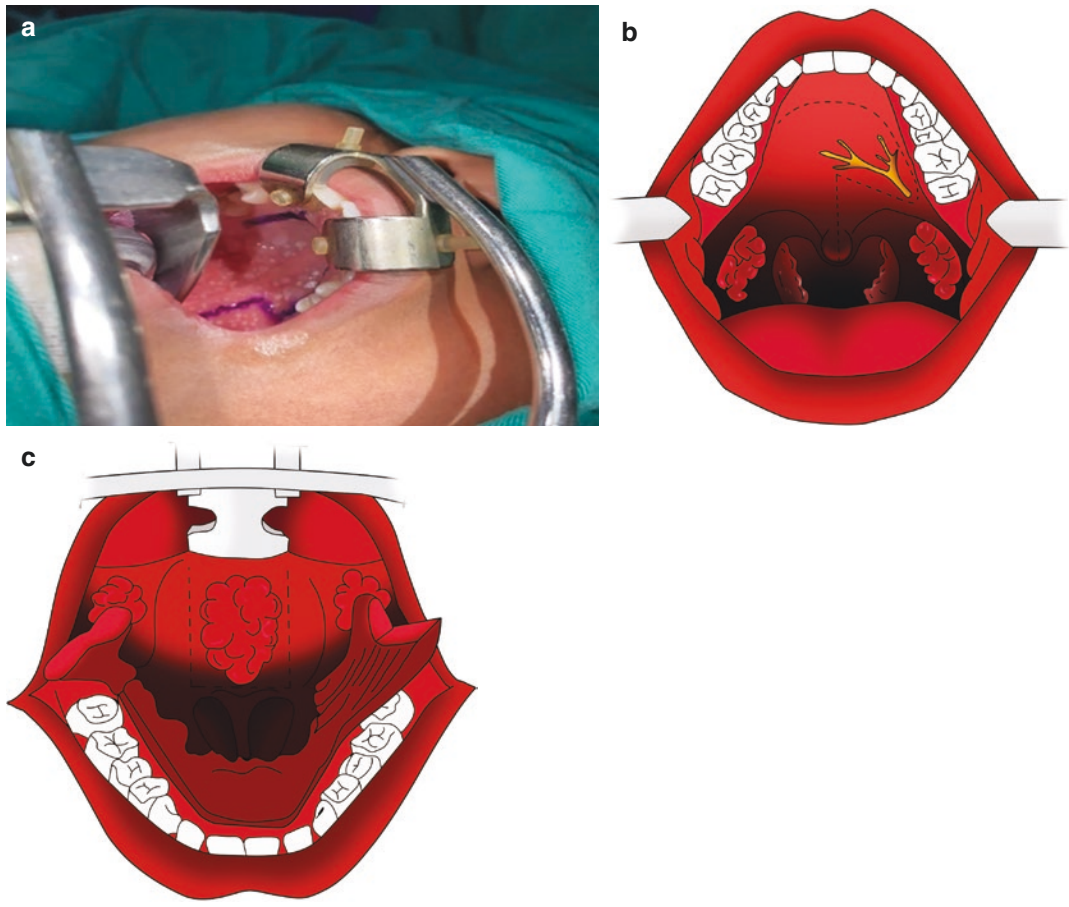


Fig. 7.2 Transoral transpalatine approach. (**a**) Transoral incision. (**b**) Mucosal incision along the palatal aspect of the alveolar ridge. (**c**) Mucosal flap raised and hinged laterally

sion lateral to the lateral pterygoid muscle, involvement of cavernous sinus, infratemporal fossa extension and peritubal extension [15–17].

7.3.2.1 Procedure

1. The patient is placed in the supine position with their head extended as much as possible.
2. Mayfield clamp fixation is required if image-guided navigation is employed.
3. Tracheostomy is performed.
4. Crockard wide-field retractors and dissecting instruments that have been specially designed for working through narrow long-distance transoral approach are needed.
5. Mouth gag is inserted, and the oral cavity and soft and hard palate are infiltrated with 1:200,000 adrenaline.
6. The soft palate is split to one side of the midline.
7. The hard palate mucosa is incised along the ipsilateral junction of the hard and soft palate within 5 mm of the maxillary dentition.
8. This mucosal incision is extended along the palatal aspect of the alveolar ridge up to the level of the first molar and then taken in an arc across the palate to the opposite side.
9. A mucoperiosteal flap is elevated exposing the bony hard palate. The greater palatine neurovascular bundle is coagulated and divided.
10. Muscular insertions of the soft palate from the hard palate are divided to increase exposure.
11. A self-retaining retractor is then inserted to keep the two halves of the soft palate out of the field.
12. Dissection through the posterior nasopharyngeal wall gives access to the lower clivus.
13. Removal of some palatal vomerine bone gives access to the sphenoid floor.
14. Perform a Le Fort I osteotomy and then split the palate in the midline, displacing each maxilla laterally, known as an ‘open-door maxillotomy’, which gives access to clivus and craniocervical junction.
15. A suitable mucosal flap is raised and tucked laterally or inferiorly.
16. The length of this flap varies according to the extent of the lesion being removed. The larger the flap, the better the chance of being able to approximate it at the end of the procedure.
17. If access to the clivus is required, the prevertebral fascia and muscles have to be opened and this is best undertaken in the midline. The important anatomical landmark is the anterior arch of the atlas.
18. Most resection is usually performed in a piecemeal fashion.
19. Dural tears require watertight closure, which is possible with tissue sealants.
20. The dead space created by tumour resection can be filled with autograft soft tissue secured in place by fibrin glue and covered by pedicled local mucosal or mucoperichondrial flaps.
21. The prevertebral fascia, musculature and pharyngeal mucosa are reapproximated.
22. The soft palate is approximated in a three-layered closure to minimize a fistula.
23. Bone plates and screws are applied if the maxilla has been split.
24. Removal of the tracheostomy is determined by the clinical progress of the patient in terms of swallowing and resolution of oedema.

7.3.2.2 Advantages

Transoral transpalatine technique is a simple and direct approach to the nasopharynx.

It is also extendable through the Le Fort I-palatal split approach.

7.3.2.3 Disadvantages

The major drawback is narrow working field and long working distance and no access laterally to the parapharyngeal and infratemporal spaces. Apart from this, it requires tracheostomy. The rate of palatal dehiscence and oronasal fistula is around 30–40%. Patients are also prone to the risk of meningitis due to wound contamination.

7.3.3 Transmandibular-transcervical approach

This approach (Fig. 7.3) is suitable for tumours that are encroaching into the anterior part of the infratemporal fossa. It is contraindicated if the tumour has intracranial intradural invasion more than 2 cm or involving the parasellar and posterior infratemporal region [18, 19].

7.3.3.1 Procedure

1. The patient is placed in the supine position and a tracheostomy is done.
2. Skin incision made from mastoid tip extending to the midline of the lip to split it. Subplatysmal flap is raised and directed beneath the submandibular gland.
3. The tendons of the digastric and stylohyoid muscles can be released from their hyoid attachment and reflected superiorly along with the submandibular gland to increase exposure of the mandible.
4. The great vessels in the carotid sheath and adjacent cranial nerves are then identified.
5. Dissection is continued as near to the skull base following the internal and external carotid arteries.
6. A mandibular osteotomy is performed after pre-plating is done. The authors prefer a paramedian mandibulotomy.
7. The floor of the mouth is dissected. The tongue is retracted to the opposite side, the mucosa incised and the mylohyoid muscle divided together with the anterior belly of the digastric muscle. The lingual and hypoglossal nerves are identified and preserved.
8. The mandible is retracted laterally to reach the parapharyngeal space, which then becomes continuous between the mouth and neck. The external carotid artery can be ligated distal to the lingual artery to increase the retraction of the mandible.
9. This finally allows an access to the nasopharyngeal part of the parapharyngeal space and the anterolateral infratemporal fossa.
10. Additionally, the incision can be extended upward towards the hard palate and pterygoid plates ending about 1 cm medial to the gingival margin should a more median access be required.
11. Blunt dissection lateral to and behind the superior and middle constrictor muscles produces a surgical working space.

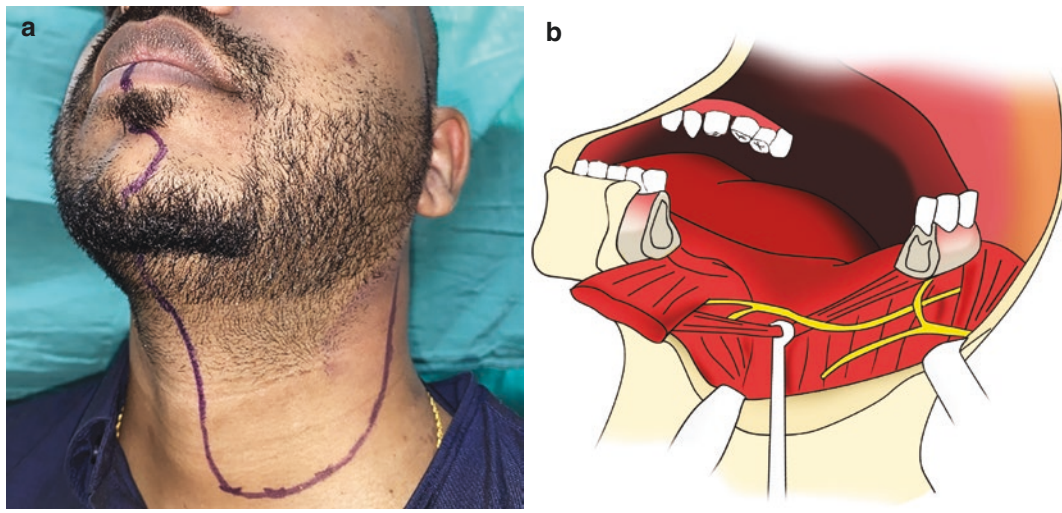


Fig. 7.3 Transmandibular transcervical approach. (**a**) Extended incision from the mastoid tip rising anteriorly to split the lip. (**b**) A median mandibular osteotomy exposing the floor of the mouth by diving the anterior belly of digastric and mylohyoid muscle. Lingual and hypoglossal nerves are in view

12. Additional posterolateral division of the styloid musculature and glossopharyngeal nerve and superior dissection along the retropharyngeal-prevertebral plane release the oropharynx, making retraction easier to the contralateral side.
13. Next, to access the cartilaginous part of the ET, the ICA should be accurately identified followed by transection of tensor and levator muscle.
14. Transection of the ET releases the nasopharynx from the skull base at the level of the pharyngeal tubercle.
15. Access to nasopharynx and upper sphenoid body can be further increased by removing the posterior portion of the hard palate. If the lesion reaches the posterior aspect of the infratemporal fossa, combination with a lateral approach may be required to allow en bloc resection.
16. Any dural defect is repaired in watertight fashion.
17. The remaining pharyngeal sleeve is reattached to the prevertebral muscles at the skull base; the pharynx is realigned by suturing the ET at intratubal splint. The palatal muscles are reapproximated, the mucoperiosteal palatal flap is repositioned and the mucosa is sutured.
18. A pre-planned palatal splint is then applied at hard palate. The floor of the mouth is reconstructed, and the mandible is fixed with the pre-fitted miniplates.
19. Large drains though a separate stab incision in the lower neck are placed.
20. The lower lip is closed to achieve accurate alignment of the vermilion border.

7.3.3.2 Advantages

The transmandibular-transcervical technique gives good direct access to the epipharynx and the parapharyngeal and anterior infratemporal space. It also enables good vascular control.

7.3.3.3 Disadvantages

This approach places the wound at a hazard of potential infection through oral contamination, possible mandibular non-union and prolonged need for tracheostomy. Apart from that, restoration of normal or adequate swallowing is often significantly delayed (mean 7 weeks). Therefore, temporary PEG is often needed.

7.4 Anterolateral Approach: Maxillary Swing

This approach (Fig. 7.4) is suitable for nasopharyngeal tumours with limited extension to the anterior infratemporal region. However, it is contraindicated for tumours encroaching the petrous ICA, petrous apex, parasellar and/or posterior

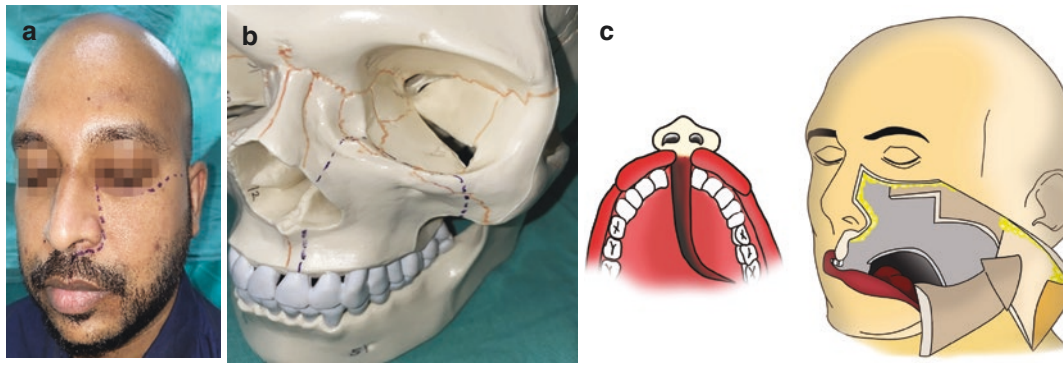


Fig. 7.4 Anterolateral: Maxillary swing approach. (**a**) Weber-Ferguson-Longmire incision made, extending laterally to the zygoma. (**b**) Osteotomy site to separate maxilla from zygoma, medially along the inferior orbital rim and in midline. (**c**) Transoral view showing palatal split. Entire maxilla swung laterally together with cheek flap and masseter muscle

infratemporal region (combination with lateral approach required) [20].

7.4.1 Procedure

1. Patient is placed in a supine position and draped.
2. The authors prefer a preliminary tracheostomy.
3. Skin incision: Weber-Ferguson-Longmire incision is made.
4. The vertical incision limb is through the upper lip and is continued between the central incisors and onto the hard palate until the junction of hard and soft palate.
5. The incision is then curved laterally to run behind the maxillary tuberosity.
6. The facial incision is made through the subcutaneous, muscular and periosteal layers to expose the planned osteotomy line.
7. The osteotomy is begun by separating the zygoma from the maxilla, moving medially along the infraorbital rim until the frontal process is divided from the anterior maxillary wall. Then the medial maxillary wall is separated from the midline nasal complex in an antero-posterior fashion.
8. The posterior wall is released using an osteotome inserted through the antrum.
9. The palatal bone is incised, and a midline osteotomy is fashioned.
10. The pterygoid plates are separated from maxillary tuberosity by using a curved osteotome.
11. Finally, the maxilla can be swung laterally attached to the cheek flap and the masseter muscle.
12. The nasopharynx including the cartilaginous ET bilaterally becomes well exposed. This allows en bloc resection of the lesion.
13. Additional ipsilateral turbinectomy gives tissue for free graft that can be placed on exposed bone in the epipharynx. Nasal packing keeps the graft in place.
14. Maxilla is returned to its anatomical position and fixed to the zygoma and contralateral maxilla with miniplates.
15. Alveolar ridges are approximated by using a preoperatively fashioned dental splint.
16. The facial and intraoral incisions are closed in layers.
17. A grommet should be inserted if cartilaginous ET was resected.
18. Oral feeding can be started after 72 h.
19. Any non-resorbable nasal packs should be removed on the seventh post-operative day and the dental plate after about a month or when all the mucosal wounds have healed.

7.4.2 Advantages

Maxillary swing is relatively a simple technique, which gives wide exposure and good cosmetic and functional results.

7.4.3 Disadvantages

However, it gives very limited parapharyngeal and infratemporal exposure. Lack of access to the neck renders lack of vascular control. Patient will also suffer from post-operative trismus from pterygoid myositis or fibrosis. In some patients, the maxilla can become necrosed.

7.5 Lateral Infratemporal Fossa Approach Type C

This procedure (Fig. 7.5) is indicated in infratemporal fossa (ITF) tumours that extend into the temporal bone with involvement of the epipharynx such as juvenile angiofibroma class III b–IV (Fisch) and nasopharyngeal carcinoma (NPC). This procedure is contraindicated in lesions extending into the sella, contralateral middle fossa or anterior skull base [21, 22].

7.5.1 Procedure

1. A postauricular C-shaped incision is made that extends superiorly into the temporal region and inferiorly into the neck.

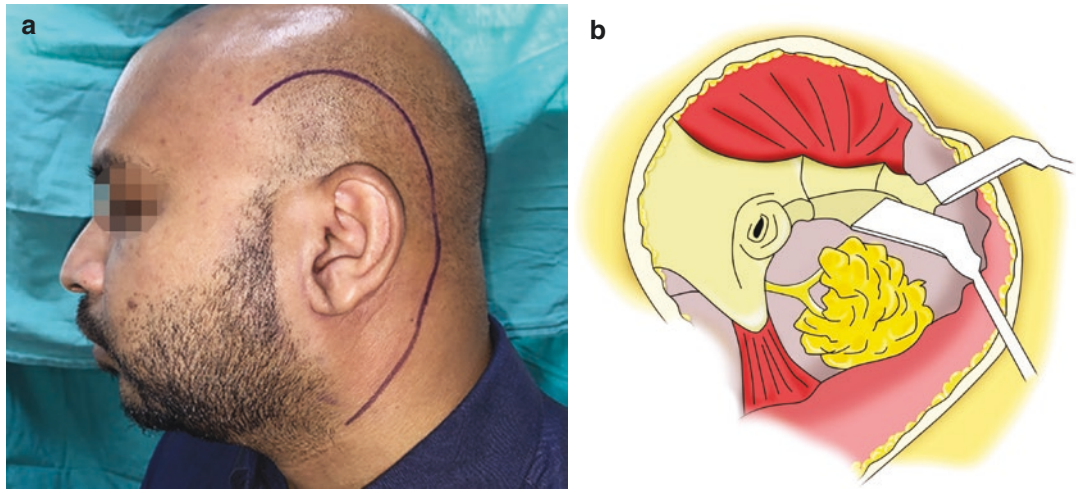


Fig. 7.5 Lateral infratemporal fossa approach, type C. (**a**) Skin incision from the temporal region extending inferiorly to the neck. (**b**) Skin flap together with pinna reflected anteriorly and the main trunk of facial nerve is identified to divide zygomatic branch anterior to the temporomandibular joint without damaging frontal branch

2. The temporalis muscle, mastoid and zygoma are exposed. A periosteal flap is elevated, and the external auditory canal is transected and closed in a blind sac.
3. The pinna and skin flap are reflected anteriorly.
4. For vascular control, the neck is dissected so that carotid and jugular vessels are accessible.
5. The main trunk of the facial nerve is identified together with its frontal branch.
6. The zygomatic arch is exposed and divided anterior to the temporomandibular joint (TMJ) and just behind the orbital rim preserving the frontal branch.
7. The zygomatic arch is reflected inferiorly attached to masseter muscle.
8. The temporalis muscle and fascia are elevated from the temporal fossa and reflected inferiorly, exposing the superolateral quadrant of ITF.
9. A subtotal petrosectomy is done in which the sigmoid sinus, ICA and middle fossa dura are skeletonized with preservation of the labyrinth.
10. The TMJ capsule is exposed followed by excision of the articular disc and displacing the condyle inferiorly.
11. Additional space can be established by release of the sphenomandibular and stylomandibular ligament.
12. The glenoid fossa is resected to give extensive exposure of ITF, and this can be enlarged further by division of the mandibular nerve and middle meningeal artery.
13. The pterygoid process with lateral and medial plates is removed, giving access to the anterior third of the ET and nasopharynx.
14. The nasopharyngeal cavity is entered through incision of the pharyngobasilar membrane and nasopharyngeal mucosa. Subsequent dissection is done to complete the resection.
15. To close the defect, the temporalis muscle can be rotated into it. The alternative is to use the latissimus dorsi flap.
16. The TMJ is reconstructed by interposing temporalis muscle between the condyle of the mandible and the middle fossa dura.
17. The skin and subcutaneous tissue are closed in layers.
18. Drain is placed and secured.
19. Normal oral feeding can be started on the first post-operative day.

7.5.2 Advantages

The type C lateral ITF approach gives a wide and direct access to the infratemporal region, including the parasellar and temporal regions. It also provides short working distance.

7.5.3 Disadvantages

The drawbacks of this procedure are transient post-operative trismus, malocclusion and hypaesthesia of the lower half of the face and ipsilateral tongue (V3). As the ET is resected, it results in permanent conductive hearing loss. Temporary frontal facial paresis occurs in 30%.

7.6 Subtemporal-Preauricular Infratemporal Fossa Approach

This is a combined approach (Fig. 7.6) requiring an established team comprising a lateral skull base ENT surgeon and a neurosurgeon. This approach is not often performed, but it is done for large ITF tumours (T4) encroaching the nasopharynx, the cavernous sinus and the middle cranial fossa. It is contraindicated in bilateral optic chiasm or ICA involvement, or in lesions extending to the posterior cranial fossa for which a combination with a retrosigmoid or transotic approach is necessary [23].

7.6.1 Procedure

1. This procedure requires preoperative tracheostomy.
2. The ipsilateral scalp, face, neck, lower abdomen and thigh are prepared and draped.
3. An extended Blair incision is made and a cervico-facial flap raised.
4. The facial nerve trunk is identified, and its major branches are dissected peripherally.
5. The parotid gland is raised from the masseteric fascia.
6. The temporal branches of external carotid are ligated.

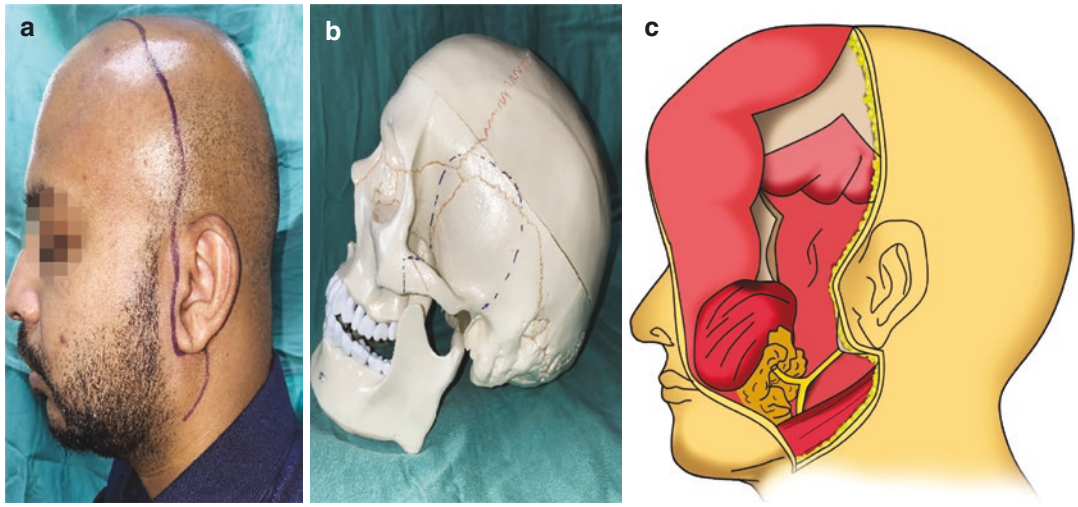


Fig. 7.6 Subtemporal preauricular infratemporal fossa approach. (**a**) An extended Blair incision. (**b**) Osteotomy site for the zygomatic arch including in a fronto-temporal craniotomy; also to include glenoid fossa and floor of the middle fossa lateral to the foramen spinosum and ovale. (**c**) Removal of more bone medial to glenoid fossa and greater wing of the sphenoid giving access to the Eustachian tube. Removal of the pterygoid process giving access to the anterior Eustachian tube and posterolateral aspect of nasopharynx

7. The temporalis muscle is elevated from the temporal squama.
8. Osteotomies of the zygomatic arch allow inferior reflection of the temporalis muscle.
9. A fronto-temporal craniotomy is then fashioned, which includes the root of the zygomatic arch, the glenoid fossa and the floor of the middle fossa lateral to the foramen spinosum and ovale, extending anteriorly to the pterion (Fig. 7.6c).
10. Using a microscope, further medial dissection elevates the dura to expose the arcuate eminence, greater superficial petrosal nerve, middle meningeal artery and mandibular nerve (V3).
11. The middle meningeal artery is ligated and divided.
12. The V3 can be retracted if it is not invaded by the lesion.
13. Through this exposure, lesions around the middle third of the Eustachian tube can be resected.
14. Removal of more bone medial to the glenoid fossa and antero-medially along the greater wing of the sphenoid gives further access to the anterior Eustachian tube and pterygopalatine fossa.
15. Selective removal of the pterygoid process allows access to the anterior third and pharyngeal ostium of the ET and to the posterolateral aspect of the nasopharynx.
16. Further dissection along the pharyngobasilar membrane exposes the entire nasopharyngeal soft-tissue sleeve allowing circumferential resection.
17. If the lesion extends to the cavernous and petrous ICA, the ET is removed completely, which gives access to the horizontal and vertical petrous segments of the ICA.
18. The floor of the cavernous sinus can be accessed by unroofing the horizontal segment of the ICA exposed.
19. Further exposure of the inferior and medial border of the cavernous ICA is to be attained by removal of the pterygoid root and the lateral walls of the sphenoid.

7.6.2 Advantages

This approach gives a wide exposure of the infratemporal region, the petrous and cavernous segments of the internal carotid and the cavernous sinus. It also provides good access for reconstruction.

7.6.3 Disadvantages

The procedure requires craniotomy. The postoperative CSF leakage can be as high as 15–20%. It does not give adequate exposure of the posterior petrous bone and otic capsule.

7.7 Facial Translocation

This approach (Fig. 7.7) is suitable for extensive tumours (T4) of the anterior and middle skull base extending into the orbit, paranasal sinus and posterior cranial fossa with intracranial involvement. However, it is contraindicated in tumours involving the bilateral optic chiasm and ICA [24].

7.7.1 Procedure

1. The patient is supine with the head turned 30–40° to the opposite side and positioned in an open head rest or Mayfield clamp.
2. The ipsilateral scalp, face, neck, lower abdomen and thigh are prepared and draped.
3. A modified Weber-Ferguson incision is made in order to create a wide cheek flap pedicled on the facial and inferior labial vessels.
4. The cheek flap includes the lateral third of the upper lip, the entire cheek soft tissue including the maxillary periosteum, lower lid, facial nerve and parotid gland.
5. The incision starts from the philtrum of the lip and is continued along the nasal silhouette.
6. It then passes horizontally transecting the medial canthus and follows the lower eyelid

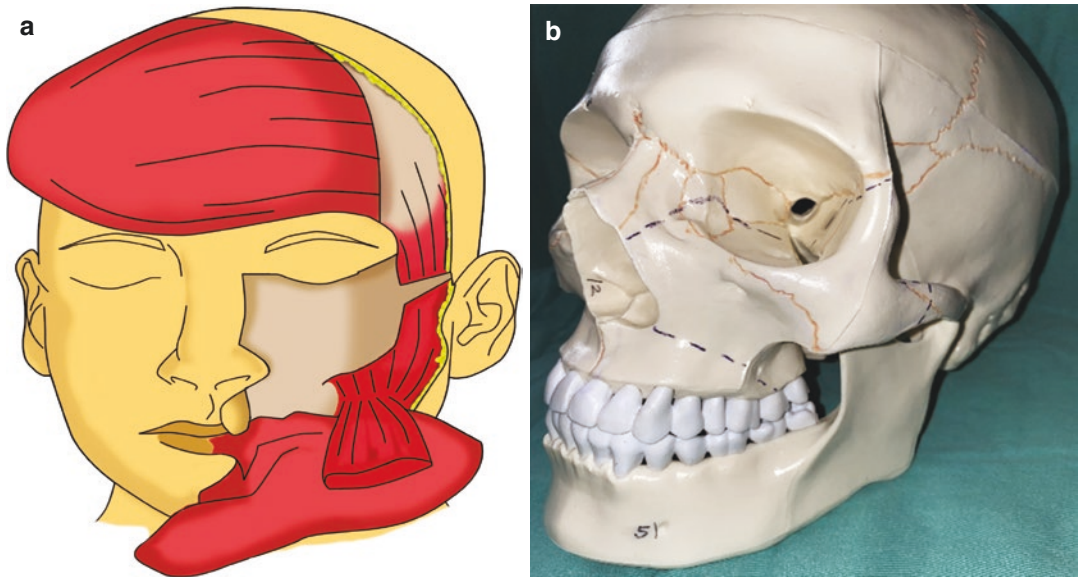


Fig. 7.7 Facial translocation. (**a**) A fronto-temporal scalp flap reflected to the midline, while the cheek flap along with the transected masseter muscle reflected inferiorly to the level of hard palate. Upper lip is divided and extended to the last molar. (**b**) Osteotomy sites passing through frontozygomatic and temporozygomatic sutures, inferiorly at the level of hard palate and medially the orbit and tip of the inferior orbital fissure to the lateral orbital wall to create a orbito-maxillo-zygomatic free bone flap

dividing the conjunctiva and the lateral canthus. It then joins the preauricular incision.

7. The frontal branches of the facial nerve can be transected and tagged for later reconstructive neurorrhaphy.
8. The soft tissues of the cheek are elevated from the facial skeleton and in doing so the infraorbital nerve is transected and the masseter muscle is divided just below the zygomatic arch.
9. A bicoronal incision is then made that meets the lateral extension of the previous transfacial incision. This allows elevation of soft tissues from the temporal muscle and frontal bone, thus creating a fronto-temporal scalp flap.
10. The fronto-temporal scalp flap to the midline, while the cheek flap along with transected masseter muscle, is reflected inferiorly to the level of the hard palate.
11. This manoeuvre requires division of the upper lip and extension of the lip incision along the gingivolabial sulcus as far as the last molar tooth.
12. An orbito-maxillo-zygomatic free bone flap is created.
13. Osteotomies pass through the frontozygomatic and temporozygomatic sutures laterally; inferiorly through the maxilla at the level of the nasal floor parallel to the hard palate to reach the pterygopalatine fossa; medially through the orbit in line with the inferior part of the lacrimal fossa and the tip of the inferior orbital fissure; and laterally continue along the lateral orbital wall to join the transected frontozygomatic suture.
14. The posterior wall of the maxilla is freed from the pterygoid plates with a chisel.
15. A subperiosteal osteotomy of the coronoid process and mandibular neck allows the temporal muscle and fascia to be mobilized from the temporal fossa and reflected inferiorly along with the mandible.
16. This gives access to the nasopharynx, pterygoid process, anterior surface of the sphenoid as well as infratemporal fossa.
17. Further removal of the pterygoid processes and muscles exposes the lateral wall of the

nasopharynx and foramen rotundum with the maxillary nerve.
18. If even more access is required, it can be achieved by removal of bone from any of the exposed surfaces, and by doing this the entire infratemporal, petroclival and cavernoclival borders can be visualized.
19. Reconstruction follows the previously described steps, starting with watertight sealing of the dura with bulky microvascular free flaps (e.g. rectus abdominis, latissimus dorsi), which also eliminates the dead space and provides a well-vascularized barrier between the dura and the nasopharyngeal mucosa.
20. The free bone flaps are replaced and fixed with miniplates.
21. The cheek flap is realigned, and the medial and lateral canthal ligaments are reattached with stents being placed in the lacrimal duct.
22. Finally, the frontal branches of the facial nerve are reanastomosed and the skin soft tissue is closed in layers.
23. Nasal packings are introduced to prevent obliteration of the nasal airway by encroachment of the reconstructive tissue in the operative defect.
24. Nasogastric feeding is necessary for a few days, but oral alimentation can begin during the first week.
25. Any non-resorbable nasal packs are removed on the eighth day.
26. Lacrimal stents are left in place for 3 weeks.

7.7.2 Advantages

Facial translocation gives direct wide exposure of the anterior and middle cranial base and good access for reconstructions. This enables radical resection of extensive tumours.

7.7.3 Disadvantages

The major drawback of this procedure is that this is a complex multistep surgical technique requiring craniotomy. Therefore, there is the risk of CSF leak. This also requires additional procedure to drain the nasolacrimal duct. The dissection also results in temporary or permanent palsy of the frontal branches of the facial nerve. There is high risk of post-operative osteonecrosis.

7.8 Endoscopic Endonasal Transpterygoid Nasopharyngectomy (EETN)

The primary treatment for untreated nasopharyngeal carcinoma (NPC) is radiotherapy for early-stage lesion and concurrent chemoradiation for advanced tumour. The reported incidence of local recurrence was approximately 8–58% [25–27]. Local recurrent NPC can be treated with salvage re-irradiation or surgery [28]. Ridge recommended that resection of locally discrete recurrent NPC should be considered unless the patient is not fit for operation [29]. Surgery should be considered for patients presenting with residual or recurrent tumour after radiotherapy or chemoradiotherapy, and for patients with glandular or mesenchymal differentiation tumours as initial treatment, which are poorly responsive to radiotherapy [30]. Furthermore, high-dose re-irradiation may result in severe complications like osteoradionecrosis, brain necrosis, radiation-induced myelitis, hypopituitarism and trismus [31, 32].

Endoscopic endonasal transpterygoid nasopharyngectomy (EETN) has emerged as a viable treatment option for local recurrent NPC with minimal invasiveness, avoiding morbidity from external approaches and facial scar. A literature review by Emanuelli et al. revealed that the endoscopic method attained a higher negative surgical margin of 93.75% than external approach (71.6%) [33].

7.8.1 Patient Selection

Patient selection is perhaps the most important aspect of effectively treating patients with endoscopic endonasal transpterygoid nasopharyngectomy (EETN). Generally speaking, patients

categorized as rT1, those categorized as rT2 with minimal parapharyngeal extension and selected patients categorized as rT3 (involvement of floor of sphenoid sinus) can be treated with EETN [34]. Exclusion criteria for patients can be based on disease factors and patient factors. Disease factors for exclusion include significant parapharyngeal space extension, internal carotid artery involvement, cavernous sinus with multiple cranial nerve involvement, brain parenchymal involvement and presence of distant metastasis. Patient factors include those patients who are medically unfit to tolerate surgery and undergo general anaesthesia.

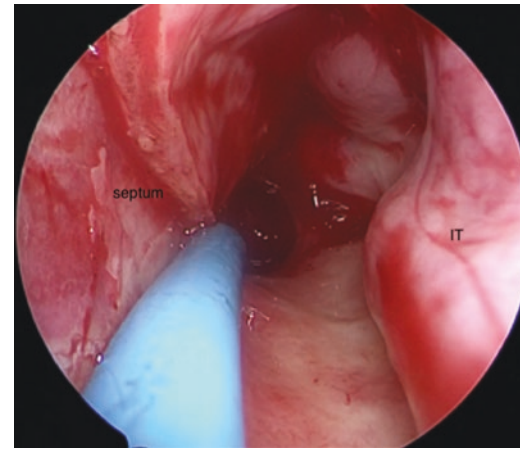


Fig. 7.8 Creating HB nasoseptal flap

7.8.2 Surgical Technique

The surgery is done under general anaesthesia with the patient lying in supine position. The nasal cavities are decongested with Moffett's solution [30] for 15–30 min. The solution contains 1 mL adrenaline 1:1000, 2 mL of 10% cocaine and 4 mL of 8.4% sodium bicarbonate mixed together with 13 mL of water for injection. A topical decongestant of Moffett's solution could reduce nasal blood flow, optimizing surgical field for surgery. Infiltration of both middle turbinates and nasal septum with a solution of lidocaine 1% and epinephrine 1/100,000 enhances the haemostasis. Surgery proceeds via a purely endoscopic endonasal approach using a 0° and 30° rod lens endoscope. A fundamental premise of the endonasal endoscopic approach is that the two surgeons work concomitantly, using a bimanual, three/four-handed technique via both nostrils and nasal cavities. This facilitates dynamic visualization as well as bimanual dissection, which is vital for depth perception, traction and countertraction and for maintenance of a blood-free surgical field [30].

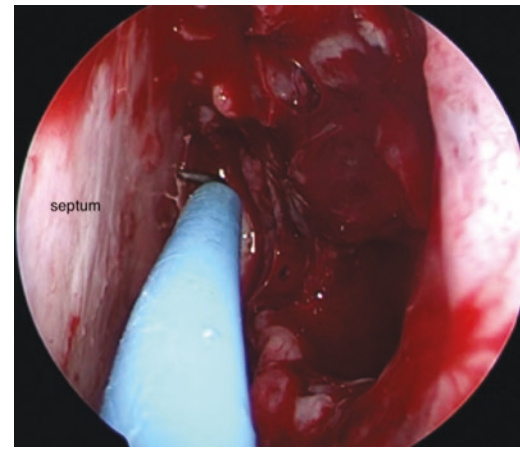


Fig. 7.9 Creating Caicedo flap

7.8.2.1 Nasoseptal Flap

Firstly, the Hadad-Bassagasteguy nasoseptal flap (HBF) should be harvested from the contralateral side of the tumour [30, 35]. It is critical to harvest the HBF from the contralateral side because its pedicle and proximal blood supply would be surrendered ipsilateral to the transpterygoid dissection. Later, a Caicedo reverse flap is transposed from the contralateral side to cover the HBF donor defect [35, 36]. Clinical harvesting of these septal flaps presumes that the tumour does not involve this area. If tumour involves the nasal septum, other vascularized flaps can be considered (Figs. 7.8 and 7.9).

7.8.2.2 Sinonasal Corridor

Later, the surgery continues with enlarging the natural sinonasal corridor ipsilateral to the lesion by removing the inferior half of the right middle turbinate and completing an uncinectomy, large middle meatal nasomaxillary window, and anterior and

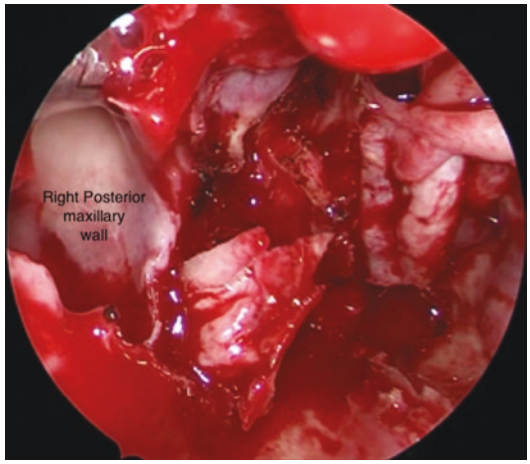


Fig. 7.10 Right medial maxillectomy performed as part of the transpterygoid approach

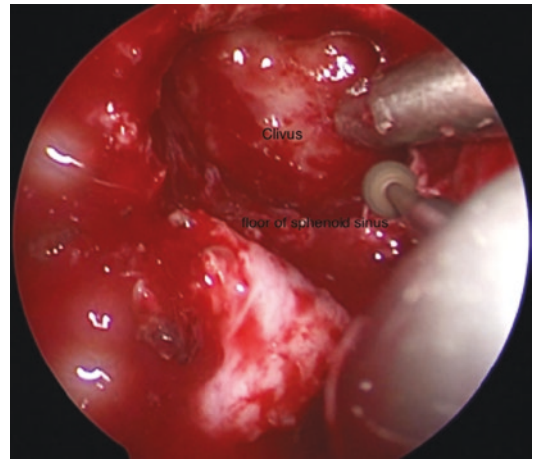


Fig. 7.11 Drilling anterior wall and floor of the sphenoid sinus

posterior ethmoidectomies. Later, a medial maxillectomy is performed to expose the entire height of the posterior wall of the maxillary sinus and allow an extended dissection of the pterygopalatine fossa. This medial maxillectomy is limited anteriorly by the nasolacrimal duct, which acts like a fulcrum point, preventing free movement of the scope laterally. Endoscopic Denker's approach can be performed to further increase the lateral angle of exposure and optimize instrument manoeuvrability if needed [37]. Endoscopic Denker's approach is a procedure to remove the piriform aperture, as well as the anterior maxillary wall, until the lateral wall of the antrum is in direct and full view, particularly the entire infratemporal fossa (Fig. 7.10).

7.8.2.3 Posterior Septectomy

Additional lateral control is obtained by bringing the instruments from the contralateral side of the nose through a posterior septectomy. A generous posterior bony septectomy allows a bimanual technique traversing both sides of the nasal cavity. This extensive posterior septectomy allows visualization of the entire posterior wall of the maxillary sinus using a 0° endoscope that crosses over the contralateral side of the nose.

7.8.2.4 Inferior Sphenoidectomy

The anterior face of the sphenoid sinus is often opened early during the approach, enlarging the sphenoid ostium after completing the ethmoidectomies. As the superior part of the sphenoid crest is removed, the floor of sella turcica and intersinus and intrasinus septations, as well as the lateral walls of the sphenoid sinus, come into direct view. The lateral walls of the sphenoid and the medial pterygoid plates (lateral wall of the posterior choana) form a vertical strut that intersects the floor of the sphenoid sinus. After complete removal of the vomer, the intersinus septum and the sphenoid sinus floor, sphenoidectomy should extend superiorly to be in plane with the roof of the nose and laterally to be in plane with the laminae papyracea bilaterally [38]. Complete removal of the sphenoid sinus floor is performed until the cavity is flush with the clivus (Fig. 7.11).

7.8.2.5 Transpterygoid Dissection

Transpterygoid dissection starts with the identification of the vidian nerve proximal to the pterygopalatine ganglion, as it exits from the vidian canal. The vidian nerve can be localized following the palatovaginal canal laterally or by drilling its canal starting at the pterygoid wedge. The vidian nerve, within the pterygoid canal, courses towards the second genu of the internal carotid artery between the horizontal and vertical segments. For the most part, the vidian canal remains inferior to the second genu of the ICA; therefore, initial drilling in a 3 to 9 o'clock orientation helps

to prevent injury to the ICA. In some cases, the superior aspect of the canal is covered just with a very thin bone or may even be dehiscent, thus exposing the nerve in the floor of the sphenoid sinus [38].

The maxillary division of the trigeminal nerve passes through the foramen rotundum as it courses from Meckel's cave into the pterygopalatine fossa [39]. The maxillary nerve can also be identified in its canal coursing the lateral wall of the sphenoid sinus. The pharyngeal end of the Eustachian tube or torus tubarius is just posterior to the pterygoid process. Removal of the pterygoid process exposes the cartilaginous Eustachian tube. The parapharyngeal segment of the ICA is posterior to the Eustachian tube in most of the cases.

All these landmarks are crucial to identify during the transpterygoid approach before tumour extirpation (Figs. 7.12 and 7.13).

7.8.2.6 Tumour Extirpation

Tumour removal begins by marking out at least 1 cm margin if technically possible around the tumour. The mucosal cuts are made with needle-point electrocautery, which helps with haemostasis. The superior and posterior dissection occurs by elevating the mucoperiosteum from the floor of the sphenoid sinus and the clivus posteriorly. The dissection proceeds inferiorly to the level of the soft palate, and the prevertebral musculature deep to the pharyngobasilar fascia and prevertebral fascia are encountered [40]. Electrocautery or Kerrison rongeurs can be used and are effective at removing portions of the prevertebral muscle and fascia, as these structures are quite resilient. The muscles are included in the en bloc resection to get the better margin of clearance.

Laterally, the medial pterygoid plate and pterygoid process are exposed, above which lies the sinus of Morgagni, through which passes the Eustachian tube and tensor veli palatini muscle. These structures can be excised along with the levator palatini muscle to expose the parapharyngeal tissues [41]. The Eustachian tube cartilage laterally is identified and included in the specimen. Following complete tumour removal, margin status is confirmed by sending circumferential and deep margins for frozen section analysis (Figs. 7.14 and 7.15).

7.8.2.7 Nasopharyngeal Reconstruction

Reconstruction with a vascularized pedicle flap at the nasopharyngeal defect facilitates the healing of the defect, resists irradiation and protects the ICA against exposure and blowout [30, 39]. The nasoseptal flap or HBF is rotated into the nasopharyngeal defect. The edges of the flap are allied well to cover the bare area, especially exposed bony portion at the clivus. Absorbable

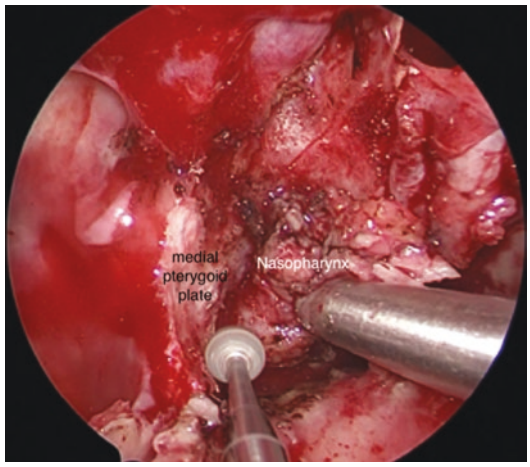


Fig. 7.12 Drilling pterygoid base and medial pterygoid plate

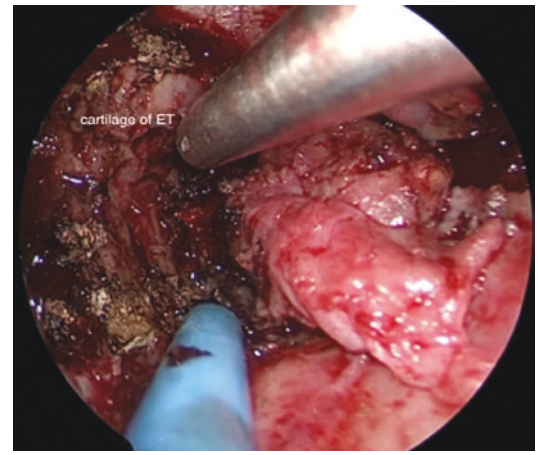


Fig. 7.13 Resecting of cartilage part of Eustachian tube

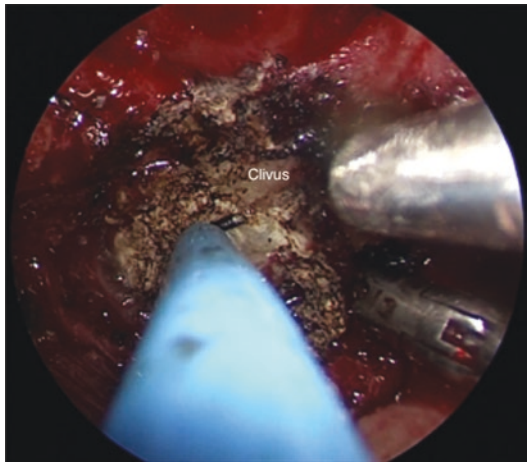


Fig. 7.14 Resecting posteriorly at prevertebral muscle

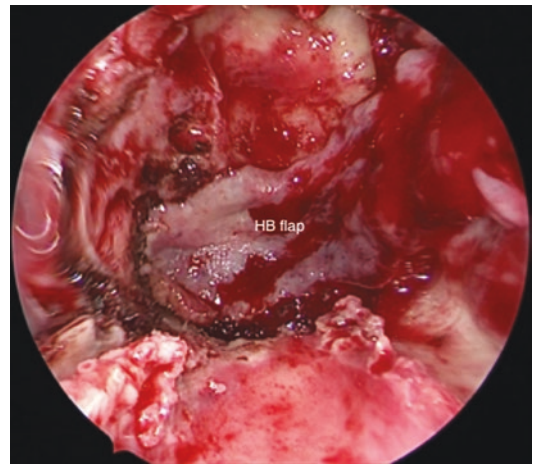


Fig. 7.16 Placing of HB flap to the resected area

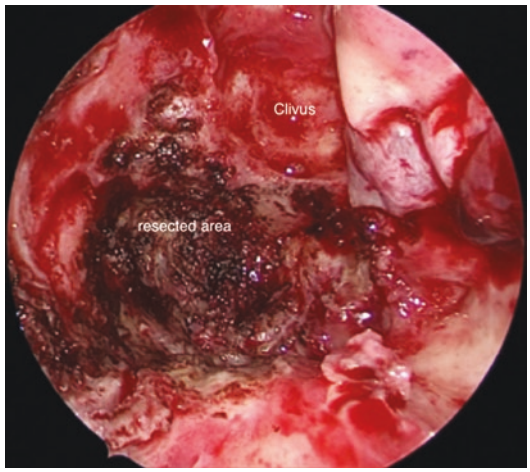


Fig. 7.15 Final view of resection of right FOR of nasopharynx

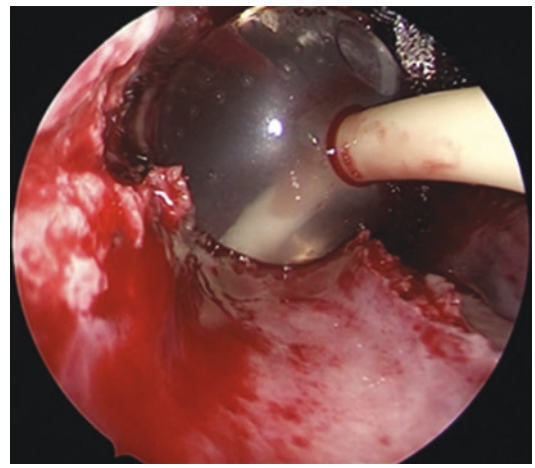


Fig. 7.17 Catheter tube with balloon to hold the flap at place

gelatin sponges are placed on the flap, and a Foley catheter is used to support the nasoseptal flap against the nasopharyngeal defect. In cases where nasoseptal flap is unavailable, a lateral nasal wall flap can be harvested for reconstruction. Other reconstructive options include healing by secondary intention or use of regional flaps such as pedicled temporoparietal fascia flap (Figs. 7.16 and 7.17).

Following reconstruction, the nasal cavity is thoroughly inspected for haemostasis followed by careful suction of the nasopharyngeal cavity.

7.9 Post-operative Care and Complications

The patient is admitted to a standard ward unit and is usually discharged from hospital within 2–3 days. After discharge from the ward, the patients are generally seen every 1 to 2 weeks to undergo endoscopic examination. During these clinic visits, decrusting is performed, paying careful attention not to disrupt the nasoseptal flap or any other flaps that were laid on. Patients are asked to liberally use sodium bicarbonate mixed with mupirocin nasal rinse every 4 h. The re-

epithelialization process at the operation site can take up to 3 or more months, even with nasoseptal flap. Post-operative headache is a common complaint following EETN due to exposed bone. Covering exposed bone with pedicled nasoseptal flap can reduce this incidence significantly.

Serous otitis media is another common complication encountered in the post-operative period. This can be managed by myringotomy with tympanostomy tube insertion or amplification with hearing aids [40].

Post-operative epistaxis can occur secondary to bleeders that are not secured during the surgery, especially when nasoseptal flap is not used, and secondary to bleeding from posterior septal artery. Other possible surgical sequelae include xerophthalmia secondary to injury of the vidian nerve, numbness in the V2 distribution, skull base injury including cerebrospinal fluid leak and injury to the internal carotid artery in its parapharyngeal, petrous or clival portions.

7.10 Miscellaneous

Holistic approach is a must in managing patients with nasopharyngeal carcinoma, which includes the surveillance of disease and optimizing the care, nutrition and pain management. Direct visualization is the most sensitive method to demonstrate recurrence of NPC, and about 27.8% of deep-seated recurrent NPC was detected by MRI [42]. However, post-radiation mucositis or crust may limit endoscopic examination of the mucosal surface. Narrowband imaging (NBI) and Storz Professional Image Enhancement System (SPIES) are able to provide image-enhanced endoscopy to increase the diagnostic sensitivity of primary or recurrent tumours. These systems are able to recognize the superficial changes of neoangiogenesis due to alterations of the vessel architecture depending on the degree of dysplasia [43]. A study reflected that NBI offers a timely, convenient and highly reliable assessment of mucosal recurrent NPC, which accounts for about 62.5% of the patients with early (T1) or occult recurrent NPC that were detected with positive findings by NBI [44]. Image-enhanced endoscopy also assists in the targeted biopsy of the suspicious area and thus higher diagnosis accuracy. Restaging of NPC can be performed by using either magnetic resonance imaging (MRI), combined positron emission tomography (PET) and computed tomography (CT) or both as a combination is more accurate than the use of either technique individually [42].

In the early part of the disease, even with cranial nerve involvement, nasopharyngeal tube feeding will be sufficient. However, in extensive disease, PEG or gastrostomy tube may be warranted. Hung et al. have demonstrated that progesterone analogues such as megestrol acetate (MA) and medroxyprogesterone (MPA) improve the quality of life in terms of performance status, pain control and plasma EBV DNA load in patients with locally recurrent/metastatic NPC under palliative care. Both MA and MPA are orally active synthetic analogues of natural steroid progesterone [45].

7.11 Conclusion

Selection of appropriate technique is necessary according to the extension of the lesion. Therefore, detailed studying of the pathology is essential. The decision-making should always be done in a multidisciplinary setting. Careful selection of the patient for surgical treatment is extremely vital. The operation is best carried out in centres which have established working teams and regular exposure to such patients. Surgeons need to give equal emphasis to the rehabilitation of swallowing and hearing rehabilitation.

The advances in endoscopic equipment and clarity are best utilized to make the above procedures an open endoscopic combined approach. Endoscopic endonasal transpterygoid nasopharyngectomy (EETN) is a feasible approach for the surgical treatment of selected primary and recurrent nasopharyngeal malignancy tumours. The surgical technique requires trained and experienced team with specialized equipment. This technique has relatively low morbidity with promising preliminary outcomes and local control of the disease that is comparable to conventional techniques.

References

1. Chen YP, Chan A, Le QT, Blanchard P, Sun Y, Ma J. Nasopharyngeal carcinoma. Lancet (London, England). 2019;394(10192):64–80. https://doi.org/10.1016/S0140-6736(19)30956-0.
2. Devi BC, Pisani P, Tang TS, Parkin DM. High incidence of nasopharyngeal carcinoma in native people of Sarawak, Borneo Island. Cancer Epidemiol Biomarkers Prev. 2004;13(3):482–6.
3. Aziz A, Ramli RR, Mohamad I, Bhavaraju VMK. Young nasopharyngeal carcinoma: a review of an 8-year experience in the East Coast Malaysia Hospital. Egypt J Otolaryngol. 2017;33:490–4.
4. Suzina SA, Hamzah M. Clinical presentation of patients with nasopharyngeal carcinoma. Med J Malaysia. 2003;58(4):539–45.
5. Abdullah B, Alias A, Hassan S. Challenges in the management of nasopharyngeal carcinoma: a review. Malaysian J Med Sci (MJMS). 2009;16(4):50–4.
6. Hao SP, Tsang NM. Surgical management of recurrent nasopharyngeal carcinoma. Chang Gung Med J. 2010;33(4):361–9.
7. Thompson LD. Update on nasopharyngeal carcinoma. Head Neck Pathol. 2007;1(1):81–6. https://doi.org/10.1007/s12105-007-0012-7.
8. Petersson BF, Bell D, El-Mofty SK, Gillison M, Lewis JS, Nadal A, Nicolai P, Wenig BM. Tumours of the nasopharynx: nasopharyngeal carcinoma. In: El-Naggar AK, Chan JKC, Grandis JR, Takata T, Slootweg PJ, editors. WHO classification of head and neck tumours. Lyon: IARC; 2017. p. 65–9.
9. Tsang RK, Kwong DL. Scott-Brown's otorhinolaryngology and head and neck surgery. 8th ed. Boca Raton: CRC Press; 2018.
10. Wei WI, Mok VW. The management of neck metastases in nasopharyngeal cancer. Curr Opin Otolaryngol Head Neck Surg. 2007;15(2):99–102. https://doi.org/10.1097/MOO.0b013e3280148a06.
11. Wang SY, Lou JL, Chen J, Zhang SZ, Guo L. Salvage surgery for neck residue or recurrence of nasopharyngeal carcinoma after primary radiotherapy: options of surgical methods and regions. World J Surg Oncol. 2016;14:89. https://doi.org/10.1186/s12957-016-0822-8.
12. Lin KW, Huang TC, Cheng HT. Utilization of anterolateral thigh flap and transverse cervical recipient vessels for head and neck cancer patients with former neck dissection and irradiation: a case series study. Ann Plast Surg. 2019;82(4):415–9. https://doi.org/10.1097/SAP.0000000000001647.
13. Tan NC, Lin PY, Chiang YC, Chew KY, Chen CC, Fujiwara T, Kuo YR. Influence of neck dissection and preoperative irradiation on microvascular head and neck reconstruction—analysis of 853 cases. Microsurgery. 2014;34(8):602–7. https://doi.org/10.1002/micr.22270.
14. Song M, Chen WK, Zhang Q, Chen SW, Zhuang SM, Yang AK. Irradiation of the recipient site does not adversely affect successful free flap transfer in the repair of head and neck defects after salvage surgery for recurrent nasopharyngeal carcinoma originally treated with radiotherapy. J Plast Surg Hand Surg. 2013;47(1):40–5. https://doi.org/10.3109/2000656X.2012.729510.
15. Williams WG, Lo LJ, Chen YR. The Le Fort I-palatal split approach for skull base tumors: efficacy, complications, and outcome. Plast Reconstr Surg. 1998;102(7):2310–9. https://doi.org/10.1097/00006534-199812000-00006.
16. Donald PJ, Bernstein L. Transpalatal excision of the odontoid process. Otolaryngology. 1978;86(5) https://doi.org/10.1177/019459987808600511.
17. Kennedy DW, Papel ID, Holliday M. Transpalatal approach to the skull base. Ear Nose Throat J. 1986;65(3):125–33.
18. Biller HF, Shugar JM, Krespi YP. A new technique for wide-field exposure of the base of the skull. Arch Otolaryngol (Chicago, Ill: 1960). 1981;107(11):698–702. https://doi.org/10.1001/archotol.1981.00790470046011.
19. Krespi YP, Sisson GA. Transmandibular exposure of the skull base. Am J Surg. 1984;148(4):534–8. https://doi.org/10.1016/0002-9610(84)90383-0.
20. Wei WI, Lam KH, Sham JS. New approach to the nasopharynx: the maxillary swing approach. Head Neck. 1991;13(3):200–7. https://doi.org/10.1002/hed.2880130306.
21. Andrews JC, Fisch U, Valavanis A, Aeppli U, Makek MS. The surgical management of extensive nasopharyngeal angiofibromas with the infratemporal fossa approach. Laryngoscope. 1989;99(4):429–37. https://doi.org/10.1288/00005537-198904000-00013.
22. Fisch U. The infratemporal fossa approach for nasopharyngeal tumors. Laryngoscope. 1983;93(1):36–44. https://doi.org/10.1288/00005537-198301000-00007.
23. Sekhar LN, Schramm VL Jr, Jones NF. Subtemporal-preauricular infratemporal fossa approach to large lateral and posterior cranial base neoplasms. J Neurosurg. 1987;67(4):488–99. https://doi.org/10.3171/jns.1987.67.4.0488.
24. Janecka IP, Sen CN, Sekhar LN, Arriaga M. Facial translocation: a new approach to the cranial base. Otolaryngol Head Neck Surg. 1990;103(3):413–9. https://doi.org/10.1177/01945998901030031.
25. Suárez C, Rodrigo JP, Rinaldo A, Langendijk JA, Shaha AR, Ferlito A. Current treatment options for recurrent nasopharyngeal cancer. Eur Arch Otorhinolaryngol. 2010;267(12):1811–24. https://doi.org/10.1007/s00405-010-1385-x.
26. Ma J, Mai HQ, Hong MH, Min HQ, Mao ZD, Cui NJ, Lu TX, Mo HY. Results of a prospective randomized trial comparing neoadjuvant chemotherapy plus radiotherapy with radiotherapy alone in patients with locoregionally advanced nasopharyngeal carcinoma. J Clin Oncol. 2001;19(5):1350–7. https://doi.org/10.1200/JCO.2001.19.5.1350.
27. Lin JC, Liang WM, Jan JS, Jiang RS, Lin AC. Another way to estimate outcome of advanced nasopharyngeal

carcinoma—is concurrent chemoradiotherapy adequate? Int J Radiat Oncol Biol Phys. 2004;60(1):156–64. https://doi.org/10.1016/j.ijrobp.2004.03.002.
28. You R, Zou X, Hua YJ, Han F, Li L, Zhao C, Hong MH, Chen MY. Salvage endoscopic nasopharyngectomy is superior to intensity-modulated radiation therapy for local recurrence of selected T1-T3 nasopharyngeal carcinoma—a case-matched comparison. Radiother Oncol. 2015;115(3):399–406. https://doi.org/10.1016/j.radonc.2015.04.024.
29. Ridge JA. Squamous cancer of the head and neck: surgical treatment of local and regional recurrence. Semin Oncol. 1993;20(5):419–29.
30. Al-Sheibani S, Zanation AM, Carrau RL, Prevedello DM, Prokopakis EP, McLaughlin N, Snyderman CH, Kassam AB. Endoscopic endonasal transpterygoid nasopharyngectomy. Laryngoscope. 2011;121(10):2081–9. https://doi.org/10.1002/lary.22165.
31. To EW, Lai EC, Cheng JH, Pang PC, Williams MD, Teo PM. Nasopharyngectomy for recurrent nasopharyngeal carcinoma: a review of 31 patients and prognostic factors. Laryngoscope. 2002;112(10):1877–82. https://doi.org/10.1097/00005537-200210000-00033.
32. Chang JT, See LC, Liao CT, Ng SH, Wang CH, Chen IH, Tsang NM, Tseng CK, Tang SG, Hong JH. Locally recurrent nasopharyngeal carcinoma. Radiother Oncol. 2000;54(2):135–42. https://doi.org/10.1016/s0167-8140(99)00177-2.
33. Emanuelli E, Albu S, Cazzador D, Pedruzzi B, Babighian G, Martini A. Endoscopic surgery for recurrent undifferentiated nasopharyngeal carcinoma. J Craniofac Surg. 2014;25(3):1003–8. https://doi.org/10.1097/SCS.0000000000000698.
34. Hadad G, Bassagasteguy L, Carrau RL, Mataza JC, Kassam A, Snyderman CH, Mintz A. A novel reconstructive technique after endoscopic expanded endonasal approaches: vascular pedicle nasoseptal flap. Laryngoscope. 2006;116(10):1882–6. https://doi.org/10.1097/01.mlg.0000234933.37779.e4.
35. Prosser JD, Figueroa R, Carrau RI, Ong YK, Solares CA. Quantitative analysis of endoscopic endonasal approaches to the infratemporal fossa. Laryngoscope. 2011;121(8):1601–5. https://doi.org/10.1002/lary.21863.
36. Caicedo-Granados E, Carrau R, Snyderman CH, Prevedello D, Fernandez-Miranda J, Gardner P, Kassam A. Reverse rotation flap for reconstruction of donor site after vascular pedicled nasoseptal flap in skull base surgery. Laryngoscope. 2010;120(8):1550–2. https://doi.org/10.1002/lary.20975.
37. Benjamin E, Wong DK, Choa D. 'Moffett's' solution: a review of the evidence and scientific basis for the topical preparation of the nose. Clin Otolaryngol Allied Sci. 2004;29(6):582–7. https://doi.org/10.1111/j.1365-2273.2004.00894.x.
38. Hosseini SM, Razfar A, Carrau RL, Prevedello DM, Fernandez-Miranda J, Zanation A, Kassam AB. Endonasal transpterygoid approach to the infratemporal fossa: correlation of endoscopic and multiplanar CT anatomy. Head Neck. 2012;34(3):313–20. https://doi.org/10.1002/hed.21725.
39. Yip J, Macdonald KI, Lee J, Witterick IJ, Zadeh G, Gentili F, Vescan AD. The inferior turbinate flap in skull base reconstruction. J Otolaryngol. 2013;42(1):6. https://doi.org/10.1186/1916-0216-42-6.
40. Monteiro E, Witterick I. Endoscopic nasopharyngectomy: patient selection and surgical execution. Oper Tech Otolaryngol Head Neck Surg. 2014;25(3):284–8. https://doi.org/10.1016/j.otot.2014.04.010.
41. Kassam AB, Prevedello DM, Carrau RL, Snyderman CH, Gardner P, Osawa S, Seker A, Rhoton AL Jr. The front door to Meckel's cave: an anteromedial corridor via expanded endoscopic endonasal approach-technical considerations and clinical series. Neurosurgery. 2009;64(3 Suppl):ons71–83. https://doi.org/10.1227/01.NEU.0000335162.36862.54.
42. Teo PT, Tan NC, Khoo JB. Imaging appearances for recurrent nasopharyngeal carcinoma and post-salvage nasopharyngectomy. Clin Radiol. 2013;68(11):e629–38. https://doi.org/10.1016/j.crad.2013.06.003.
43. Abdullah B, Rasid N, Lazim NM, Volgger V, Betz CS, Mohammad ZW, Hassan N. Ni endoscopic classification for Storz Professional Image Enhancement System (SPIES) endoscopy in the detection of upper aerodigestive tract (UADT) tumours. Sci Rep. 2020;10(1):6941. https://doi.org/10.1038/s41598-020-64011-6.
44. Wang WH, Lin YC, Chen WC, Chen MF, Chen CC, Lee KF. Detection of mucosal recurrent nasopharyngeal carcinomas after radiotherapy with narrow-band imaging endoscopy. Int J Radiat Oncol Biol Phys. 2012;83(4):1213–9. https://doi.org/10.1016/j.ijrobp.2011.09.034.
45. Hung CY, Lin TL, Kuo YC, Hsieh CH, Wang HM, Hsu CL. Progesterone analogues reduce plasma Epstein-Barr virus DNA load and improve pain control in recurrent/metastatic nasopharyngeal carcinoma patients under supportive care. Biom J. 2017;40(4):212–8. https://doi.org/10.1016/j.bj.2017.06.006.

8 Salivary Glands Tumours and Its Surgery

Norhafiza Mat Lazim

8.1 Introduction

Salivary gland surgery is critical in the head and neck surgical armamentarium as it involves many vital structures involved in many of the human basic functioning. For instance, parotid gland surgery is intricately involved with facial nerves, which supply the motor fibres for facial muscle of expression. Muscle of facial expression is important for protecting the eyes, aiding the mastication process, and maintaining the facial aesthetic for social integration. Submandibular gland disease and tumour will also cause impairment and aesthetic embarrassment with the presence of level Ib mass. Passing of submandibular duct stones into the mouth vestibule causes significant pain. If infected, the opening of Wharton's duct at the floor of mouth can be inflamed and discharging pus. Tumour arising from the submandibular glands, if extensive enough, may cause skin fixation, mandibular erosion, or compression on the hypoglossal nerve. Hypoglossal nerve palsy will result in the deviation of tongue and muscle atrophy and interfere with effective speech and swallowing. All of these complications will interfere with patients' daily functioning and quality of life (QOL). Sublingual gland is rarely affected by the pathology with the exception that it is at risk of malignant tumour development. The incidence however is low.

Tumours of the salivary glands, for example, are common and on the rise, but their aetiology and pathophysiology are largely unknown, despite the identification of some risk factors [1]. There are multiple risk factors that have been identified as the risk factors for salivary gland cancers. These risk factors display geographical and racial difference due to the degree of exposure and familial factors that may also play additive roles. These risk factors include chemical exposure, oncogenic viruses, familial inheritance, and genetic predisposition. Certain occupations are however associated with salivary gland cancer including rubber product manufacturing, asbestos mining, plumbing, and some types of woodworking [2].

Pleomorphic adenoma is the most common benign tumour of salivary glands. It commonly arises from the parotid glands and submandibular glands. It accounts for 60–70% of all benign tumours of the parotid gland. This tumour shows a female predominance and frequently arises in patients in the fourth to sixth decades of life [3]. The most common salivary gland neoplasm with a variety of histologic appearances is pleomorphic adenoma. Because of this variety, precise preoperative diagnosis via fine needle aspiration cytology is challenging [4]. The malignant salivary

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N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_8

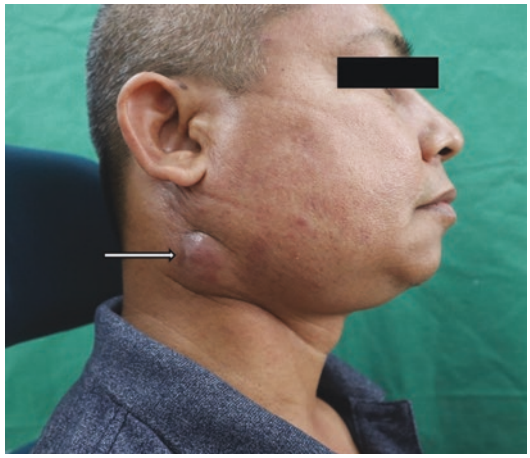

Fig. 8.1 A parotid mass at right level Ib with overlying skin is erythematous and fixed. This is a submandibular gland carcinoma with skin infiltration

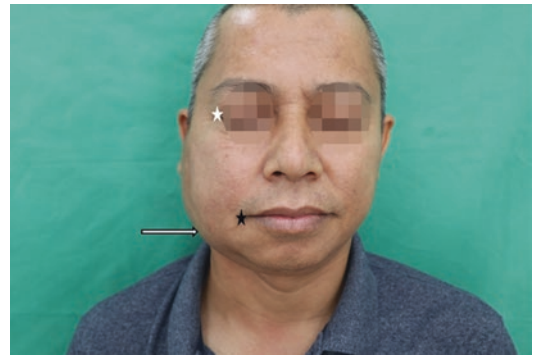

Fig. 8.2 It is important to assess the facial nerve function preoperatively in order to determine a specific surgical approach for the facial nerve branches if it is infiltrated by the tumour. In this case, both the upper and lower branches of facial nerve are intact (stars). Thus, if these facial nerve branches can be skeletonized from the mass, it should be preserved

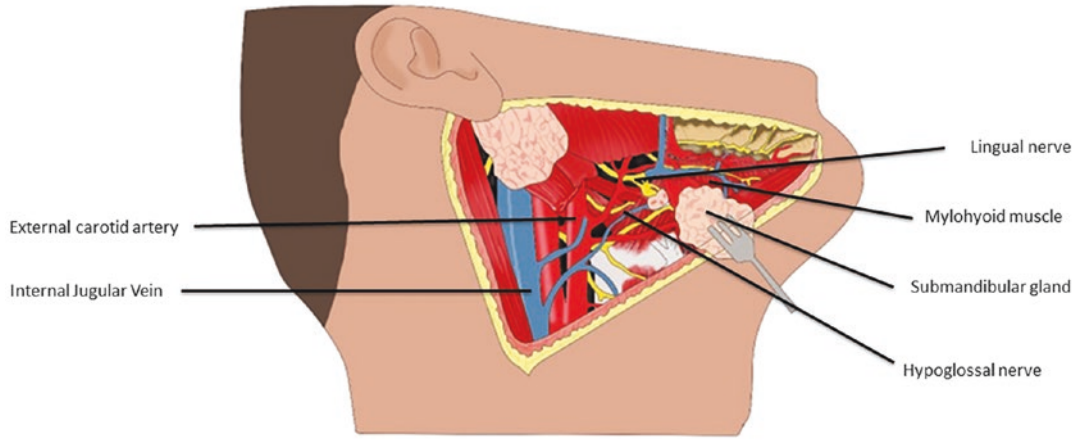

Fig. 8.3 Submandibular gland is closely related to muscles like mylohyoid and hypoglossal nerve, which can be infiltrated by aggressive malignant tumour

gland tumour commonly involves the submandibular glands (Fig. 8.1) and minor salivary glands. The commonest malignancy is mucoepidermoid carcinoma, accounting for 10–15% of cases [5]. Adenoid cystic carcinoma is the aggressive type of salivary gland malignancy with the predilection of lung metastases and perineural spread. Most commonly, facial nerve can be infiltrated with malignant tumour from parotid glands (Fig. 8.2). Other structures like mylohyoid muscle, hypoglossal nerve, and mandible can be affected by malignant tumour of submandibular gland (Fig. 8.3).

In otolaryngology, salivary gland surgery is a common procedure. In benign and malignant salivary gland tumours, parotidectomy and submandibulectomy represent the most common forms of surgical treatment. With parotidectomy, facial nerve identification and preservation are vital especially in benign tumour surgery like pleomorphic adenoma. In malignant parotid and submandibular tumour, the facial nerve and its branches may be involved at the initial presentation (Fig. 8.4). A lower branch like marginal mandibular nerve paresis is commonly associated with malignancy of submandibular gland tumour (Fig. 8.5). There are, however, no guidelines for specific imaging modalities to benign and malignant salivary gland tumours (Table 8.1).

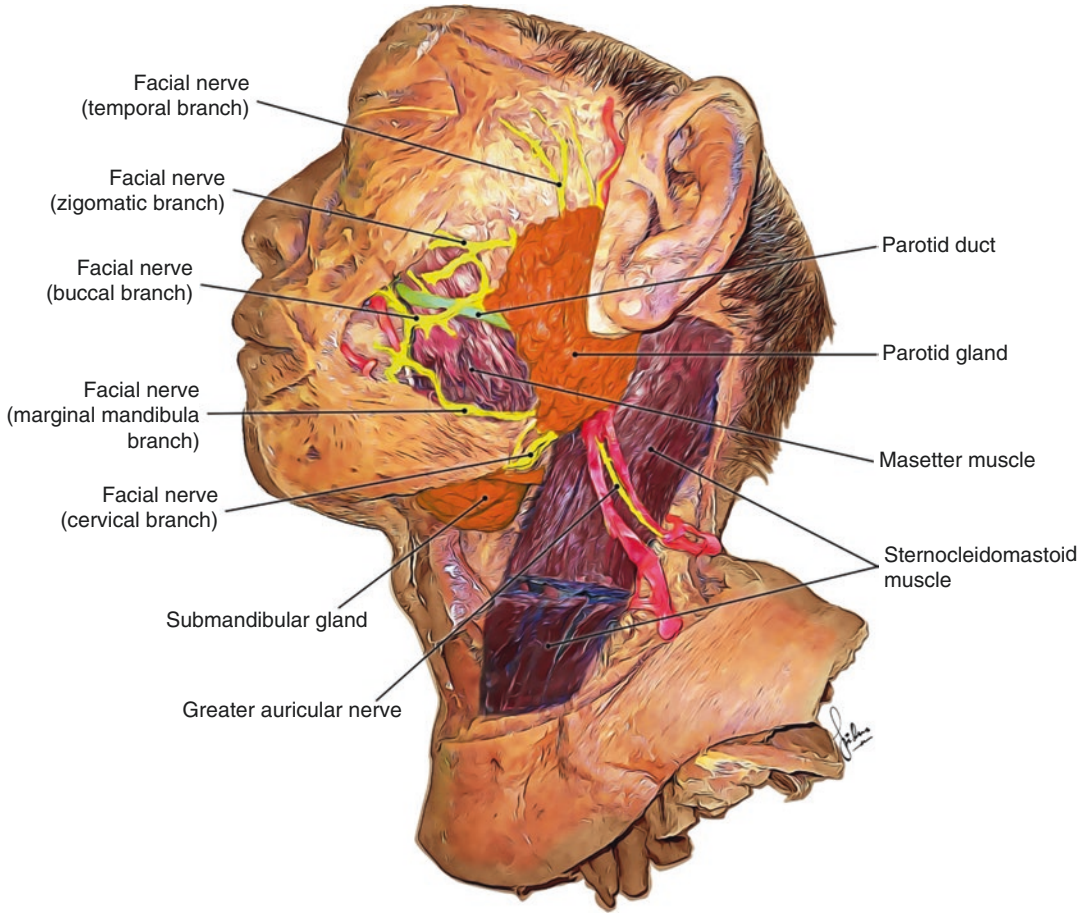

Fig. 8.4 Anatomical relationship of facial nerve and parotid glands with critical adjacent structures in the neck region is important for the conduct of safe surgery. There are five main peripheral branches of the nerve, temporal, zygomatic, buccal, marginal mandibular, and cervical branch, which are located beneath the superficial lobe of parotid gland

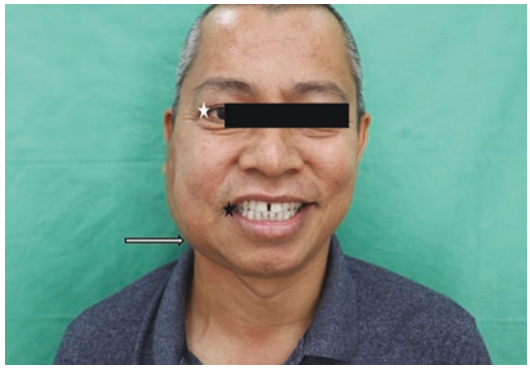

Fig. 8.5 The marginal mandibular nerve, the lower branch of facial nerve which supplies the orbicularis oris, is intact with the evident of symmetry of oral commissure. In marginal mandibular nerve paresis, the lower lip of the affected side will be elevated due to loss of depression of depressor angular oris, which is supplied by the marginal mandibular nerve

Table 8.1 Histology of the common salivary gland tumours

	Benign	Malignant
1.	Pleomorphic adenoma	Mucoepidermoid carcinoma
2.	Warthin's tumour	Acinic cell carcinoma
3.	Myoepithelioma	Epithelial myoepithelial carcinoma
4.	Basal cell adenoma	Adenoid cystic carcinoma
5.	Oncocytoma	Salivary duct carcinoma
6.	Cystadenoma	Carcinoma ex pleomorphic adenoma
7.	Lymphadenoma	Carcinosarcoma

8.2 Clinical Presentation of Salivary Gland Tumour

Clinical presentation of salivary gland tumours varies. The majority however will present with the mass at the parotid or submandibular areas, respectively. The associated symptoms include pain, mass that gradually enlarges, associated swelling at the neck, and numbness in the cervicofacial region. For instance, the carcinoma ex pleomorphic adenoma normally presents with a sudden increase in size of a long-standing parotid mass [6]. This should raise the suspicion of malignant transformation. Another presenting feature which suggests malignancy includes facial nerve palsy. A malignant submandibular mass may present with the involvement of lower branches of facial nerve like marginal mandibular nerve paresis (Fig. 8.6), neck nodes, skin fixation, skin ulceration, and symptoms of distant metastases such as bone pain and haemoptysis. During clinical examination, it is crucial to do the sternocleidomastoid contraction (Fig. 8.7) in order to assess the tumoural mass and its margins to the sternomastoid muscle as well as to rule out the infiltration to the muscle.

Submandibular gland tumour may present with different characteristics of submandibular

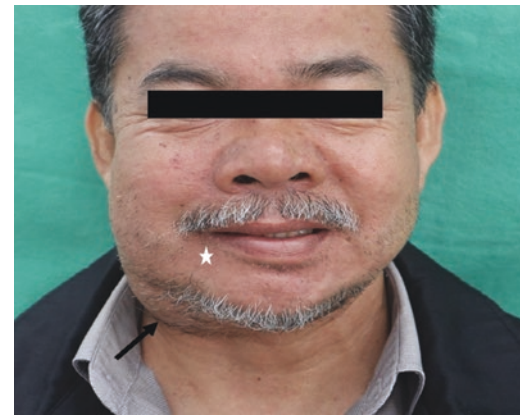

Fig. 8.6 A submandibular mass (arrow) at right level Ib with minimal asymmetry of oral commissure. There is right marginal mandibular nerve palsy as evident from the loss of depression of right lower lip (star). The marginal mandibular nerve supplies both the levator angular oris and depressor angular oris, but the majority of fibres innervate the depressor angular oris

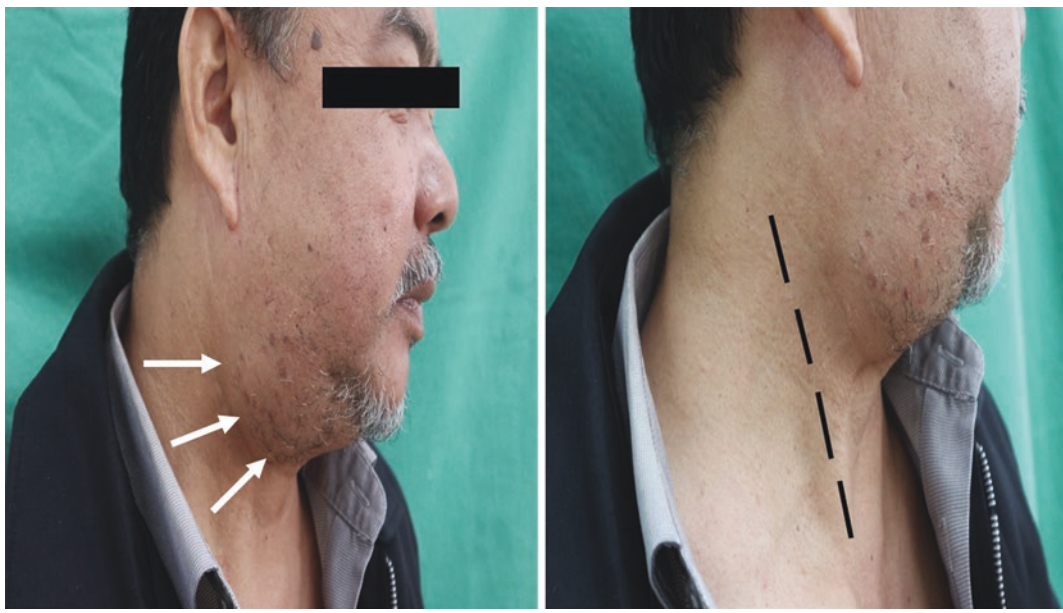

Fig. 8.7 A submandibular mass at right level Ib with extension into level Ia and II right-neck region. During clinical examination of the neck, it is vital to perform SCM contraction and assess the inferior border of mass in relation to SCM muscle in order to rule out SCM muscle involvement, which necessitates resection during the neck dissection

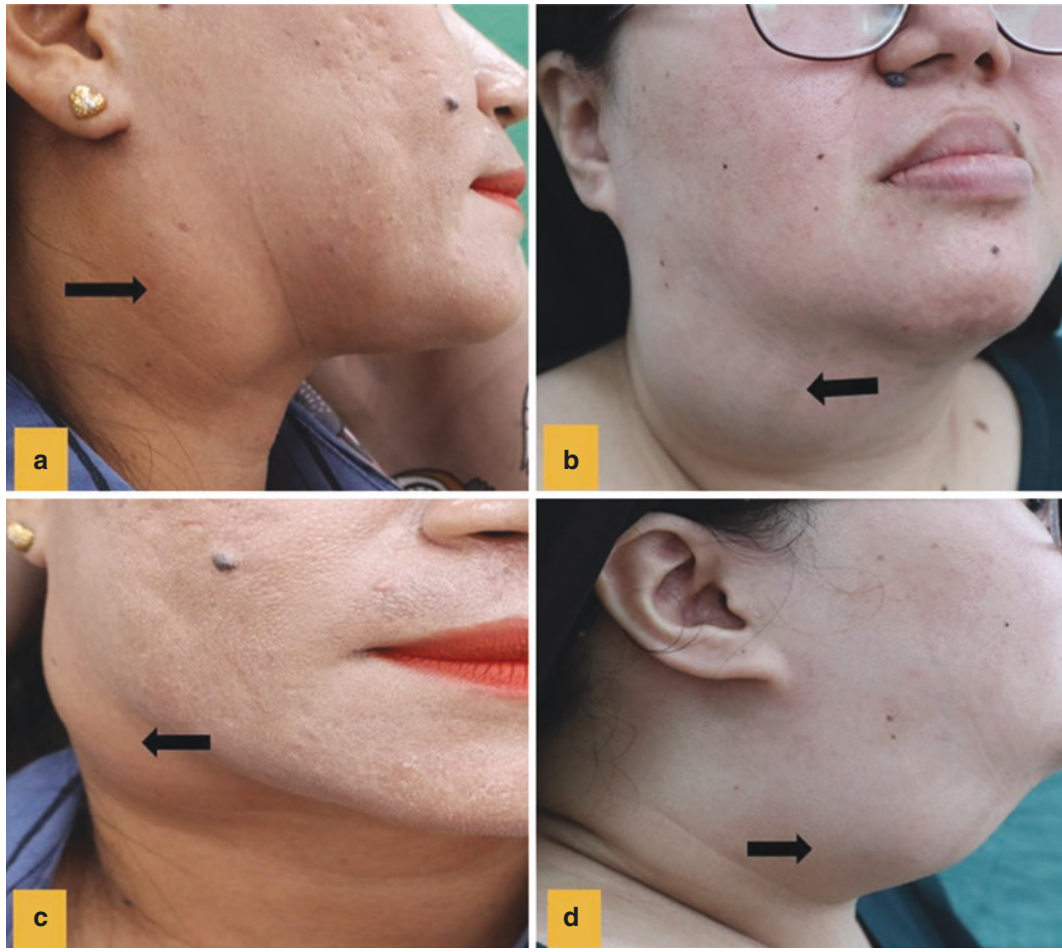

Fig. 8.8 Multiple presentation of submandibular tumours. (**a**) Submandibular gland mass occupy level Ib and II of right neck. (**b**) Anterior view showed right submandibular mass. The submandibular mass should be ballotable from the floor of the mouth. (**c**) Submandibular mass occupy level Ib &, II, of right neck. (**d**) The submandibular mass view from lateral side of neck

mass (Fig. 8.8). Importantly, if malignancy is suspected, assessment of mandible, neck nodes, and distant metastases should be performed as a routine assessment.

Imaging assessment and tissue diagnostic procedures are necessary for an accurate final diagnosis of salivary gland tumours. Ultrasound, CT scan, MRI, and PET scan are the common imaging methods used depending on the patient's characteristics and requirement of tissues or organs of involvement. CT scan and MRI are complementary tools that provide useful information. In the majority of cases, the CT scan is preferable as it allows assessment of the tumoural mass and also the adjacent bony involvement, neck node metastases, or distant metastases (Fig. 8.9). Although advanced imaging methods such as diffusion-weighted imaging and PET-CT aid in characterization, biopsy or excision is frequently required for definitive tissue diagnosis [7]. In our practice, a fine needle aspiration cytology is needed to ascertain the tissue diagnosis before embarking on any surgery as indicated.

Nowadays, surgeons have many options for treating the benign parotid surgery depending on the extent of the mass involvement and patient desire. Most of the time, either partial lobectomy, total lobectomy, or superficial parotidectomy can

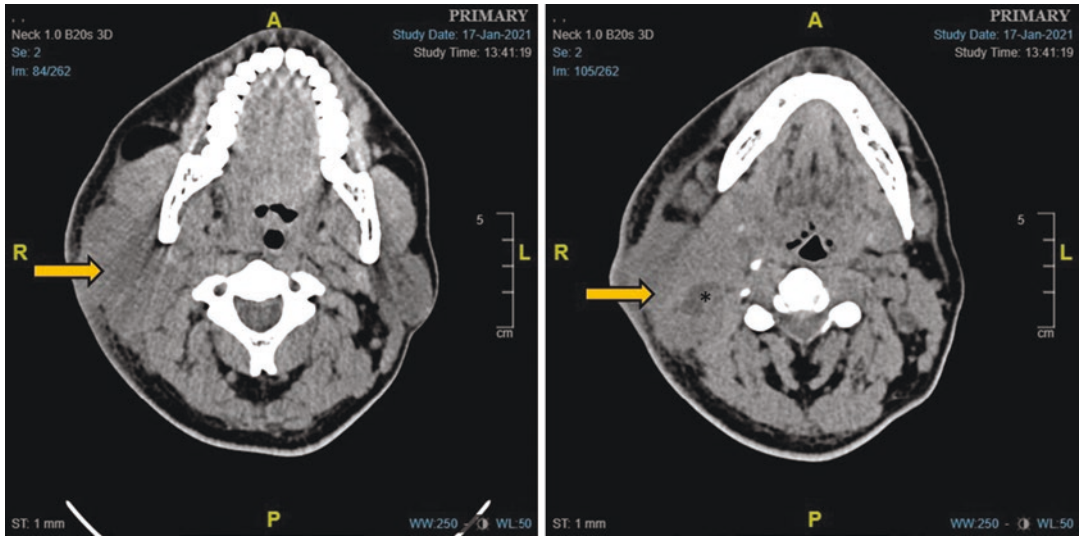

Fig. 8.9 CT scan of right parotid gland showing a heterogenous mass (arrow) arising from the superficial lobe of parotid gland

be performed. Extracapsular dissection (ECD) is one of the many surgical techniques available in parotid surgery and, with proper training and if used for proper indications, can achieve excellent results.

In the majority of benign parotid surgery cases, superficial parotidectomy represents a universal solution and should be the first technique that young surgeons learn. In order to select the most appropriate surgical technique, surgeons need to carefully consider the patient and his/her preoperative imaging, as well as his/her own special expertise [8]. Superficial parotidectomy is the mainstay of surgical treatment of benign parotid tumour, which is commonly involved with the superficial lobe of the parotid glands. However, it is not recommended for malignant salivary gland tumours, as total parotidectomy should be performed.

Submandibular gland, on the other hand, has a close relationship with multiple cranial nerves, namely hypoglossal nerve, lingual nerve, glossopharyngeal nerve, and marginal mandibular nerve. Both benign and malignant tumours of submandibular glands mandate a submandibulectomy. Any surgeon performing submandibulectomy for a benign tumour should be able to identify these nerves and preserve it in addition to the vascular and other structure preservation. Additionally in extensive cases, submandibular tumour may cause oropharyngeal and airway impairment (Fig. 8.10).

Neck dissection is necessary as a treatment of malignant salivary gland tumour. The most common neck node involvement is at levels Ia, Ib, II, II, and IV. For submandibular malignancy, levels I–III should be addressed, whereas for parotid malignancy level II–IV neck nodes ipsilaterally should be addressed.

The morbidity following such traditional surgery is well documented and includes postsurgical complications such as post-operative partial or complete facial nerve damage, Frey's syndrome, facial scarring, greater auricular nerve numbness, sialocoeles, and salivary fistula [9]. The incidence of facial palsy in parotid surgeries is up to 26.7% transient and 1.7% complete facial palsy, despite good surgical knowledge of parotid gland anatomy and meticulous surgical technique. In cases of malignancy and revision, the risk of facial palsy increases further [10].

Evidence of facial nerve paresis preoperatively reflects facial nerve involvement by the tumour. The surgeon might anticipate the need to sacrifice the facial nerve and should discuss with the patient preoperatively if facial nerve needed to be resected and grafted. If the facial nerve function is intact preoperatively, in malignant

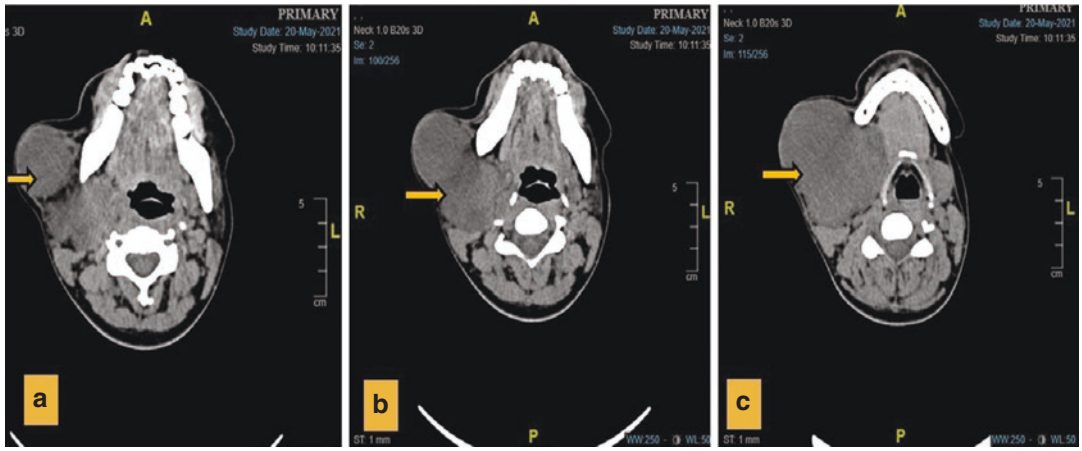

Fig. 8.10 (**a**) CT scan image showed right submandibular gland mass with medial extension to oropharyngeal airway (**b**) and abutting the thyroid cartilage (**c**)

cases, careful observation of the facial nerve calibre and vessel patterns by microscopes or magnifying loupes can give a clue to the nerve infiltration. There is no imaging modality that can give confirmation on facial nerve infiltration. Thus, intraoperative finding is crucial in determining the facial nerve involvement and deciding on the degree of resectability of facial nerve [11]. This is important in order to achieve better oncological outcomes for this type of tumour.

In patients with salivary gland carcinoma, distant metastases are the leading cause of treatment failure. The locoregional recurrence is also common in aggressive histology type of tumour. For instance, adenoid cystic carcinoma has strong predilection for lung metastases and perineural spread. Characteristically, the perineural spread is a skipped lesion along the nerve, which poses difficulty in determining the free margins of the nerve if transection of the facial nerve and grafting are planned. Survival is negatively associated with high-grade histology, bone metastases, and total number of distant metastases in patients with distant metastases of salivary gland carcinoma. Metastasectomy can help to increase disease-free survival time [12].

8.3 Surgical Anatomy of Salivary Glands

The major salivary glands have complex anatomical relationships with the surrounding structures, especially with regard to the neurovascular structures. Apart from the facial nerve which lies in close proximity with the parotid glands, the hypoglossal nerve and lingual nerve also lie intimately with the submandibular glands. Other soft-tissue structures are equally important. This includes the muscles, the artery and veins, the mandible, which are all critical when deciding the surgery for tumour of salivary glands. This implies that any surgeon involved in the management of salivary gland disease should acquire a sound understanding of surgical anatomy of the salivary glands and its surrounding structures [13].

When addressing the parotid glands, there are several important structures that are commonly used as surgical landmarks in identifying the facial nerve. The facial nerve main trunk should be first identified during the dissection, so that the peripheral branches can be followed and safely preserved. Among these common landmarks are tympanomastoid suture, mastoid tip,

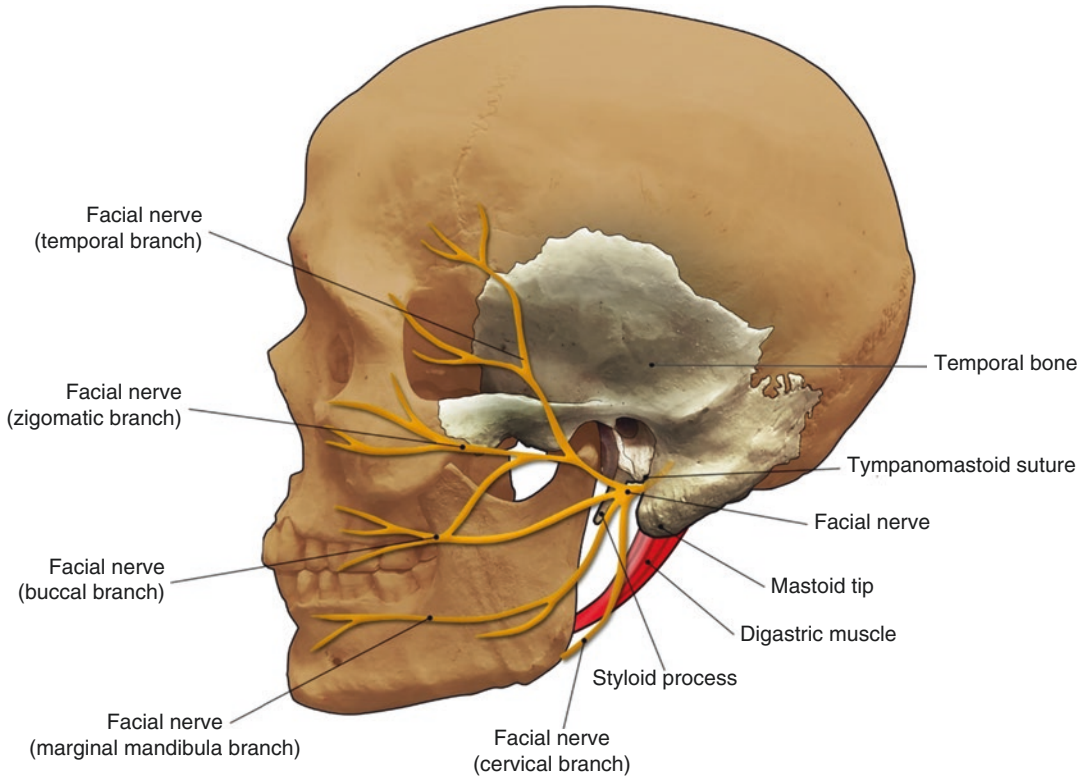

Fig. 8.11 Anatomical relationship of facial nerve trunk with digastric muscle, tympanomastoid suture, and mastoid tip

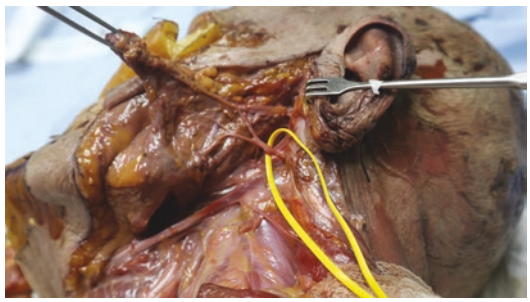

Fig. 8.12 Main trunk of facial nerve is located just above the posterior belly of digastric. It divides into two main branches, the upper temporo-zygomatic branch and the lower cervico-marginal mandibular branch

anterior belly of digastric muscle, tragal cartilage, and styloid process (Fig. 8.11).

When the facial nerve exits the stylomastoid foramen, it descends shortly before lying medial to the anterior belly of digastric muscle and makes it way by curving forward to branch into two segments of upper temporo-zygomatic and lower cervico-mandibular branch (Fig. 8.12).

8.4 Facial Nerve Surgical Anatomy

It is known that at the stylomastoid foramen, the facial nerve exits the skull base and then splits into a superior temporofacial trunk and an inferior cervicofacial trunk, generally within the parotid gland. Then these trunks divide into many tiny rootlets, forming a parotid plexus. Ultimately, these parotid plexus rootlets join the five branches classically taught: temporal, zygomatic, buccal, mandibular marginal, and cervical. Such branches, however, are variable and often present in duplicates or triplicates [14]. The nerve lies superficial to the facial and retromandibular vein and facial and maxillary artery. Its ducts arise from the anterior part of the glands and pierce the masseter muscle (Fig. 8.13) before end at the area of second upper molar tooth in the gingivobuccal sulcus.

During parotid tumour resection, reliable preoperative facial nerve mapping may help to avoid

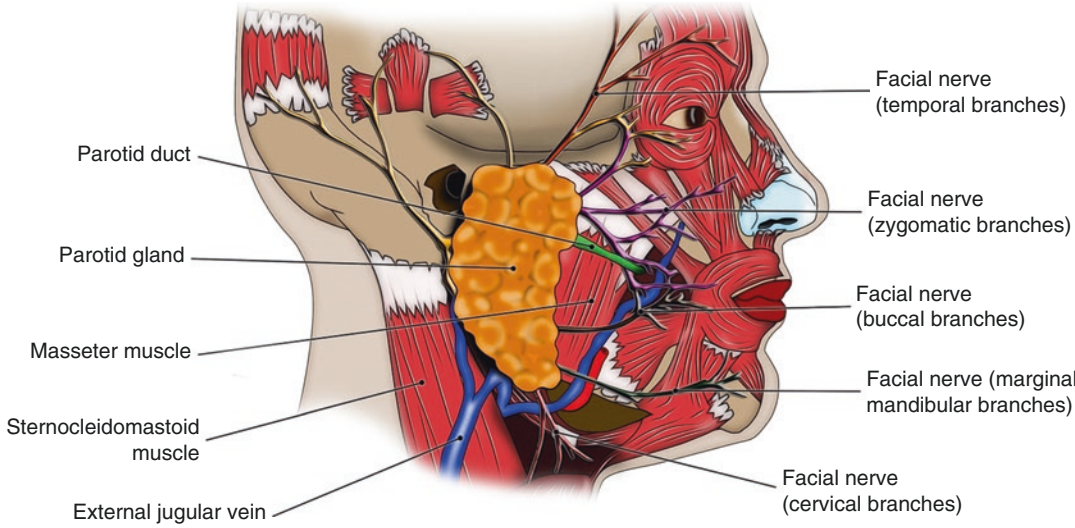

Fig. 8.13 Other critical structures adjacent to facial nerve, which need to be addressed during parotidectomy (facial artery and vein, retromandibular vein, masseter muscle, SCM, and parotid duct)

or minimize facial nerve injury. In order to perform a safe parotid surgery, precise knowledge of facial nerve anatomy is crucial. It should be borne in mind that variation to the normal anatomy contributes to the challenges in parotidectomy. Although several surgical landmarks to identify the facial nerve have been described in literature, their position is variable, inconsistent, and difficult to follow in some cases [15]. With these differences and variation, added up with the distortion of the nerve due to expanding tumoural mass, the dissection requires extra diligence so as to identify and preserve all five main peripheral branches of the nerve.

To help the surgeon identify the facial nerve when performing parotid gland surgery, many surgical landmarks have been utilized. However, no conclusive proof exists that one landmark is better than the rest. Based on our practice, tragal pointer is the most consistent landmark that can be used to find and preserve the facial nerve trunk. This pointer is the triangular cartilage end of the external ear canal. The facial nerve trunk is consistently located 1.0 cm medial and deep to this pointer. During dissection, the ear can be palpated to orientate the location of the tragal pointer for estimation of facial nerve trunk.

The other useful landmark is that the facial nerve trunk was consistently positioned close to the midpoint between the inferior mastoid tip and the superior bony-cartilaginous junction of the EAC [15]. By palpating the protuberance of mastoid tip, the facial nerve can be expected to lie superiorly halfway to the bony-cartilaginous junction of the external ear canal. The distance between the osteocartilaginous junction and the mastoid tip ranged from 17 to 21 mm, with a mean of 19.5 mm. The mean distances between the osteocartilaginous junction and the facial nerve trunk and between the mastoid tip and the facial nerve trunk were 9.2 and 10.3 mm, respectively [16].

The tympanomastoid suture is another useful surgical landmark for finding the facial nerve trunk. The suture of the tympanomastoid was closest to the main trunk and was therefore regarded as the most reliable landmark. Its average distance was 2.7 mm from the main trunk of the facial nerve [17]. The author did not recommend this surgical landmark, as by the time the tympanomastoid suture is found, the facial nerve might have been injured. A detailed anatomy knowledge and surgical experience are needed if using this landmark during the parotidectomy.

In parotid surgeries, the postauricular artery can be used as another landmark to identify the main facial nerve trunk. In 12 cadaveric dissections, the posterior auricular artery was found to run inferior to the facial nerve trunk, while in 2 cadaver dissections, the posterior atrial artery was found to cross below the main facial trunk. The mean distance between the facial nerve trunk and the PAA ranged from 2 to 14 mm. In 12 out of 14, the stylomastoid artery was found to arise from the posterior auricular artery, and it was found to run medial to the trunk of the facial nerve [10].

8.5 Roles of Imaging in Parotid Gland Surgery

Radiological imaging is essential for adequate management of parotid gland tumour. This is especially true in the setting of extensive tumours, with suspicion of lymph node metastases and adjacent tissue involvement. For benign tumours of parotid glands such as pleomorphic adenoma, assessment of deep lobe involvement is achieved by performing CT scan (Fig. 8.14). This is necessary as the decision for superficial parotidectomy or total parotidectomy with facial nerve preservation should be carried out.

For malignant tumours of parotid glands, CT scan would be ideal for the assessment of mandibular cortex erosion, presence of lymph node involvement, masticator muscle infiltration, or skin involvement. These features are crucial for the surgeon to decide the details of surgical approach and discuss with the patients and family members.

In the expert hands, MR imaging can be used to visualize the facial nerve and the facial nerve segments in the temporal bone in the intracranial cisternal and canalicular portions. However, in parotid glands, it is challenging to identify the facial nerve on the MRI as the consistency is similar with the adjacent parotid gland tissues. Even though the MR imaging signal and resolution are maximized using a localized surface coil, the

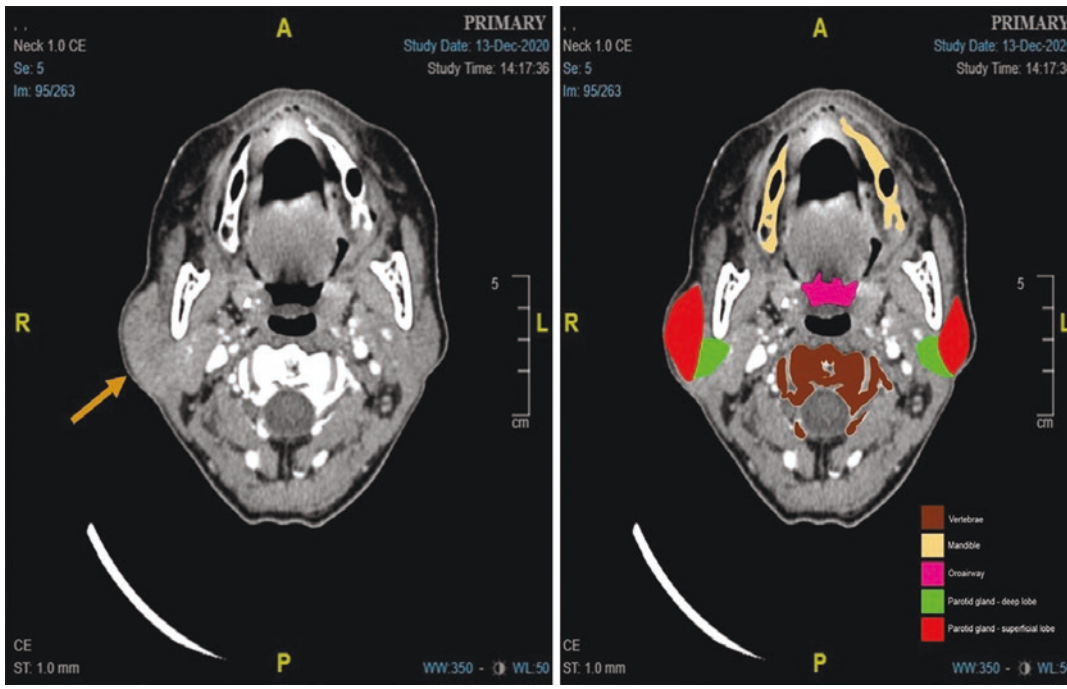

Fig. 8.14 CT scan showed a homogenous mass arising from the right parotid glands with minimal deep lobe involvement (green) on the right parotid gland (arrow). The image mapping in colours for other structures' identification

intraparotid facial nerve distal trunk and branches are not consistently visible on conventional MR or CT images. There is currently no MR imaging technique commonly used to imagine the facial nerve [14]. Confident identification of the more distal branches of the facial nerve appears to be primarily hindered by three factors:

1. The small size of the nerve fibres in the intervening parotid plexus below the current practical clinical imaging resolution
2. Variant terminal branch anatomy, including variation in the number and location of the branches, which precludes location-based identification
3. Difficulty discriminating small nerve fibres, small ducts, and small vessels [14]

The use of the retromandibular vein as a facial nerve marker has been shown to be another sensitive method for identifying the facial nerve [18]. The anatomical landmark can be used as a virtual line drawn from the lateral border of the posterior belly of the digastric muscle and the retromandibular vein to the lateral edge of the mandible. In the majority of the cases, the facial nerve lies superficial to the retromandibular vein. In few cases, the nerve may also be located below the facial nerve. The retromandibular vein has to be ligated proximal and distal to the tumoural mass, after the identification and preservation of the facial nerve branches.

The facial nerve, the Utrecht line, the Conn's arc, and the retromandibular vein were among the landmarks used for CT scan and MRI presurgical evaluation of parotid tumour patients by the radiologist. Vaiman et al. reported that in cases where selective deep lobe parotidectomy is planned, no existing CT scan landmark can be accepted as completely reliable. The anatomy can be distorted due to the expanding mass. If the location of the tumour in the deep gland lobe is suspected, MRI imaging is necessary to assess the tumour for a better surgical extirpation [19]. As in this parapharyngeal space area, critical neurovascular structures might be involved or compressed by tumours. These structures include the last four cranial nerves, parasympathetic fibres, and deep muscles of neck.

The tumour location was determined in relation to four computerized tomography (CT) scans, the facial nerve line, Utrecht line, Conn's arc, and retromandibular vein, and confirmed by intraoperative findings [20]. In predicting the tumour location, the Utrecht line was the most precise, sensitive, and specific of the four landmarks. However, the FN line was significantly more precise than the Utrecht line and Conn's arc for tumours less than 2 cm in diameter. Magnetic resonance imaging is used to determine the effectiveness of multiplanar analysis of the retromandibular vein in determining the position of the parotid gland tumour and its relationship to the facial nerve, together with the most common radiological criteria [21]. Combined with the evaluation of the parapharyngeal space, the multiplanar modality is effective in helping the surgeon to achieve precise planning: it allows the tumour to be located and the course of the facial nerve to be predicted with good precision.

The parotid duct and the retromandibular vein criterion can be used to assess the accurate location of the parotid tumours [22]. In fact, for the determination of the location of parotid tumours, the parotid duct criterion is highly useful. Combining the criterion for the parotid duct with the criterion for the retromandibular vein could improve the diagnostic accuracy of the location of the parotid tumour compared to using the latter criterion alone. This allows a comprehensive presurgical planning to ensure that a safe and effective surgery can be performed.

Other techniques include preoperative MR imaging using steady-state double echo with water excitation sequence. Based on this, the facial nerve line, the retromandibular vein, and the Utrecht line, the tumour locations were categorized as deep or superficial [23]. By directly visualizing the intraparotid facial nerve using the 3D double-echo steady state with water excitation sequence compared to indirect methods, surgeons can achieve greater diagnostic performance in localizing parotid gland tumours.

8.6 Parotid Gland Surgery

Parotid gland surgery is exquisite as it involves the facial nerve identification and preservation. Injury to the facial nerve will result in significant cosmesis deformity and cause interruption of an individual's communication and social integration. The affected patient can be presented with facial asymmetry, inability to drink due to drooling, or exposure keratopathy due to incomplete closure of eyelids. Thus, it is imperative to identify the nerve and preserve the facial nerve's function. The aim of parotid gland surgery is to remove the tumour with adequate margins while maintaining the facial nerve integrity.

8.6.1 Benign Parotid Tumour Surgery

The goal of surgical management of benign parotid tumours is to eliminate the mass completely with the preservation of the function of the facial nerve. In the setting of benign parotid gland tumour such as pleomorphic adenoma, breaching of the capsule is highly associated with recurrence. Additionally, the facial nerve has to be preserved in all operated benign cases. The surgical excision of this lesion remains the subject of significant debate. The objective is to prevent facial disability and achieve complete resection without capsule or pseudocapsule perforation [3].

Different surgical options are currently available for the treatment of benign parotid gland tumours. Despite several meta-analyses, the discussion on optimal treatment continues: for instance, more limited resections like extracapsular dissection and partial lateral parotidectomy versus more extensive and traditional options are included in these options (lateral parotid lobectomy, total parotidectomy) [24]. Currently, most surgeons prefer to perform superficial parotidectomy for pleomorphic adenoma that is limited to the superficial lobe of the parotid gland.

There are a variety of terms used to describe parotid gland surgery for benign tumours. These include either complete superficial parotidectomy, partial superficial parotidectomy, or extracapsular dissection during surgery [25]. Since extracapsular dissection has resulted in a significantly higher percentage of permanent facial paralysis, recurrent disease, and positive margins of resection than superficial parotidectomy, superficial parotidectomy is recommended for the treatment of benign parotid gland tumours [26]. Even though the superficial parotidectomy is associated with significant prolonged surgery time, it is the most effective treatment of benign parotid tumour such as pleomorphic adenoma. In the expert hands, surgical complications and facial nerve injury are rare.

In the extracapsular dissection, the rate of positive margins was significantly higher compared to the superficial parotidectomy group. After extracapsular dissection, recurrent disease is higher compared to superficial parotidectomy, and permanent facial palsy was significantly more frequent than superficial parotidectomy.

The high rate of tumour recurrence that occurred with simple enucleation of parotid pleomorphic adenoma was significantly reduced by superficial parotidectomy. For the treatment of pleomorphic adenoma, superficial parotidectomy or partial superficial parotidectomy is commonly practised worldwide. Reports covering a spectrum from total parotidectomy to extracapsular dissection are common in Europe and Asia. The results of surgical treatment of mobile, superficial pleomorphic adenoma smaller than 4 cm are not significantly altered by the surgical approach [27]. The capsular exposure, tumour-facial nerve interface, capsular rupture, recurrence, facial nerve dysfunction, and Frey's syndrome are similar in occurrence.

The availability of a staging system of parotid gland tumour would be ideal to facilitate the making of clinical decisions and the comparison of treatment outcomes. Based on the size of the tumour and its location within the parotid gland, there are four categories (Table 8.2).

A guideline for surgical approach is proposed for each category and for different pathological types. Other criteria need to be considered in deciding the best surgical approach for each type of tumours, not merely based on this guideline. These include details of the patient's factors,

Table 8.2 Classification of parotid gland tumours

Category	Classification of parotid gland tumours
Category 1	Tumours up to 3 cm, which are mobile, close to the outer surface, and close to the parotid borders, are included in category I.
Category 2	Deeper tumours up to 3 cm are included in category II.
Category 3	This comprises tumours larger than 3 cm involving two parotid gland levels.
Category 4	Tumours are larger than 3 cm involving more than two parotid gland levels.

availability of the expertise, instrumentation, etc. Additionally, the purpose of this classification is to facilitate prospective multicentre studies of surgical techniques for the treatment of benign parotid tumours and to allow the results of various clinical studies to be compared [24]. A refined classification of salivary gland tumour should be made available at a near future. This enhances the management of this tumour and improves patient's prognosis and survival.

8.6.2 Malignant Parotid Tumour Surgery

In malignant parotid surgery, the approach is different. The aim of the surgery is to remove the tumour with free surgical margin, and the issue of facial nerve preservation is dependent on whether the facial nerve is involved or not, intraoperatively and post-operatively. The neck dissection should also be performed during the initial parotidectomy. The micrometastases for salivary gland malignant tumour are at level II, III, and IV neck nodes.

Management of facial nerve in the setting of malignant parotid tumour is challenging. Issue of scarification or preservation of facial nerve should be judiciously considered. The balance between the benefit and the risk of facial nerve preservation or scarification will dictate the final approach for the facial nerve. If preoperatively, the clinical examination showed evidence of facial nerve paralysis, and intraoperatively if the nerve adherent to the tumoural mass cannot be skeletonized, then the facial nerve should be sacrificed. This is crucial to achieve an oncologically sound treatment outcome. If, however, facial nerve is intact preoperatively, and the nerve is able to be dissected of the mass, and there is no suspicion of the facial nerve infiltration, then the nerve should be preserved.

Total parotidectomy is performed for malignant tumours, tumours that arise either from the superficial lobe or from the deep lobe. All bulky tumoural tissue plus the periparotid tissue should be removed in total to reduce recurrent tumour. The periparotid tissues contain microscopic tumour deposit that might be left behind if it is not excised together with the bulk of parotid tumour mass. During the surgery, cutting through the tumour should be avoided as this will cause tumour spillage onto the surgical bed. This is another risk factor for recurrent tumour post-surgery. Ideally, the tumour capsule should be maintained intact during the dissection.

Selective neck dissection should be conducted during the initial parotidectomy in suspicious neck node infiltration or clinically positive neck nodes ipsilaterally. Most of the time, the lateral neck dissection incorporating the neck node levels II–IV is performed. Otherwise, the choice of types of neck dissection will depend on the neck node status characteristics. The extent of adjacent structure resection such as mandible, muscle of mastication, and skin depends on the infiltration that can be assessed clinically and radiologically.

Intraoperatively, the neck dissection should be carried out first before embarking on the parotidectomy. This is the same principle that applies to other head and neck malignant tumours. If the parotidectomy is performed first, the tumour cells from the parotid surgical bed might be transferred to the fresh uncontaminated area of the neck, either via gloves or via instrumentation.

8.7 Surgical Techniques and Dissection

8.7.1 Superficial Parotidectomy

During an operative session of superficial parotidectomy, the patient should be well prepared. The consent should have been comprehensively

prepared during the outpatient clinic review. The anaesthetic team should also be informed on the procedure and the necessary equipment required preoperatively. This is particularly with the choice of intubation, use of intraoperative neural monitoring, and requirement of short-acting muscle relaxant, as it will interfere with the nerve monitoring during the surgery. The instrument should be checked and made available before the surgery.

8.7.1.1 Patient Positioning and Facial Nerve Application

Patient will be placed in supine position, with head turned to contralateral side. If a neck dissection is planned, the neck can be extended with rolled towel or shoulder bag. The facial nerve monitoring should be done with four-channel electrodes secured to the respective sites, frontalis, orbicularis oculi, orbicularis oris, and mentalis. The requirement of short-acting muscle relaxant should be communicated with the in-charge anaesthetist.

8.7.1.2 Skin Incision

The area is cleaned with diluted povidone iodine, and the draping is done. The draping should expose the half face on the operative side, which includes the angle of mouth and lateral eyelid exposure. This is important for the observation of contraction of the muscles during dissection, so as to give a clue whether the facial nerve branch is in close proximity.

The landmark will be drawn, especially the margins of the tumour, the typical skin incision, and modified Blair incision which starts at 1–3 mm anterior to tragal cartilage and extending down to the earlobe before curved down to the neck, along the skin crease, two finger breadths below the angle of mandible (Fig. 8.15).

8.7.1.3 Raising of the Skin Flap

The skin flap is raised anteriorly till anterior margins of the parotid mass. The superficial musculoaponeurotic system (SMAS) can be incorporated to the flap to thicken the flap. The thicker the flap, the better the flap viability due to vascular supply. The subplatysmal flap is raised using blade size 15 or monopolar with Colorado tip. Countertraction and traction of skin by assistant will facilitate the process, without deeper cutting of the tissues. The platysma muscle is deficient in the midline of the neck and posteriorly at the region of level V. Some patients have a very thin platysma, whereas others may have thicker platysma. The thicker the flap, the better the vascular supply and viability of the flap.

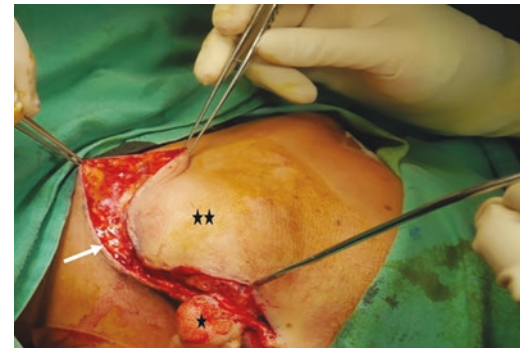

Fig. 8.15 Subplatysmal skin flap is raised via a modified Blair skin incision (arrow). The left parotid mass tumour (2 stars) and ear lobule (a star)

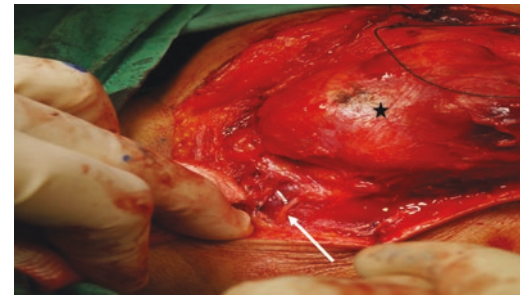

Fig. 8.16 The greater auricular nerve (GAN) runs across superficial to SCM, and its branch to ear lobule should be preserved. The parotid mass (star) will be dissected away from the nerve

8.7.1.4 Greater Auricular Nerve Preservation

During the incision over the sternocleidomastoid muscle, the greater auricular nerve can be identified crossing the muscle, as a thick whitish nerve (Figs. 8.16 and 8.17). Its anterior branches supply the parotid capsule that can be sacrificed. Its posterior branch supplies the ear lobule and should be preserved, especially in benign cases. The transected nerves can result in neuroma as a late complication and tend to cause significant pain.

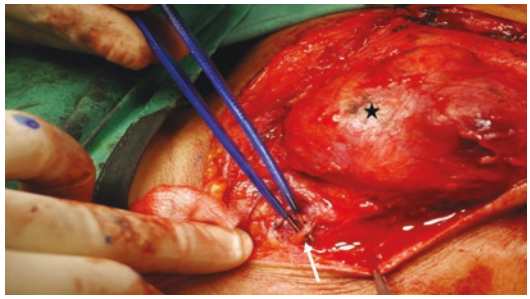

Fig. 8.17 The GAN (arrow) runs across superficial to SCM and is preserved

8.7.1.5 Skeletonization of SCM Muscle

The anterior border of sternomastoid can be skeletonized using the monopolar or tissue scissors. Care needs to be taken as deep to the SCM muscle is the carotid sheath, which harbours the carotid artery, the vagus nerve, and the internal jugular vein. At inferior third of SCM, the omohyoid muscle can be identified as it runs across the SCM. The omohyoid muscle is the landmark for identification of the IJV. The IJV lies just beneath the omohyoid muscle.

8.7.1.6 Dissection at the Tragal Area

The subcutaneous tissues near the tragal area are deepened, and dissection is carried out in continuity to the anterior border of SCM that has been skeletonized and deepened. The stylomastoid artery should be identified in this region, as it can cause heavy bleeding, if inadvertent cut of the artery occurs. Sometimes it is difficult to find the bleeding end, especially due to high fatty deposition in this region. The stylomastoid artery can be easily clipped, hence secured.

If the dissection area is red with blood stain, warm normal saline wash can be performed to make the dissection area whiter so as to identify the facial nerve trunk better.

8.7.1.7 Facial Nerve Trunk Identification

The dissection continues at the tragal area, deepening the tissue superiorly and inferiorly, so as to create a shallow bowl. If the bowl is too deep, it will be difficult to dissect tissue structures and find the facial nerve trunk.

The tragal pointer is used as a landmark to find the facial nerve trunk. The facial nerve trunk lies 1.0 cm deep and inferior to the tragal pointer. When the area is near, the dissection continues with cold instruments. Lahey swab can be used to push the tissues and to find the trunk with ease.

The facial nerve stimulator is used to confirm the nerve. The voltage reduces to 0.5 ampoule when stimulating the nerve. Higher voltage and frequent testing can lead to neuropraxia, in addition to the traction on nerves.

8.7.1.8 Facial Nerve Branch Preservation

The facial nerve trunk is followed until it divides into two main branches, the upper temporozygomatic branch and the lower cervicomandibular branch (Fig. 8.18). The parotid tissue is dissected over the nerve, lifted, and cut. This technique is performed along the nerve, to expose the nerve until the anterior border of the parotid mass.

At this stage of dissection, the retromandibular vein should be identified and ligated. The vein lies very close to the nerve, just inferior to it. Thus, vigilant ligation of the vein is necessary to avoid the facial nerve injury.

The anterior branch becomes very thin, and meticulous dissection is necessary. The nerve stimulator can be used to guide dissection at this stage. However, sometimes, the nerve becomes fatigue already. Thus, the use of surgical loupes will be of great help in identifying these smaller branches of the facial nerve.

8.7.1.9 Removal of the Parotid Mass

Once all the branches of the nerve have been traced and preserved (Fig. 8.19), the remaining parotid tissue can be released, in order to facilitate the removal of the tumour mass in total.

In case of malignant carcinoma of parotid, it is important to ensure the removal of periparotid tissues also as this can be the area of micrometastatic tumour foci. This technique will also ensure negative surgical margins post-operatively, which is vital to reduce the likelihood of locoregional recurrence.

8.7.1.10 Homeostasis Control

After the parotid mass has been removed, the homeostasis is secured. Any bleeding vessels are

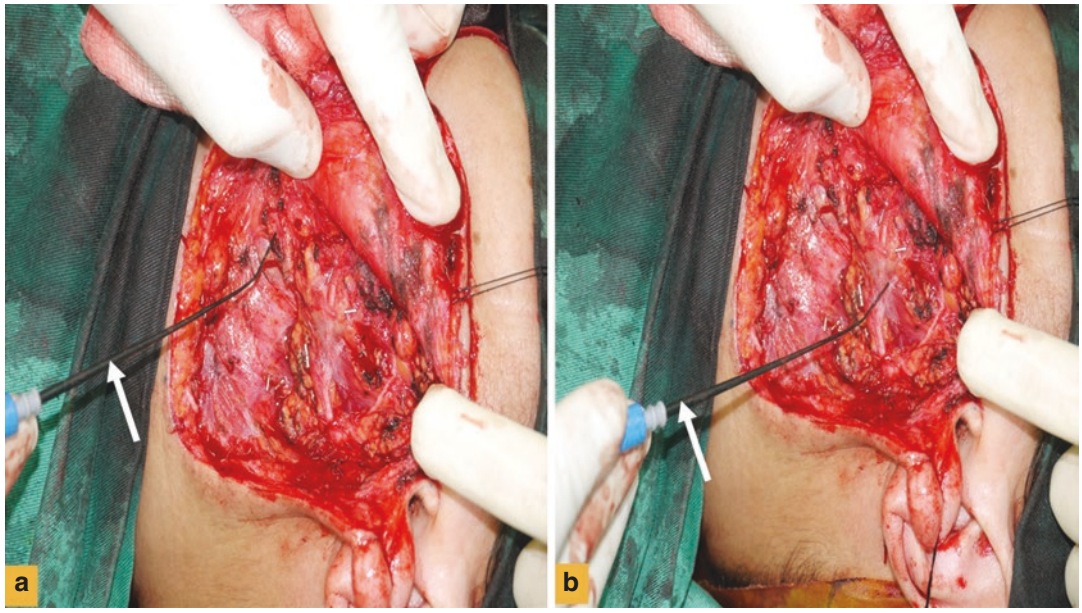

Fig. 8.18 Lower branches (**a**) and upper branches (**b**) of facial nerve are tested with a facial nerve stimulator proe (arrow) to ensure its functionality

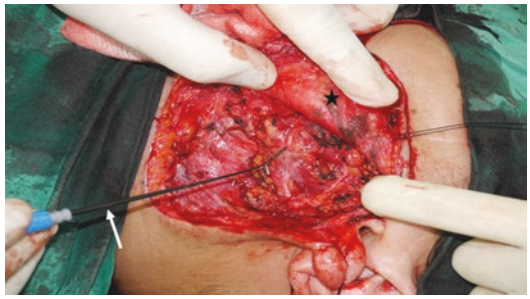

Fig. 8.19 Facial nerve stimulator (arrow) is used to assess the functioning of facial nerve. All branches of the nerve are preserved. Skin flap is retracted (star)

cauterized. Warm saline wash can help the oozing vessels, and sometimes the surgical can be applied to the wound to help stop the bleeding. The nerve is stimulated for a last time to make sure that it is functioning and intact (Fig. 8.19). The nerve impulse as well as the contraction muscle of expression is observed.

8.7.1.11 Drain Insertion and Wound Closure

The drain size 10 is inserted and secured with silk 3.0. The wound is closed in two layers with Vicryl 2.0. The subcuticular closure with white Vicryl or Safil is excellent for post-operative aesthetics. The patient is prescribed with IV dexamethasone, analgesia, and antibiotics for 2–3 days post-operatively.

8.7.1.12 Post-operative Follow-Up

Patient is reviewed at 1 week, 4 weeks, and 12 weeks post-operatively. During this follow-up, the wound is inspected for any evidence of infection or seroma.

8.7.2 Total Parotidectomy with Facial Nerve Preservation

Total parotidectomy is indicated in case if tumours involved both the superficial and deep lobe of parotid glands. In this type of surgery, both the superficial and deep lobe of the parotid glands will be removed. The facial nerve, which runs between the superficial and deep lobe of parotid glands, needs to be identified, skeletonized, and preserved.

In the majority of cases, the superficial parotidectomy will be performed first followed by the identification of the facial nerve, and the nerve

will be skeletonized from the tumour tissues. Subsequently, the facial nerve will be lateralized and the deep lobe parotidectomy can then be carried out.

Indications of total parotidectomy with preservation of facial nerve:

1. Pleomorphic adenoma of deep lobe parotid gland
2. High-grade mucoepidermoid carcinoma of superficial parotid gland
3. Carcinoma of deep lobe of the parotid glands
4. Recurrent carcinoma at superficial or deep lobe parotid glands

8.7.2.1 Case Illustration 1

This is a case of pleomorphic adenoma of right parotid glands. Clinical examination of the patient does reveal a small, firm mass measuring 4.0 cm × 5.0 cm, mobile and non-tender (Fig. 8.20). The overlying skin is not fixed to the mass. There was no medialization of lateral pharyngeal wall. However, CT scan showed mass arising from the right parotid gland, with extension to deep lobe. There was no enlarged cervical node. FNAC revealed that it is pleomorphic adenoma.

8.7.2.1.1 Step 1: Patient's Positioning and Surgical Landmark Identification

The steps are similar to those of the superficial parotidectomy. The modified Blair skin incision can be modified accordingly (Fig. 8.21), depending on the size of the parotid tumour and need for surgical access. If the tumour is large and difficult access is anticipated with the standard skin incision, mandibulotomy might be considered. However, only selected cases of malignant deep lobe involvement require mandibulotomy as the majority can be addressed with correct dissection technique.

Intraoperatively, skin flap is raised anteriorly to the level of anterior border of the mass, with preservation of greater auricular nerve (Fig. 8.22), which runs across the sternocleidomastoid muscle. The anterior branch of greater auricular nerve (GAN) supplies the parotid capsule, which can be sacrificed. The posterior branch that supplies the ear lobule should be preserved, especially when operating on a benign case. In malignant cases, both branches can be sacrificed if it causes difficult access to the clearance of malignant tumour.

The facial nerve trunk is identified (Fig. 8.23) and followed anteriorly to trace the peripheral branches. Meticulous dissection is necessary as the branches can be very fine and at risk of being

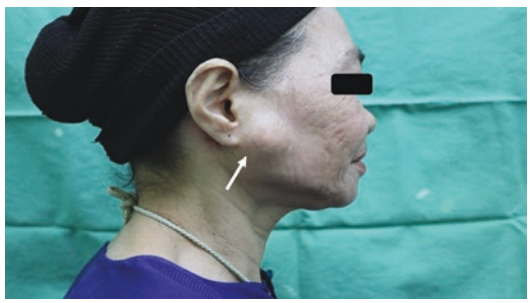

Fig. 8.20 Right parotid mass, 4.0 cm × 4.0 cm, firm, mobile (arrow). The right facial nerve is intact

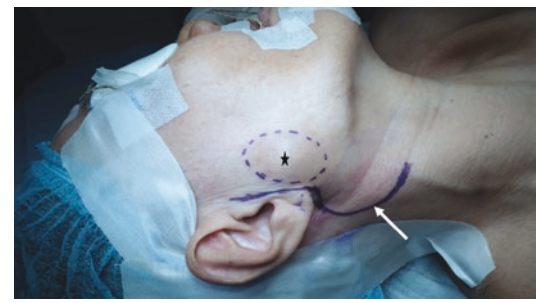

Fig. 8.21 The tumour mass is outlined (star) and the modified Blair incision is marked, which extends from anterior to tragal cartilage and descends to the neck (arrow)

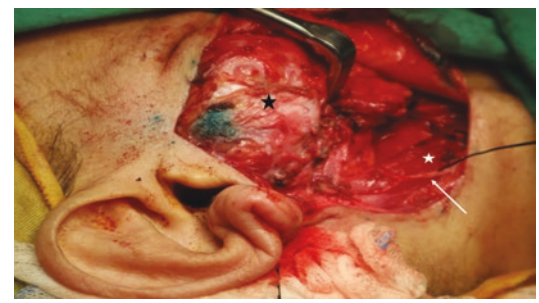

Fig. 8.22 Parotid mass is retracted (star), and the greater auricular nerve (arrow) that runs superficial to sternomastoid muscle is preserved (white star)

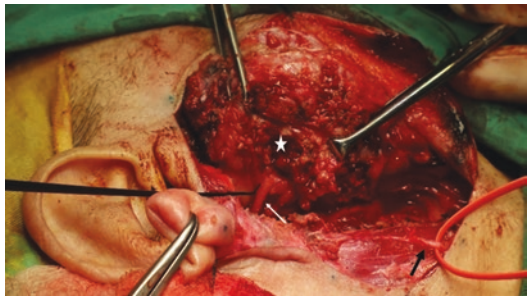

Fig. 8.23 Facial nerve trunk (arrow) going through the tumour (star), while the tumour is retracted anteriorly

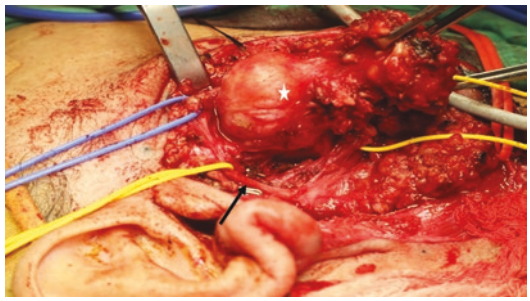

Fig. 8.24 Parotid mass (star) is located superficial to the peripheral branches of the nerves (arrow), which has been traced and exposed

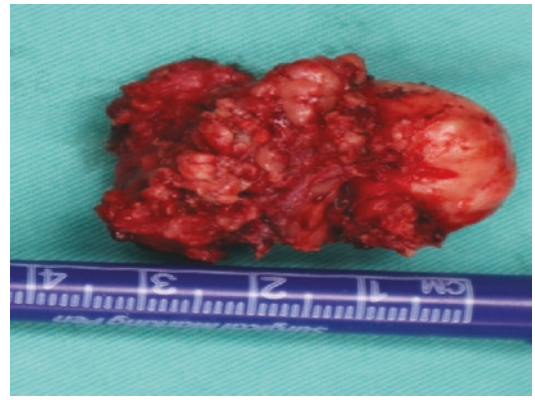

Fig. 8.25 The parotid mass which is excised measuring 3.0 cm × 3.0 cm

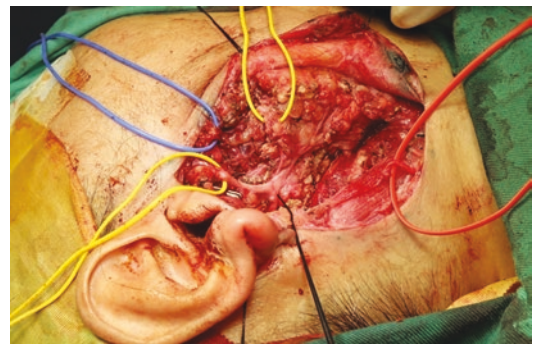

Fig. 8.26 Facial nerve trunk and all its branches are preserved

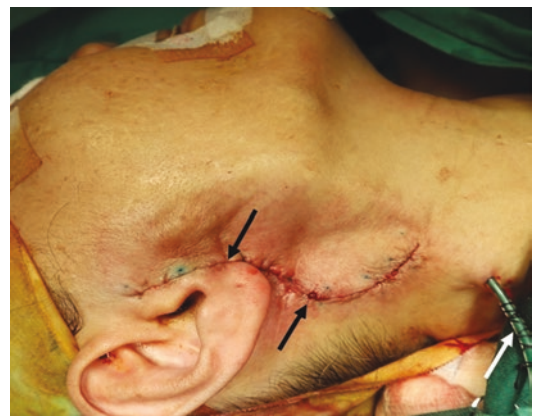

Fig. 8.27 The wound is closed in two layers with Vicryl 3.0, and a Redivac drain size 10 is secured (white arrow)

transected. Usage of fine haemostat with techniques of lift, spread, and cut can be practised to better protect this fine peripheral branches.

The parotid mass is dissected out superficial to the facial nerve peripheral branches (Fig. 8.24). The yellow vessel loop is placed under the nerve and can be used for identification and retraction. Care should be taken not to accidentally pull the loop to avoid iatrogenic injury of facial nerve.

Intraoperatively, after the superficial lobe of parotid gland has been dissected, the facial nerves and its branches are skeletonized and retracted laterally as tumour at the deep lobe also has to be removed.

The mass has been removed (Fig. 8.25), and surgical bed is irrigated with warm normal saline. The facial nerve and all the branches are tested with nerve stimulation to ensure its function (Fig. 8.26).

Surgical bed is examined for any suspicious residual mass and any active bleeders before wound closure. A drain is secured to facilitate drainage post-surgery. This will prevent haematoma or seroma post-surgery. A meticulous skin closure should be done by two-layer closure with Vicryl 3.0 (Fig. 8.27).

8.7.3 Case of Extended Total Parotidectomy with Skin Excision and Flap Reconstruction

This is a case of an elderly Malay male who presented with a long-standing left parotid mass. Investigation revealed that it was a malignant parotid carcinoma (Fig. 8.28a). Patient is planned for total parotidectomy with left modified radical neck dissection and pedicle rotational flap (Fig. 8.28b).

The skin incision should be designed meticulously, with consideration of attaining negative surgical margins. This skin incision needs to include primary tumour excision with ipsilateral neck dissection and for rotational flap utilization.

A modified Blair skin incision is used with inferior limb extension to accommodate for neck dissection. Once skin flap is raised and retracted anteromedially, this exposes the sternocleidomastoid muscle (Fig. 8.29). The neck dissection should be carried out first, so as to prevent the contamination of a fresh area if the primary tumour is addressed first. The anterolateral neck (levels I–IV) fibrofatty and lymph node tissues are dissected and removed (Fig. 8.30).

Once the neck dissection is completed, the primary tumour is dissected (Fig. 8.31). The tumour is excised together with the overlying skin due to involvement by the tumour

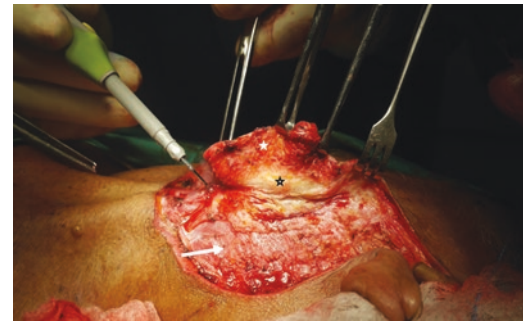

Fig. 8.29 The skin flap is elevated via a modified Blair skin incision and retracted anteromedially (white star). The skin is thin and fixed at the uppermost of the parotid mass (black star). The sternocleidomastoid muscle is visible at lateral-most part of the surgical bed (arrow)

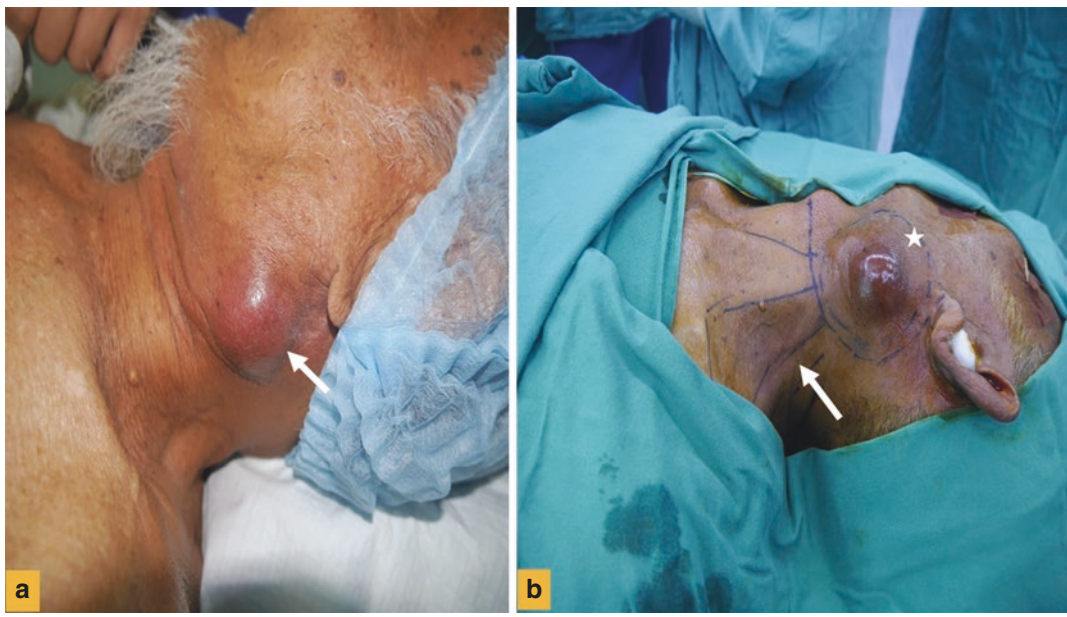

Fig. 8.28 Clinically, the skin overlying mass is tensed (arrow) with limited mobility signifying infiltration by tumour. Thus, the skin needs to be excised together with the tumour (**a**). The skin incision is marked at 1.5 cm around the primary parotid mass (star), and outline of SCM, trapezius, and level V neck nodes (arrow) is marked to facilitate the ipsilateral MRND (**b**)

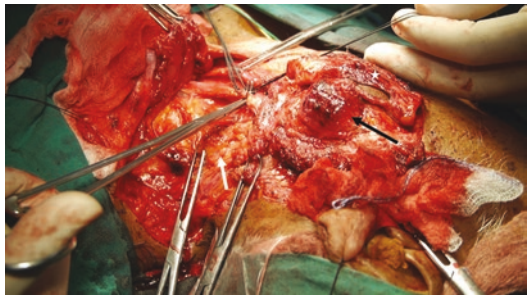

Fig. 8.30 The neck dissection is performed first before dissection of parotid mass to ensure no tumour tissue seedling onto the neck if parotid tumour is excised first (white arrow). The manipulation of parotid mass (black arrow) causes contamination to glove and cold instruments that can be transferred to the neck surgical bed. The skin around the tumour (star) is excised together with the tumour

(Figs. 8.33 and 8.34). Any suspicious residual malignant tissue is removed by piecemeal techniques (Fig. 8.32). The tumour that has been excised needs to be prepared for histopathology examination by the pathologist. This is normally done by placing a number of sutures at the anterior, posterior, superior, inferior, and deep margins of the mass (Fig. 8.35).

Post removal of the mass and neck dissection, the surgical defect is assessed for a rotational myocutaneous flap. This is done by the plastic reconstructive team at our centre. The deltopectoral skin flap is harvested and rotated to the neck and sutured to the neck surgical defect (Figs. 8.36 and 8.37).

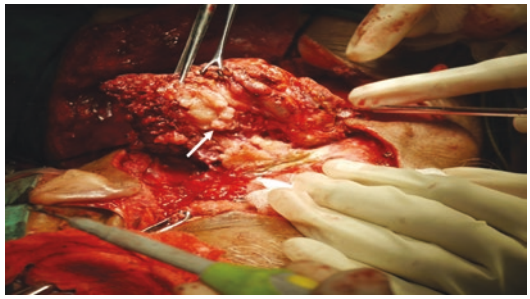

Fig. 8.31 The parotid mass has been dissected and retracted (arrow) to facilitate dissection at the medial side of the mass

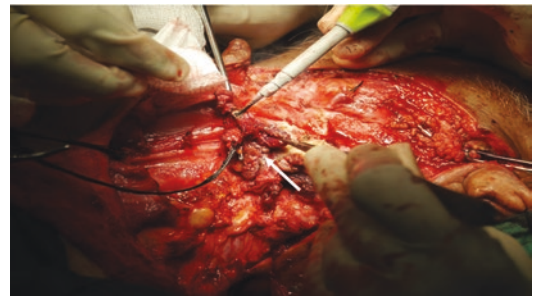

Fig. 8.32 The residual tissue at neck dissection area excised using monopolar cautery. The parotid mass has been completely excised

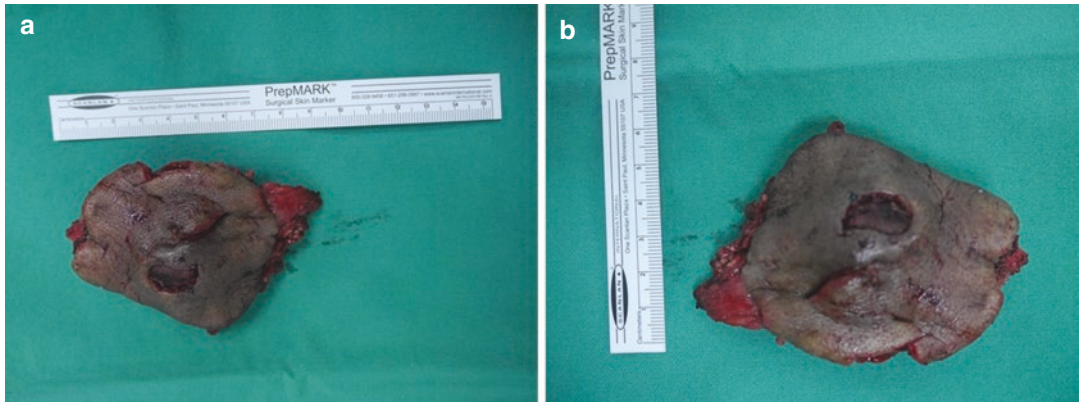

Fig. 8.33 (**a**, **b**) The skin and parotid mass that are excised measuring 6.0 cm × 5.0 cm

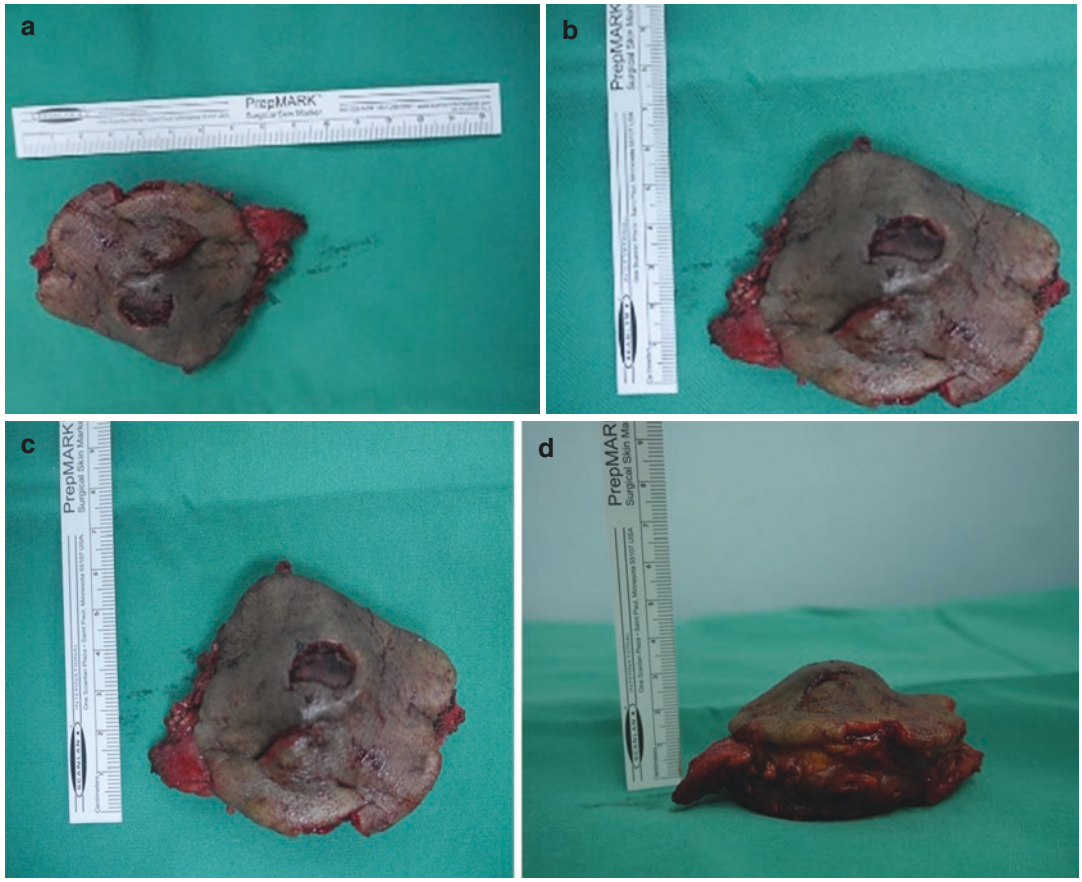

Fig. 8.34 (**a**–**d**) The tumour has infiltrated the skin which necessitate resection of tumour together with the skin

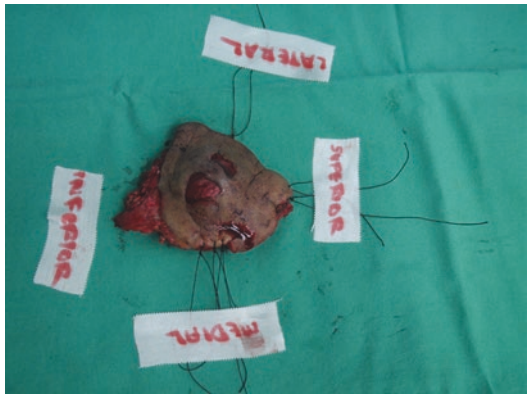

Fig. 8.35 The excised tumour mass is labelled with suture ties to orientate for histopathology examination as it is important to delineate which area is free of tumour or affected by tumour. This can be used to plan for adjuvant radiation dose post-operatively and to address the exact site of second surgery if recurrence develops

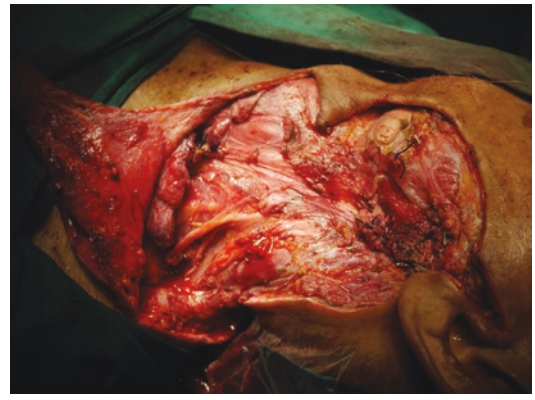

Fig. 8.36 The surgical defect post removal of the parotid tumour and neck dissection. Extensive skin flap is needed to cover this defect

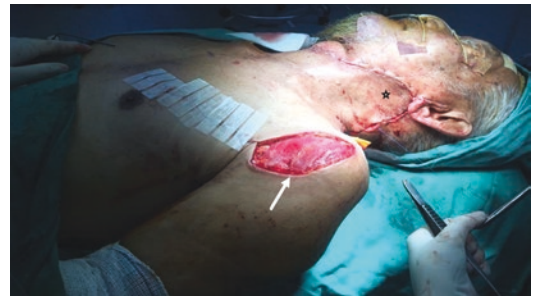

Fig. 8.37 The skin flap is harvested from the deltoid region (arrow) and sutured to the neck skin and parotid area (star). The skin closure is done in two layers. The deltoid skin defect will be grafted with skin graft, which can be harvested from the lower limb later

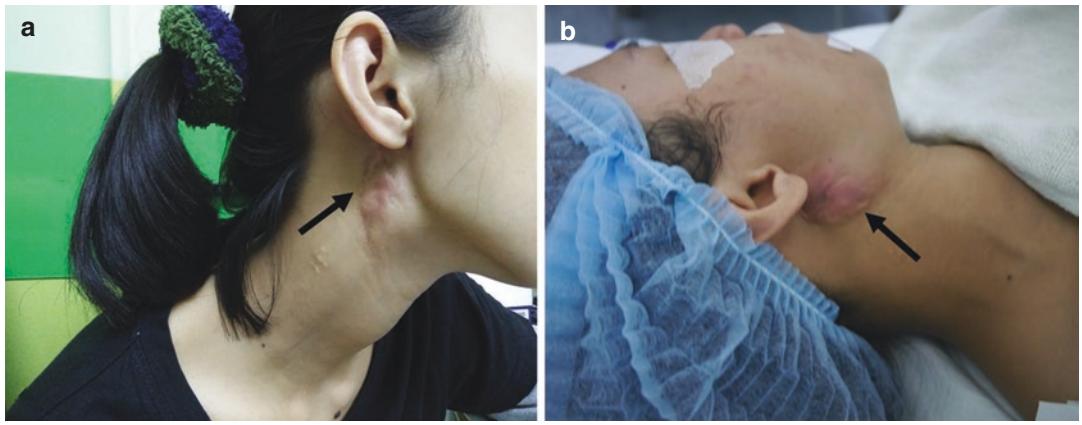

Fig. 8.38 The recurrent adenoid cystic carcinoma post total parotidectomy (**a**, **b**) (arrow)

8.7.4 Cases of Recurrent Adenocystic Carcinoma in a Young Female

This is the case of a young lady presented with a history of right total parotidectomy and neck dissection at another centre for adenoid cystic carcinoma of right parotid gland. On clinical examination, there was a mass with irregular surface and margin, and it was hard in consistency (Fig. 8.38a, b). The FNAC report confirms that it was a recurrent carcinoma. She was planned for excision of the recurrent tumour.

Intraoperatively, after a palpation of the mass to define the margin of the mass, a skin incision is designed to incorporate 1.0–2.0 cm margins of the tumour (Fig. 8.39). This ensures that a free negative margin is achieved post-operatively.

After skin incision is made with a blade, the recurrent tumour mass is dissected and retracted. This exposes the carotid artery, IJV, and vagus nerve, underneath the mass (Fig. 8.40). These structures should be preserved along with the hypoglossal nerve (Figs. 8.41 and 8.42).

The mass is removed in total with the skin and measured accordingly for a record (Fig. 8.43). The specimen is sent to pathology lab for a detailed histopathology examination.

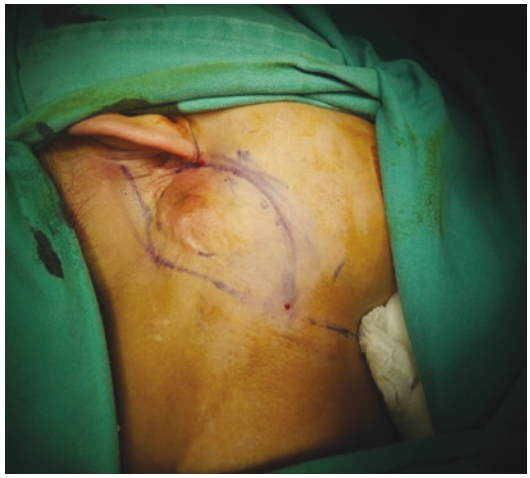

Fig. 8.39 The skin incision is marked around the recurrent tumour

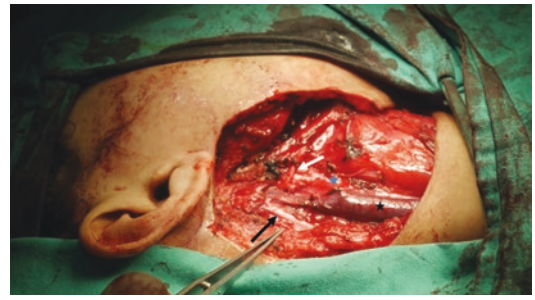

Fig. 8.41 The tumour mass has been removed. The IJV is visualized (star), and medial to it is common carotid artery (blue star). The hypoglossal nerve runs across horizontally on the carotid (white arrow). The spinal accessory nerve is seen lateral to IJV and going into SCM (black arrow)

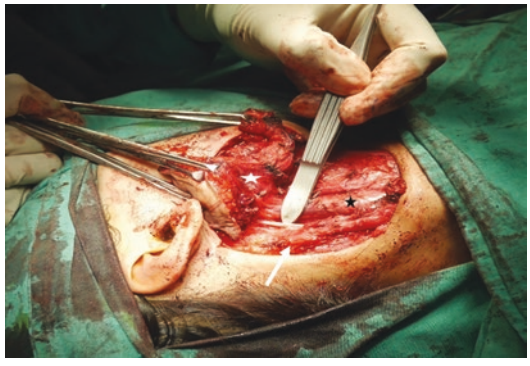

Fig. 8.40 The skin island has been excised, and the recurrent tumour tissue is dissected (white arrow) exposing the carotid sheath (IJV (black arrow), carotid artery, and vagus nerve underneath. The SCM muscle is visible laterally (arrow)

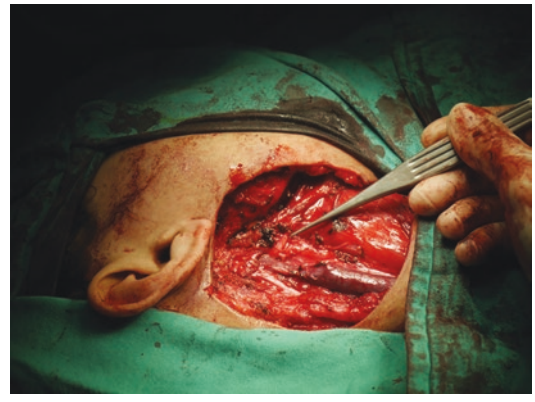

Fig. 8.42 The hypoglossal nerve is shown with a forceps

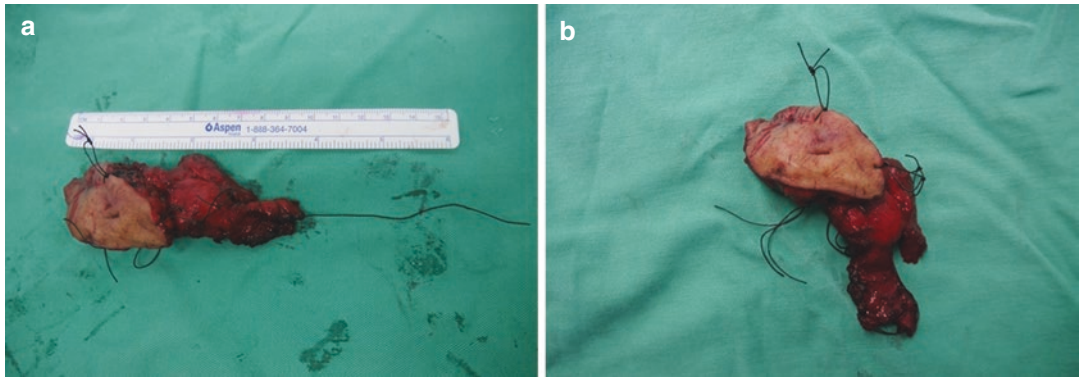

Fig. 8.43 (**a**, **b**) The tumour mass which is removed together with the skin

8.8 Complications Post Parotidectomy

Complications from parotidectomy are multiple and can be divided into intraoperative and post-operative. Intraoperative complications range across bleeding from external jugular vein or retromandibular vein puncture, greater auricular nerve injury, or transection of facial nerve branches.

Post-operative complications include:

1. Early complications:
   (a) Marginal mandibular nerve paralysis
   (b) Haematoma or seroma
   (c) Pain and discomfort
2. Late complications:
   (a) Retromandibular depression
   (b) Frey's syndrome
   (c) Permanent facial nerve paresis

Managing these complications is also challenging and requires a multidisciplinary team approach. The patient should have warned of the possible complications to avoid unwanted medicolegal issues. This is critical as facial nerve paresis causes significant facial asymmetry, which impairs patient's facial appearance.

In case of anticipated significant retromandibular depression that can occur, for instance, after removal of huge parotid pleomorphic adenoma, sternomastoid rotational flap can be performed during the surgery in order to reduce the cosmesis impairment of retromandibular depression. Subdermal fat graft can also be performed as an alternative option. However, with fat graft, the long-term complication is fat atrophy, which may facilitate repeat fat graft procedure.

Frey's syndrome is a critical complication from parotid surgery as it causes pain and discomfort to patients and involuntary sweating in the cheek region during mastication and eating. Frey's syndrome can be assessed via the symptom assessment and the more objective test of Minor starch iodine test. In our practice, even though patients do not have any complaints to suggest Frey's syndrome, the Minor starch iodine test is positive. This implies that the incidence of Frey's syndrome can be underestimated if a proper objective test is not carried out.

Management of Frey's syndrome can be divided into intraoperative procedures and post-operative procedures. Intraoperative procedures include the elevation of thicker skin flap, preserving greater amount of periparotid tissues, and doing partial-thickness sternomastoid rotational flap. Post-operative procedures include Botox injection and anticholinergic injection such as aluminium hydroxide.

8.9 Submandibular Gland Surgery

Submandibulectomy is most commonly performed for submandibular gland tumours, both benign and malignant. Other indications for submandibulectomy are sialolithiasis or sialadenosis. Submandibulectomy is also performed as part of neck dissection. Multiple critical structures need to be addressed correctly during submandibulectomy. These include marginal mandibular nerve, facial artery and vein, hypoglossal nerve, lingual nerve, and submandibular duct.

In case of malignant submandibular gland tumour, infiltration to mandible or skin or presence of neck metastases will justify the extirpation of these structures. Marginal mandibulectomy or segmental mandibulectomy can be performed accordingly depending on the degree of involvement. Large skin excision together with primary tumour necessitates reconstruction with free flap and skin grafting. The most common neck dissection practised for submandibular malignancy is supraomohyoid or anterolateral neck dissection.

8.9.1 Steps in Submandibulectomy

This is the case of a young Malay lady who presented with an extensive right submandibular swelling. It is a multilobulated mass with limited mobility and measuring 8.0 cm × 10.0 cm and hard in consistency (Fig. 8.44).

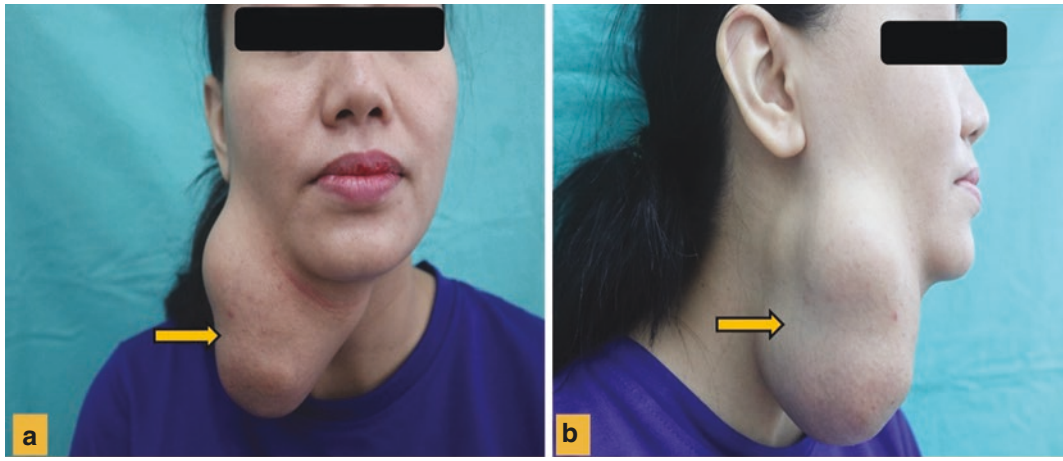

Fig. 8.44 Right submandibular mass in a young female, which is multilobulated. (**a**) Huge submandibular mass with FNAC confirmed as pleomorphic adenoma. (**b**) Multilobulated firm to hard mass with intact right marginal mandibular nerve

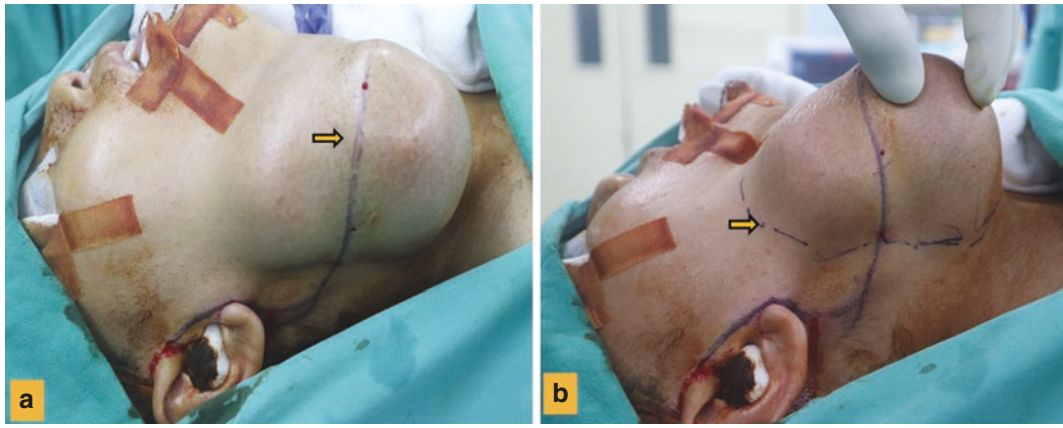

Fig. 8.45 The skin incision is designed at the epicentre of the mass and two finger breadths below the mandible to preserve the marginal mandibular nerve. (**a**) Submandibular tumour extends from right mandible superiorly to 2.0 cm above clavicle. The skin incision has been drawn on the epicenter of the mass, two fingerbreadth below mandible and along the skin crease. (**b**) The tumoural mass has been outlined to facilitate dissection later. The landmarks were palpated and orientated to the mass margins

1. Assessment of detailed characteristics of submandibular mass at the outpatient clinic and preparing patient for surgery with a well-informed consent:

   Step 1: Patient's positioning and designing of skin incision

   Patient is made to lie supine with neck hyperextended and face turned to contralateral side. The intubation airway tube is placed away from the surgical field, on the left side of the oral cavity. The landmark is identified, which includes the inferior border of mandible, the margin of the mass, the midline, the anterior border of SCM, and the external jugular vein.

   The skin incision is designed so as to avoid marginal mandibular nerve injury and good access to the inferior pole of the mass, by placing the incision along the skin crease, two finger breadths below the mandible and at the epicentre of the mass (Fig. 8.45). Stage of skin incision is favourable so that

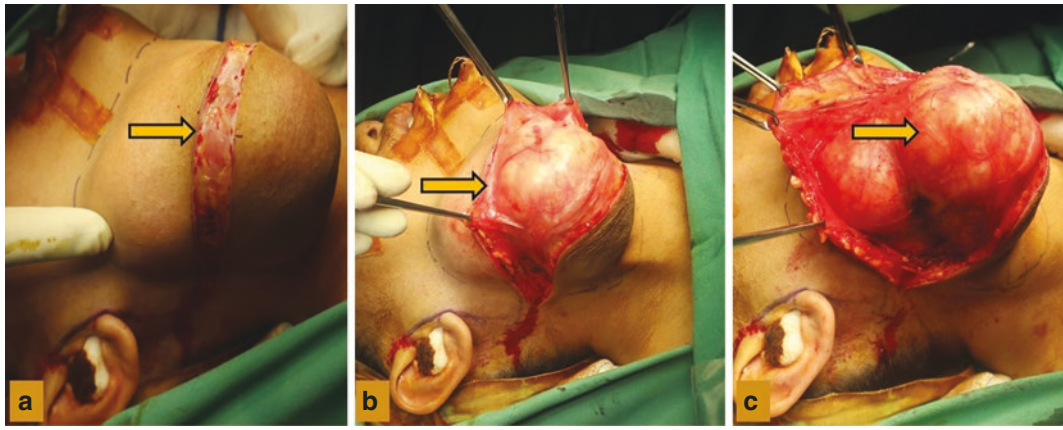

Fig. 8.46 The subplatysmal skin flap elevation. (**a**) Skin incision is made using blade size 15 along the marked area. (**b**) Platysma muscle is thinned out. Subplatysma flap is raised superiorly and inferiorly, following on the capsule of the mass. (**c**) Multilobulated and firm mass is dissected meticulously

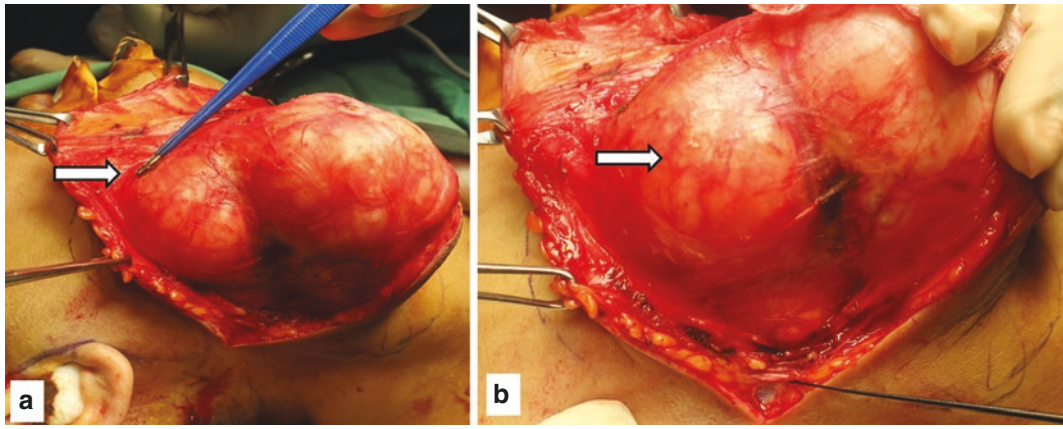

Fig. 8.47 The marginal mandibular nerve and greater auricular nerve are both preserved. (**a**) Marginal mandibular nerve runs superficial to submandibular tumour capsule, is reflected superiorly. (**b**) The tumoural mass is dissected, with greater auricular nerve (black probe) lateral to the mass is preserved

it can avoid unnecessary skin cut. In this case, the skin incision is prepared in continuity with skin incision for parotid gland in case it is affected by the tumour.

Step 2: Skin Flap elevation

The skin incision is carried out with a blade size 15 or monopolar diathermy with a fine Colorado tip. The subplatysmal flap is raised superiorly to the inferior border of mandible and inferiorly till the inferior border of the mass. The dissection is carried out on the tumour capsule without breaching of the capsule (Fig. 8.46).

Step 3: The dissection

Laterally, the dissection continues to the lateral border of the mass, avoiding the injury to the greater auricular nerve (GAN), as it lies superficial to sternocleidomastoid muscle. The marginal mandibular nerve identified on the superior part of the tumour capsule and reflected superiorly over the skin flap (Fig. 8.47).

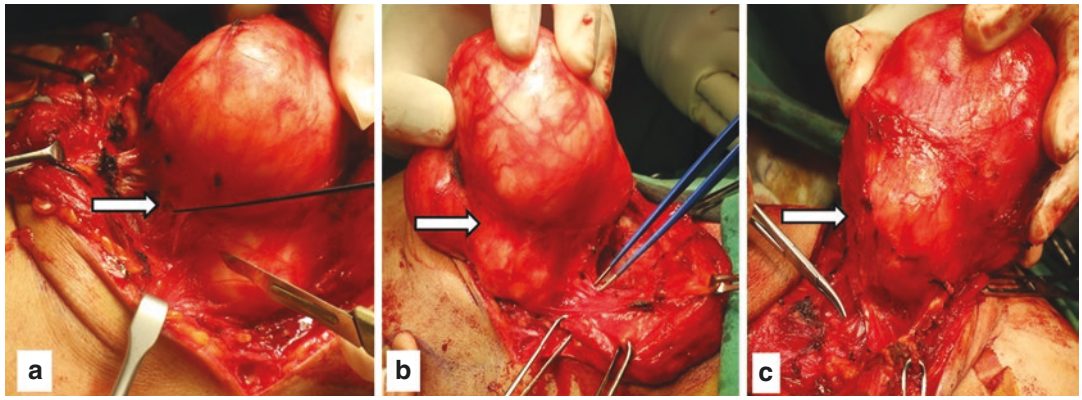

Fig. 8.48 The dissection continues while maintaining an intact capsule of the mass. (**a**) Marginal mandibular nerve is retracted superiorly while tumoural mass dissected and retracted inferiorly. (**b**) The pedicle of tissue at deep aspect of the mass before the mass is excised in total. (**c**) The capsule of the mass remains intact

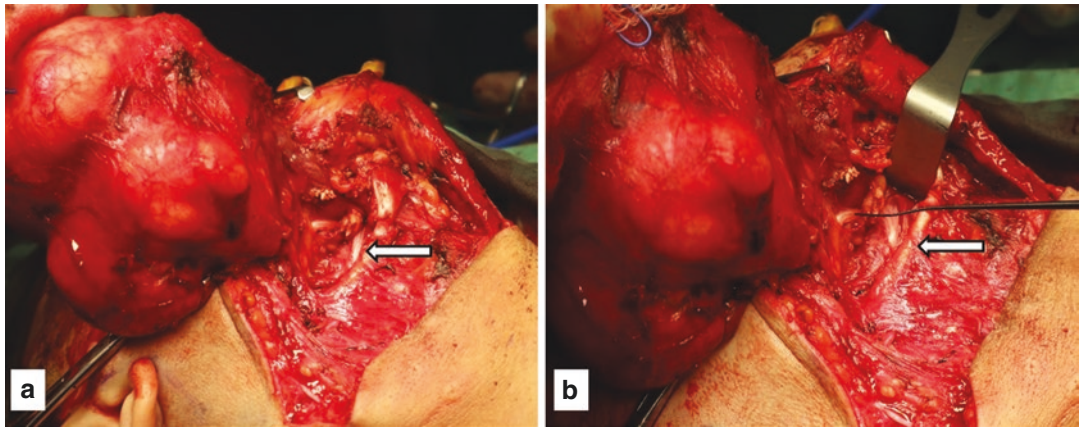

Fig. 8.49 (**a**, **b**) The hypoglossal nerve (**a**) is visible deep to the tendon of digastric muscle (**b**)

The dissection continues medially and deep to the mass, releasing the tumour from the surrounding tissue. The posterior belly of digastric is identified, and dissection continues to expose the mylohyoid muscle. The capsule of the mass is maintained intact (Fig. 8.48).

Step 4: The identification of lingual nerve, submandibular duct, and hypoglossal nerve

The mylohyoid muscle is retracted superior-anteriorly. By doing this, the lingual nerve and submandibular duct can be identified when the dissection continues. Due to the lingual nerve that passed medially, hooks around the submandibular duct, and runs laterally to the posterior part of the gland, traction of the submandibular glands inferiorly makes the 'V'-shape figure of lingual nerve. The apex of the V is where the duct is. The duct can be ligated as proximal as possible, and the lingual nerve is preserved.

The hypoglossal nerve can be found about 1.0 cm below to lingual nerve, and it lies just medial to the posterior belly of digastric muscle (Figs. 8.49 and 8.50). In some cases, the hypoglossal nerve can be low

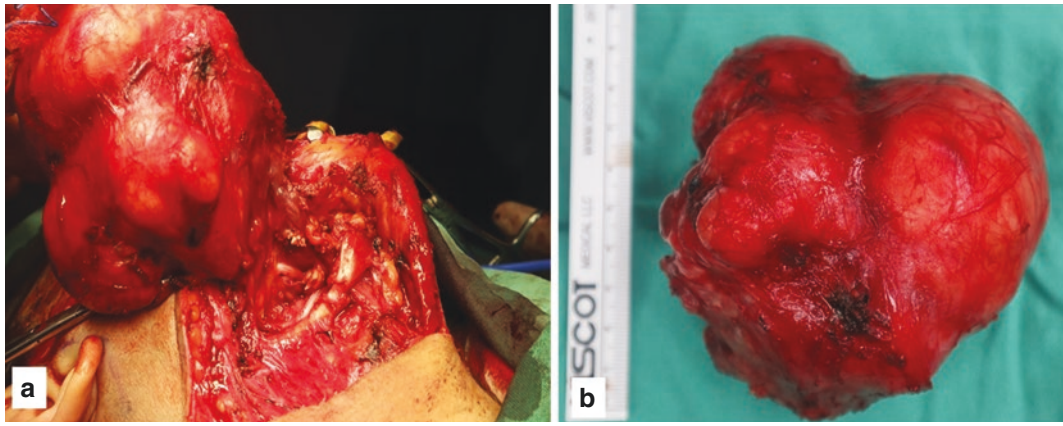

Fig. 8.50 The mass is retracted superiorly. Both hypoglossal nerve and lingual nerve are preserved (**a**). The mass weighed 600 mg is removed in total (**b**)

lying due to ptotic submandibular glands and adjacent structures.

Step 5: Extirpation of the mass

Once the mass is out, the surgical bed is irrigated with warm saline and homeostasis is secured. Any blood oozes will be cauterized with bipolar diathermy. All nerves are tested before wound is closed in two layers. The Redivac drain size 19 is secured.

Step 6: Surgical bed assessment and wound closure

After removal of the mass, the surgical bed is checked for any active bleeding. Warm saline can be irrigated and observed for the bleeding area. The bipolar is used to secure the bleeders. The lingual nerve and hypoglossal nerve are re-tested for functionality.

The drain size 10 is secured with Safil 2.0. The wound is closed in two layers. The subcutaneous tissue is secured with Vicryl 3.0, and the skin is closed with white Vicryl 3.0 subcuticular (Fig. 8.51).

8.9.2 Post-operative Assessment

During post-operative assessment on day 1, the wound area is inspected for any haematoma and marginal mandibular nerve paresis. The patient is asked to clench her teeth, and apparent paresis of the MM on the affected side can be visualized with the evident loss of depression of angular oris inferior (Fig. 8.52). The patient is prescribed with dexamethasone for 3 days to reduce oedema and improve the marginal mandibular paresis.

The drain should be checked for drainage to rule out blocked or kinked drain. The resultant collection might compress the nerve and worsen the paresis.

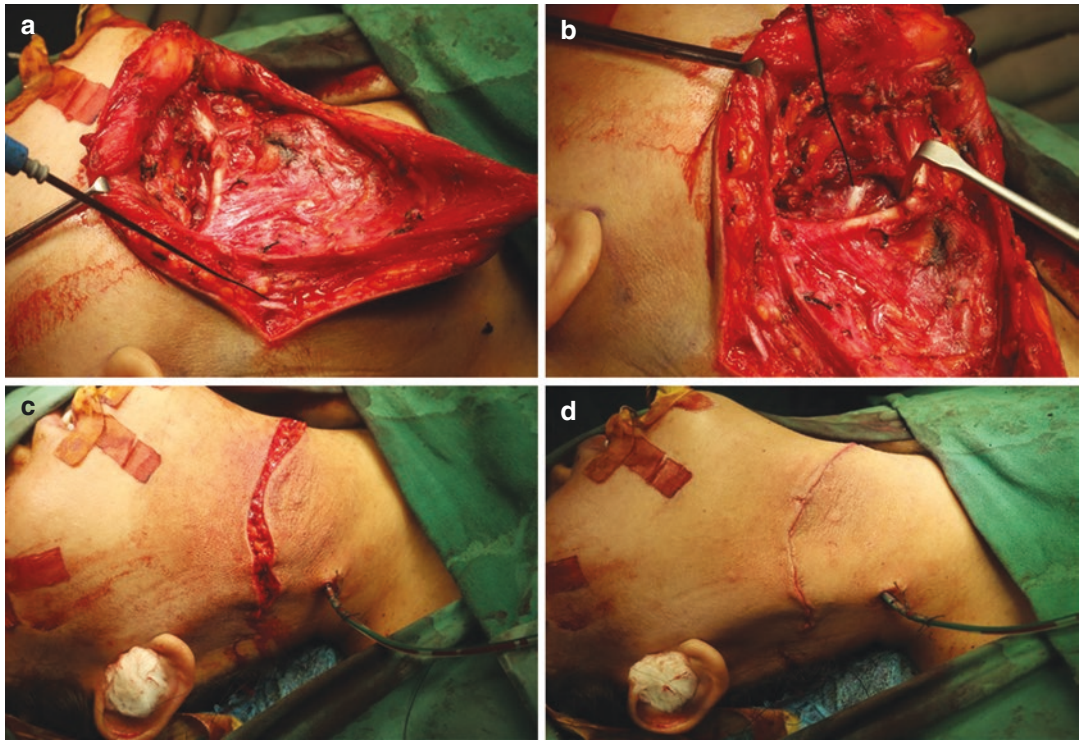

Fig. 8.51 The digastric muscle is visible (**a**) and retracted inferiorly (**b**) to expose the hypoglossal nerve (tip of nerve probe) (**b**). The skin is closed in two layers, and a Redivac drain is secured (**c**, **d**)

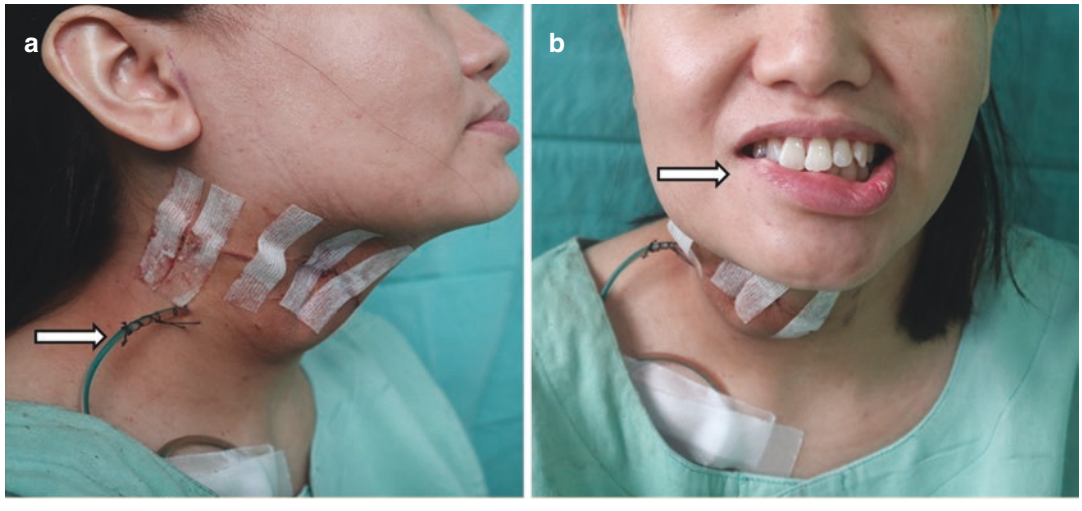

Fig. 8.52 Postoperatively, the drain is in situ (**a**). There is right marginal mandibular nerve paresis as evident by loss of depression of left lower lip (**b**)

8.10 Complications of Submandibulectomy

Xerostomia and decreased salivary flow in a resting position are specific long-term complications after submandibulectomy because the submandibular glands are responsible for 70% of resting salivary flow. Up to 22% of operated patients can be affected with it. Other complications might include a heterotrophic scar, keloid formation, injuries to the submandibular duct, ranula, and intraoperative bleeding. Damage to the hypoglossal nerve or to the cervical branch of the facial nerve is possible especially in a junior surgeon's hand.

8.11 Prognosis of Patients with Salivary Gland Tumours

Patients' quality of life after radical cancer removal depends on the extent of resection, the preservation of the facial nerve, and the preservation of neighbouring structures such as the greater auricular nerve, hypoglossal nerve, muscles of mastication, and mandible.

The removal of one or more branches of the facial nerve leads to long-term functional deficits, and cable grafting and neural repair techniques are essential for the reconstruction and recovery of the resected facial nerve. Facial nerve asymmetry is disfiguring and affects normal speech, eating, and facial expression, which is important for social integration. In addition, if the patient had neck dissection at the time of parotidectomy, complications from neck dissection can be troublesome like vocal cord paresis or spinal nerve injury. This is compounded if the patient had adjuvant radiation that causes tissue fibrosis.

8.12 Conclusion

Salivary gland surgery is critical as it involves multiple important neurovascular structures. For parotid gland surgery, the facial nerve needed to be identified and preserved. The submandibulectomy poses complications of hypoglossal nerve and lingual nerve paralysis. In case of malignant tumour, neck dissection needed to be incorporated in the initial surgery to ensure a better treatment outcome for this patient. In short, the surgeon needs to master the surgical anatomy and skills in order to perform an effective parotidectomy.

References

1. Basset CA, Cappello F, Rappa F, et al. Molecular chaperones in tumors of salivary glands. J Mol Histol. 2020;51(2):109–15. https://doi.org/10.1007/s10735-020-09871-y.
2. Eskander A, Irish J, Freeman J, et al. Overview of major salivary gland cancer surgery in Ontario (2003-2010). J Otolaryngol Head Neck Surg. 2014;43(1):50. Published 2014 Dec 10. https://doi.org/10.1186/s40463-014-0050-6.
3. Emodi O, El-Naaj IA, Gordin A, Akrish S, Peled M. Superficial parotidectomy versus retrograde partial superficial parotidectomy in treating benign salivary gland tumor (pleomorphic adenoma). J Oral Maxillofac Surg. 2010;68(9):2092–8. https://doi.org/10.1016/j.joms.2009.09.075.
4. Choi JS, Cho BH, Kim HJ, Kim YM, Jang JH. Identification of new genes of pleomorphic adenoma. Medicine (Baltimore). 2019;98(51):e18468. https://doi.org/10.1097/MD.0000000000018468.
5. Peraza A, Gómez R, Beltran J, Amarista FJ. Mucoepidermoid carcinoma. An update and review of the literature. J Stomatol Oral Maxillofac Surg. 2020;121(6):713–20. https://doi.org/10.1016/j.jormas.2020.06.003. Epub 2020 Jun 18.
6. Gupta A, Koochakzadeh S, Neskey DM, Nguyen SA, Lentsch EJ. Carcinoma ex pleomorphic adenoma: a review of incidence, demographics, risk factors, and survival. Am J Otolaryngol. 2019;40(6):102279. https://doi.org/10.1016/j.amjoto.2019.102279.
7. Lobo R, Hawk J, Srinivasan A. A review of salivary gland malignancies: common histologic types, anatomic considerations, and imaging strategies. Neuroimaging Clin N Am. 2018;28(2):171–82. https://doi.org/10.1016/j.nic.2018.01.011.
8. Psychogios G, Bohr C, Constantinidis J, et al. Review of surgical techniques and guide for decision making in the treatment of benign parotid tumors [published correction appears in Eur Arch Otorhinolaryngol. 2020 Aug 29]. Eur Arch Otorhinolaryngol. 2021;278(1):15–29. https://doi.org/10.1007/s00405-020-06250-x.
9. Nahlieli O. Complications of traditional and modern therapeutic salivary approaches. Complicanze degli approcci terapeutici tradizionali e moderni alle ghiandole salivari. Acta Otorhinolaryngol Ital. 2017;37(2):142–7. https://doi.org/10.14639/0392-100X-1604.

10. Satya Sai Reddy GG, Verma RK, Devarapalli NSP, Sahni D, Bakshi J, Panda NK. Feasibility of using posterior auricular artery as landmark for identification of facial nerve trunk in parotid surgery: a cadaver study. J Craniofac Surg. 2020. Published online ahead of print, 2020 Oct 20; https://doi.org/10.1097/SCS.0000000000007222.
11. Wierzbicka M, Kopeć T, Szyfter W, Kereiakes T, Bem G. The presence of facial nerve weakness on diagnosis of a parotid gland malignant process. Eur Arch Otorhinolaryngol. 2012;269(4):1177–82. https://doi.org/10.1007/s00405-011-1882-6.
12. Mimica X, McGill M, Hay A, et al. Distant metastasis of salivary gland cancer: incidence, management, and outcomes. Cancer. 2020;126(10):2153–62. https://doi.org/10.1002/cncr.32792.
13. Nadershah M, Salama A. Removal of parotid, submandibular, and sublingual glands. Oral Maxillofac Surg Clin North Am. 2012;24(2):295–x. https://doi.org/10.1016/j.coms.2012.01.005.
14. Guenette JP, Ben-Shlomo N, Jayender J, et al. MR imaging of the extracranial facial nerve with the CISS sequence. AJNR Am J Neuroradiol. 2019;40(11):1954–9. https://doi.org/10.3174/ajnr.A6261.
15. Al-Qahtani KH, AlQahtani FM, Muqat MM, et al. A new landmark for the identification of the facial nerve during parotid surgery: a cadaver study. Laryngosc Investig Otolaryngol. 2020;5(4):689–93. Published 2020 Jul 28. https://doi.org/10.1002/lio2.431.
16. O'Brien JX, Rozen WM, Ting JW, Leung M. A simplified landmark for the facial nerve trunk in parotidectomy: the sternocleidomastoid origin. J Plast Reconstr Aesthet Surg. 2012;65(6):832–3. https://doi.org/10.1016/j.bjps.2011.11.041.
17. de Ru JA, van Benthem PP, Bleys RL, Lubsen H, Hordijk GJ. Landmarks for parotid gland surgery. J Laryngol Otol. 2001;115(2):122–5. https://doi.org/10.1258/0022215011907721.
18. Thoeny HC. Imaging of salivary gland tumours. Cancer Imaging. 2007;7(1):52–62. Published 2007 Apr 30. https://doi.org/10.1102/1470-7330.2007.0008.
19. Vaiman M, Luckman J, Sigal T, Bekerman I. Correlation between preoperative predictions and surgical findings in the parotid surgery for tumors. Head Face Med. 2016;12:4. Published 2016 Jan 12. https://doi.org/10.1186/s13005-016-0100-6.
20. Lim CY, Chang HS, Nam KH, Chung WY, Park CS. Preoperative prediction of the location of parotid gland tumors using anatomical landmarks. World J Surg. 2008;32(10):2200–3. https://doi.org/10.1007/s00268-008-9663-0.
21. Poletti AM, Imparato S, Signorelli GC, Cugini G, Colombo G. The multiplanar analysis of the retromandibular vein in surgical planning for parotid gland tumors. Eur Arch Otorhinolaryngol. 2018;275(6):1587–93. https://doi.org/10.1007/s00405-018-4953-0.
22. Imaizumi A, Kuribayashi A, Okochi K, et al. Differentiation between superficial and deep lobe parotid tumors by magnetic resonance imaging: usefulness of the parotid duct criterion. Acta Radiol. 2009;50(7):806–11. https://doi.org/10.1080/02841850903049358.
23. Fujii H, Fujita A, Kanazawa H, Sung E, Sakai O, Sugimoto H. Localization of parotid gland tumors in relation to the intraparotid facial nerve on 3D double-echo steady-state with water excitation sequence. AJNR Am J Neuroradiol. 2019;40(6):1037–42. https://doi.org/10.3174/ajnr.A6078.
24. Quer M, Vander Poorten V, Takes RP, et al. Surgical options in benign parotid tumors: a proposal for classification. Eur Arch Otorhinolaryngol. 2017;274(11):3825–36. https://doi.org/10.1007/s00405-017-4650-4.
25. Wong WK, Shetty S. The extent of surgery for benign parotid pathology and its influence on complications: a prospective cohort analysis. Am J Otolaryngol. 2018;39(2):162–6. https://doi.org/10.1016/j.amjoto.2017.11.015.
26. Kadletz L, Grasl S, Grasl MC, Perisanidis C, Erovic BM. Extracapsular dissection versus superficial parotidectomy in benign parotid gland tumors: The Vienna Medical School experience. Head Neck. 2017;39(2):356–60. https://doi.org/10.1002/hed.24598.
27. Witt RL. The significance of the margin in parotid surgery for pleomorphic adenoma. Laryngoscope. 2002;112(12):2141–54. https://doi.org/10.1097/00005537-200212000-00004.

9 Thyroid Gland Tumour and Surgical Approach with Case Illustration

Norhafiza Mat Lazim, Zul Izhar Mohd Ismail, Muhamad Nor Firdaus Ab Rahman, and Baharudin Abdullah

9.1 Introduction

Thyroid gland diseases and tumours are showing an increasing trend in certain geographic locations globally. In our local practice, women are more commonly affected by thyroid tumours compared to men. This is especially true for a multinodular goitre which is observed to be rampant in young and middle-aged patient population. Thyroid tumours occur less frequently in paediatric patients. The incidence of thyroid malignancy is also on the rise and can be observed especially in cases with long-standing thyroid mass or goitre. Some cases arise de novo, and this is related to the familial predisposition and genetic susceptibility.

Clinical presentation of patients with thyroid malignancy varies. Some patients may present with midline neck mass, airway obstruction, neck nodes, or lung or bony metastases due to widespread systemic metastases. Due to slow growth of the tumour, the majority of patients have delayed clinical presentation. There are several types of thyroid malignancy with the papillary thyroid carcinoma (PTC) being the commonest type. Other types include medullary thyroid carcinoma, follicular carcinoma, and anaplastic carcinoma.

There are five main thyroid cancer histological types:

1. Papillary thyroid carcinoma, PTC
2. Medullary thyroid carcinoma, MTC
3. Follicular carcinoma
4. Poorly differentiated carcinoma
5. Anaplastic carcinoma

These various forms of thyroid cancers show significant variability (Table 9.1). It is noteworthy that among the first four types, which all originate from thyroid follicular cells, medullary thyroid carcinoma is the only tumour that originates from the thyroid C cells. Importantly, this heterogeneity is not only limited to histopathological diversity, but also manifested as genetic and clinical variation. For example, in several genetic and epigenetic changes in PTC, the number of interactions between the tumour and the microenvironment as well as interpatient differences has been strongly documented [1]. All these factors contribute to the great complexity of cancer cell tumour development and management.

As the incidence of thyroid cancer continues to increase, the factors that underpin surgical

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N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_9

Table 9.1 Types of thyroid malignancy and their clinical characteristics

	Types of thyroid malignancy	Characteristic features
1.	Papillary thyroid carcinoma	• Most common • Midline firm to hard neck mass • Rarely have neck metastases • Haematogenous spread is common • Thyroglobulin is a tumour marker
2.	Medullary thyroid carcinoma	• Calcitonin is tumour marker • Prone to have neck metastases • Associated with MEN syndrome
3.	Follicular thyroid carcinoma	• Aggressive form • Angioinvasion with distant metastasis predilection
4.	Anaplastic thyroid carcinoma	• Most aggressive form • Fast growing • Distant metastatic spread • Prognosis is 6 months

decision-making for individual patients are critical for clinicians who are involved in the management of these cancers [2]. Different literatures quote different recurrence risk and mortality rates of well-differentiated thyroid cancers. This however depends on the tumour's factors, patient's factors, and treatment's factors. The earlier the diagnosis is made, and the earlier the treatment intervention is carried out, the better the prognosis.

The main treatment modality for thyroid malignancy is surgical treatment. This surgery is important in order to reduce the micrometastatic spread of the tumour. Thyroid gland surgery can be divided into four main categories, which are total thyroidectomy, subtotal thyroidectomy, hemithyroidectomy, and lobectomy. The indication for each of these techniques varies. In patients who had neck metastases, the central compartment neck dissection is necessary to remove the fibrofatty and lymphatic tissues of the neck in order to prevent tumour recurrence. Currently, the role of neck dissection in thyroid malignancy is strongly debated. Additionally, post-operative adjuvant treatment with a radio iodine ablation is vital to control neck recurrence due to residual microscopic disease. In selected cases, radiation may also have a role in recurrent tumour, especially in the setting of palliative treatment.

Thyroid gland surgery is critical as multiple important neurovascular and adjacent structures are at risk of injury. Subsequently, this can impair the patient's quality of life. These structures include the recurrent laryngeal nerve (RLN), carotid artery, internal jugular vein and its branches, vagus nerve, and oesophagus. An important but avoidable thyroidectomy complication is injury to the recurrent laryngeal nerve. The identification of the RLN intraoperatively minimizes the risk of injury to the nerve. It is important to recognize the significant landmarks during dissection of thyroid glands in order to identify and preserve this nerve. RLN injury during thyroidectomy varies from 1.5% to 14% according to several studies. The true incidence may be different for different centres and different surgeons' experience. For instance, the rate of RLN paralysis among endocrine surgeons after thyroidectomy is 1.0–2.0% [3]. In 0.3–3.0% of cases, permanent RLN paralysis occurs, with transient paralysis reported at 5.0–8.0%. The permanent RLN paralysis is a serious complication, especially if the patient is a professional voice user such as singer or teacher.

Iatrogenic vocal cord paralysis is the most common cause of litigation associated with thyroid surgery performed worldwide. Pressure, laceration, heat damage, division, ligation, ischaemia, and manipulation are the main mechanisms for damaging the RLN during thyroidectomy [4]. In order to avoid post-operative complications such as hoarseness and vocal cord paralysis, a reliable landmark and method for identifying the RLN are necessary [5]. Anatomically, the area near the Berry's ligament, where the nerves penetrate the larynx, is the most common site of injury to the RLN. In more than 80% of cases, recuperation of the nerve may take place within 1 year or more.

Other than hoarseness, the other significant post-operative morbidity after total thyroidectomy is hypocalcaemia due to parathyroid insufficiency. Unintentional damage to, or

devascularization of, one or more parathyroid glands during surgery is the primary cause of hypocalcaemia [6]. Other than that, failure to find and locate the parathyroid glands itself is also a cause of hypocalcaemia. The location of parathyroid gland varies. It can be within the substance of thyroid gland itself or it resides near the tracheo-oesophageal groove. This parathyroid gland has same colour as fatty tissue around the thyroid glands, but with firmer consistency. In suspicious cases, this yellow tan-coloured tissue can be placed in a bowl of water. If it sinks, it is the parathyroid gland. If it floats, it is more of fatty tissue.

9.2 Surgical Anatomy of Thyroid Glands

Thyroid gland is an endocrine organ located at the anterior midline of the neck. The normal weight of thyroid gland in adults is approximately 25 g. It has right and left lobes, which extend from the level of the fifth cervical vertebra to the first thoracic vertebral body levels. The gland lies deep to the sternothyroid and sternohyoid muscles. It is encapsulated by an inner layer of true capsule and outer false capsule. The false capsule derives from the pretracheal layer of the deep cervical fascia of the neck. The false capsule forms a suspensory ligament (Berry's ligament), which is attached to the arch of the cricoid cartilage and oblique line of the thyroid cartilage (Fig. 9.1).

The two lobes of the gland are connected in the midline by an isthmus. The isthmus overlies the second or the third or even sometimes the fourth tracheal ring. Anterior jugular veins run on the anterior surface of the isthmus. Superior border of the isthmus is traversed by anastomotic vessels between the right and left superior thyroid arteries. Inferior thyroid veins run on its inferior border. The presence of these vessels around the isthmus makes it vulnerable to become a source of bleeding in thyroid surgery.

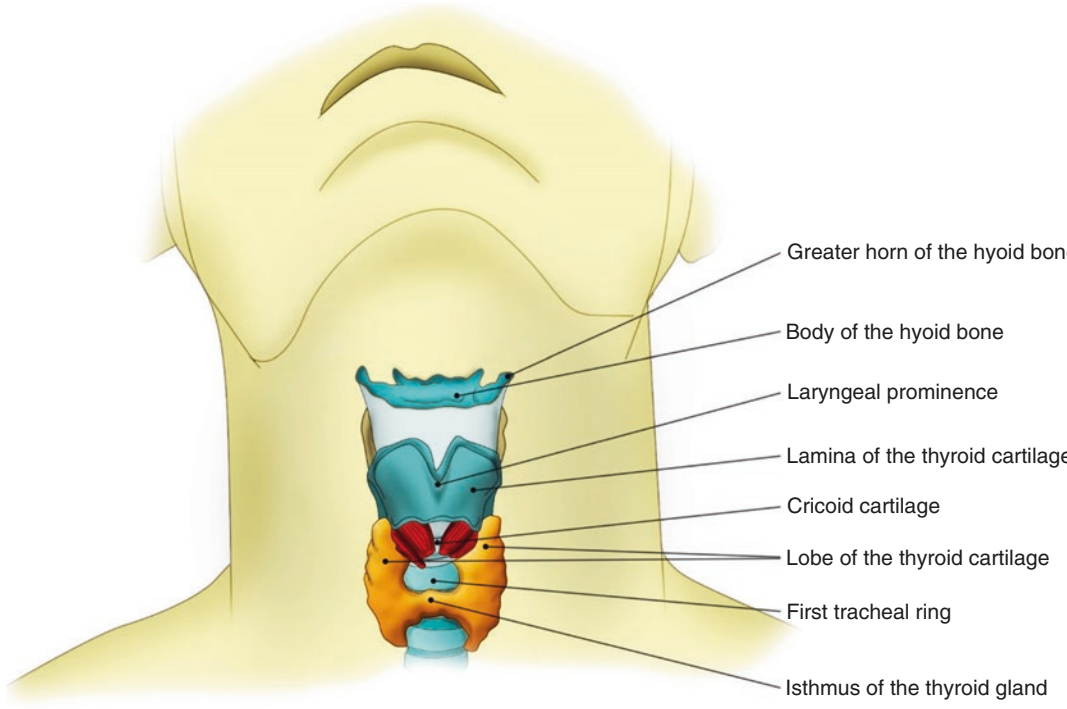

Fig. 9.1 Schematic drawing of the thyroid gland with its two lobes and isthmus showing the relations with the tracheal rings and thyroid cartilage

Each lobe of thyroid gland is described as a conical structure with three surfaces. The apices of the lobes lie at the level of the oblique lines of the thyroid cartilage. The bases of the lobes parallel the level of the fourth or the fifth tracheal ring. The lateral surface of each lobe lies deep to the sternothyroid, sternohyoid, superior belly of omohyoid, and anterior border of the sternocleidomastoid muscles. The medial surface of each lobe is related to the trachea, oesophagus, inferior constrictor muscles, cricothyroid muscles, external laryngeal nerve, and recurrent laryngeal nerve. The medial surfaces are attached to the cricoid cartilage by a lateral thyroid ligament. Carotid sheath, which contains the common carotid artery, internal jugular vein, and vagus nerve, is located on the posterolateral surface of the lobes. Anterior branch of the superior thyroid artery descends along the anterior border of the lobes. The posterior border of the lobe is the usual site of the parathyroid glands, inferior thyroid artery, and anastomotic vessels between the superior and inferior thyroid arteries. Thoracic duct is also a structure to be noted on the posterior relation to the left lobe.

Pyramidal lobe of thyroid gland is often a common finding in 28–55% of thyroid surgery [7]. It is a remnant of embryonic thyroid tissue, which arises from the isthmus. Commonly, it arises from the left lobe of the gland and extends superiorly towards the hyoid bone. In common cases of anatomical findings, it is attached to the hyoid bone by a band of fibromuscular tissue known as levator glandulae thyroideae.

Accessory thyroid gland is a common structure that should not be missed by surgeons during thyroid surgery. If present, these masses of thyroid tissues are commonly found at any point along the line of descent of embryonic thyroid tissue remnant from its site of origin. Therefore, these tissues could be found at any point from the foramen caecum at the base of the tongue until its definitive site in the neck. Occasionally, they could be located in any ectopic sites. It has been reported that accessory thyroid glands were found in the precordium, in the chamber of the heart, and in the larynx [8, 9].

Just like any other endocrine organ, thyroid gland is rich in blood supply. The arterial blood comes from the superior and inferior thyroid arteries. These arteries run within the fascial layers between the true and the false capsules. The superior thyroid artery originates as the first anterior branch from the external carotid artery. It then descends towards the superior pole of the lobe of the thyroid gland. At this point, it is closely related to the external laryngeal nerve. Upon reaching the superior poles of the lobes of the gland, the superior thyroid artery divides into anterior and posterior branches. The anterior branch runs along the anterior border of the lobes of the gland, giving off branches to the sternothyroid and sternohyoid muscles. The anterior branches from both sides anastomose on the superior border of the isthmus [10]. The posterior branch runs distally along the dorsal aspect of the thyroid gland. The inferior thyroid artery supplies the inferior aspects of the lobes of the gland. It arises as a branch from the thyrocervical trunk. It ascends to reach the posterior surface of the lobes of the thyroid gland and supplies the inferior poles of the gland. The terminal part of this artery is closely related to the recurrent laryngeal nerve.

Thyroid ima artery is a small and inconsistent artery, which is present in about 1–15% of the population [11]. It supplies the isthmus and the inferior poles of the lobe of thyroid gland. This artery may arise from variable origins such as the brachiocephalic trunk, aortic arch, right common carotid, subclavian, pericardiacophrenic artery, thyrocervical trunk, transverse scapular, or internal thoracic artery. Although its presence is rare, it is worth to note that it may serve as a potential source of bleeding during thyroid surgery. The superior poles of thyroid gland are drained by the superior thyroid veins. The lateral parts of the lobes and the Zuckerkandl tubercles are drained by the middle thyroid veins. The inferior poles of the gland are drained by the inferior thyroid veins. The superior and middle thyroid veins drain into the internal jugular vein on either side of the neck, whereas the inferior thyroid veins directly drain into the brachiocephalic veins.

Lymphatics from the thyroid gland is drained into multinodular sites. The lymphatics from the lower poles of the thyroid glands is drained either directly into the lower deep cervical lymph nodes or initially into the pretracheal or paratracheal lymph nodes, and subsequently into the lower

deep cervical lymph nodes. The upper poles of the gland are drained into the prelaryngeal lymph nodes or directly into the upper deep cervical lymph nodes.

9.2.1 Recurrent Laryngeal Nerve

The RLN is closely related to the thyroid gland. Failure to identify and preserve this nerve during thyroid surgery would result in RLN palsy. Consequently, patients would suffer from vocal cord paralysis, a very common and serious complication of this surgery. The successful visual identification of the RLN during thyroid surgery has been shown to be associated with lower incidence of vocal cord palsy. Even though intraoperative neuromonitoring has been recommended as the gold standard for prevention of RLN palsy, still it does not warrant a complete success of thyroid surgery [12]. One of the possible causes of RLN injury is the visual misidentification of the nerve. This is mainly related to anatomical variations of the RLN (Fig. 9.2), such as extralaryngeal branches, distorted RLN, intertwining between branches of the RLN and inferior thy-

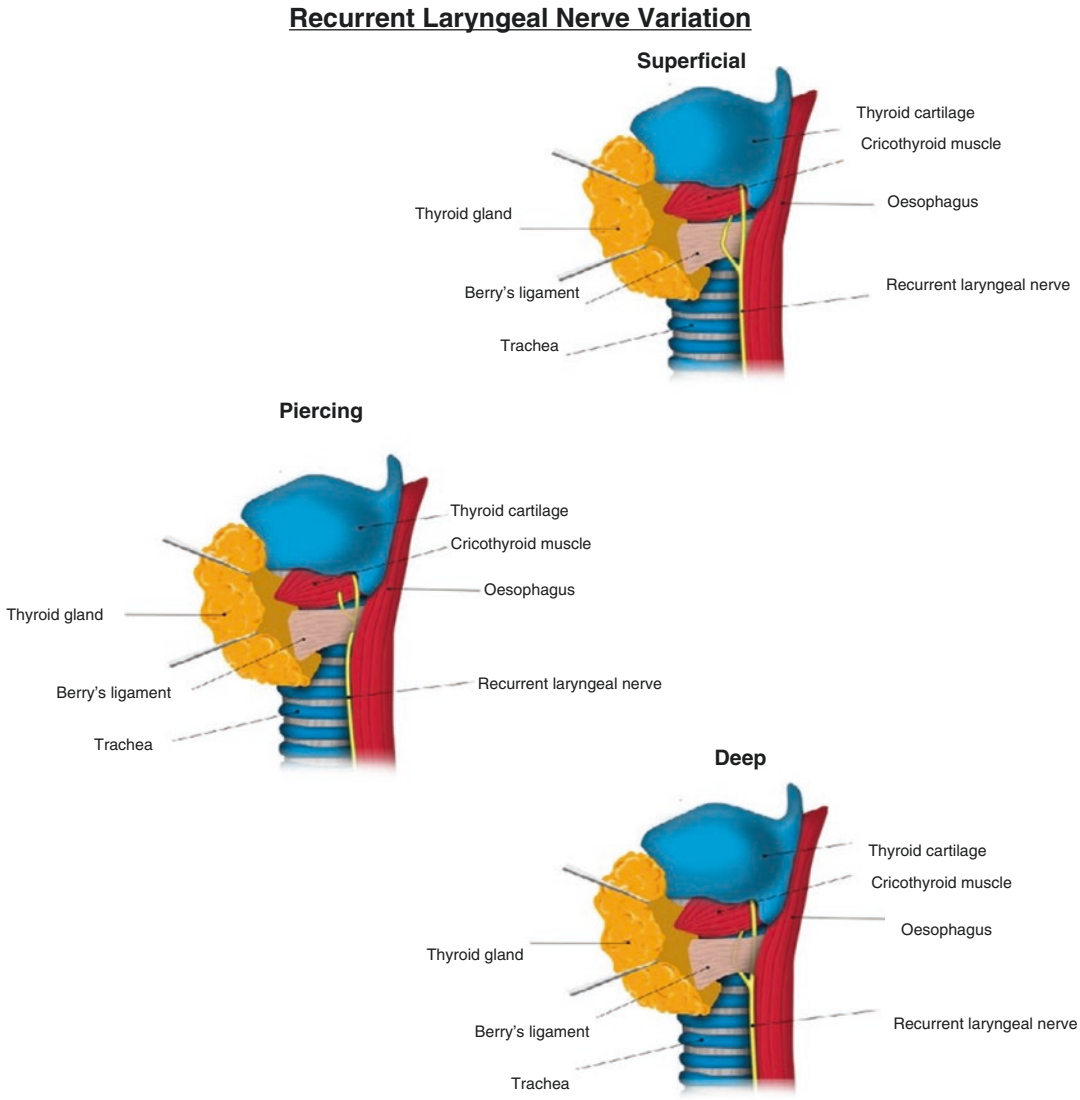

Fig. 9.2 Schematic drawing of the variation in the course of recurrent laryngeal nerve

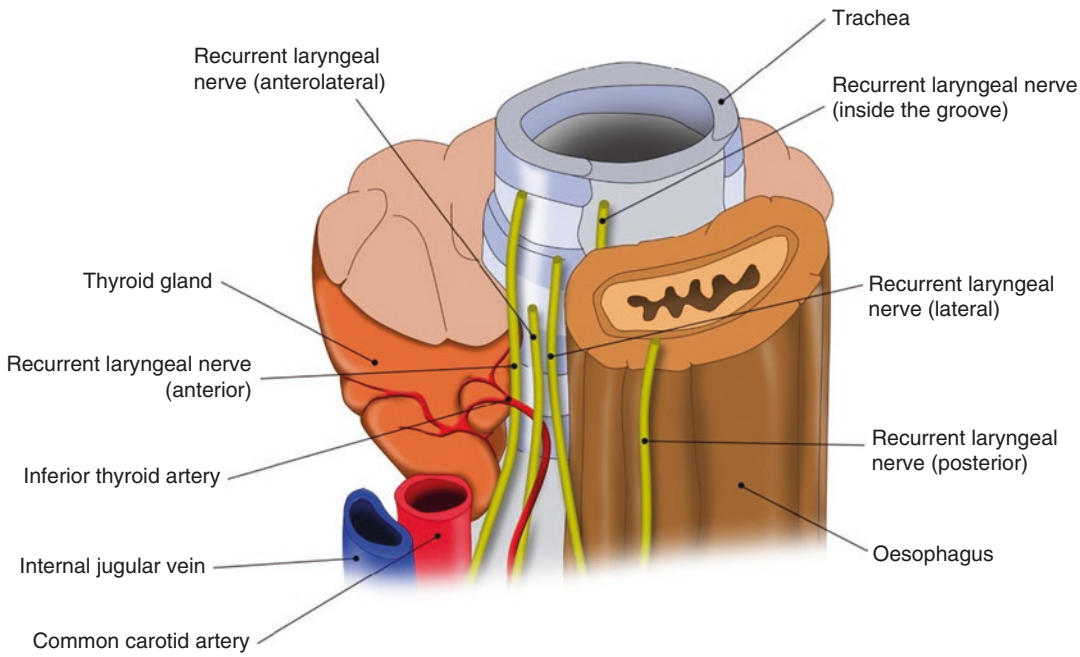

Fig. 9.3 Schematic drawing of the variation of course of recurrent laryngeal nerve in relation to thyroid glands, trachea, and oesophagus

roid artery, and non-recurrent laryngeal nerve. It has been recommended that in order to achieve a safe and successful surgery, intraoperative verification of functional and anatomical RLN integrity must be performed [12].

In most of the cases, the RLNs are closely associated with the Berry's ligament (BL) and inferior thyroid artery (ITA), where these structures cross deep to the RLN. The relations of RLN with other surrounding neck structures are variable. In about 42% of cases, RLN runs anterior to the tracheo-oesophageal sulcus, or posterior to the inferior thyroid artery (36%), or lateral to the BL (88%), or passes inferior to the inferior border of the inferior constrictor muscle (90%) or enters the larynx before its termination (55%). It has been shown that Berry's ligament is the most consistent landmark for the identification of the RLN during surgery [13]. In about 78.2% of cases, RLN passes deep to this ligament [14, 15].

Several patterns of anatomical relations between RLN and ITA have been described by Ngo Nyeki et al., 2015 [16]. In a retrovascular pattern, the right and left RLNs have been reported to run posterior to the ITA in about 53% and 77% of cases, respectively. In transvascular pattern, where the RLN is crossed by the ITA, it occurs in about 16% of cases on the right and 13% of cases on the left side, respectively (Fig. 9.3). There are also occasions in about 10% of cases where the RLN occurs as an extralaryngeal division. In this study, no cases of non-recurrent nerve were found.

The RLN courses between two fascial layers after passing immediately superior to the ITA. The superficial fascia is a vascular fascia which covers the RLN from the lateral aspect. Dissecting off this fascial layer would reveal the RLN lying in the tracheo-oesophageal groove (TEG). A deep fascial layer, the BL, is present medially towards the last 2 cm of the RLN [17].

During thyroidectomy, the 2.0 cm course of the extralaryngeal nerve above the trunk of the ITA forms the site of the greatest risk of injury to the RLN. The RLN falls back into the tracheo-oesophageal groove (TEG) and adopts a serpiginous appearance once the superficial vascular fascial and Berry's ligament layers are dissected, indicating completeness of the lobe dissection from the lateral trachea and division of the

Berry's ligament [18]. The identification and preservation of the RLN and all of its divisions are essential during thyroid surgery to reduce the morbidity of the procedure. It was reported that the relationship of the distal segment of the RLN to the cricothyroid joint was more constant after the joint course. The authors concluded that the distal identification of the nerve may be more reliable with less chance of disrupting the RLN's blood supply. With respect to the lower thyroid artery, the course of RLN is quite variable, but significant [4]. Bifurcation of RLN is another variation not to be missed by surgeons. It was reported that RLN bifurcation was found in about 33% of cases on the right side. On the left side, it was present in about 19% of cases [19].

Extralaryngeal branching of RLN is another pattern of RLN to be observed and identified during thyroid surgery. The site where RLN usually gives out extralaryngeal branches is at its most distal 2.0 cm part, either unilaterally or bilaterally. It was reported that extralaryngeal branching of RLN was observed in about 39% of intraoperative cases and about 73% in cadaver dissections [17].

9.2.2 Non-recurrent Laryngeal Nerve

The non-recurrent laryngeal nerve (NRLN) is a clinically important nerve to be aware of during thyroid surgery. It is associated with a risk of iatrogenic injury, most often leading to temporary or permanent paralysis of the vocal cord [20]. The NRLN is a rare variant of RLN and embryologically derived from RLN. It was reported to be present on the right side in only about 0.7% of patients in a clinical case series and about 1.4% in cadaveric studies. Cases of left-side NRLN are quite rare [17]. The presence of a NRLN substantially increases the risk of iatrogenic injury and complications of surgery [20].

The NRLN was found to branched out from the upper part of vagus nerve at or above the laryngotracheal junction in about 58% of cases. In another 42% of cases, the NRLN branches out from the vagus nerve below the laryngotracheal junction. In about 87% of cases, the right NRLN was associated with an aberrant subclavian artery [20].

9.2.3 Berry's Ligament

Berry's ligament (BL) is an anatomical structure not to be missed during thyroid surgery. It is a deep fibrous tissue layer derived from thickening of the pretracheal fascia that is attached between thyroid gland and cricoid cartilage as well as the first two or three tracheal rings [5]. The median length of BL ligament between the thyroid and trachea ranges from 8 to 11 mm, its thickness is 2 to 7 mm, the distance between the middle of the trachea and the ligament is 10 to 20 mm, and the distance between the site of attachment to the cricoid cartilage and the entry of the RLN is 1.9 mm [17].

There are several reports which describe the relations between the RLN and the BL (Fig. 9.4). The relations between the RLN and the BL are described according to the course of the RLN as it passes superiorly within the TEG. The RLN could be either running superficial or deep to the BL or it could also pierce the BL. In many cases, the RLN is found to course superficial to the BL. The least common pattern found was to be the piercing pattern [5]. Even though the piercing relation is the least common pattern, traction injury to the RLN is more commonly associated with this pattern. In order to avoid this complication, the TEG could be useful for tracing the RLN and provide a safe haven for the RLN identification as it ascends towards the larynx. Inexperienced surgeon might overlook this very important course of the RLN in the TEG because these anatomical structures could be well hidden to the naked eyes.

9.2.4 Parathyroid Gland Anatomy

There are four parathyroid glands located along the posterior border of the lobes of thyroid gland. They are most commonly located 1 cm above the intersection of the inferior thyroid

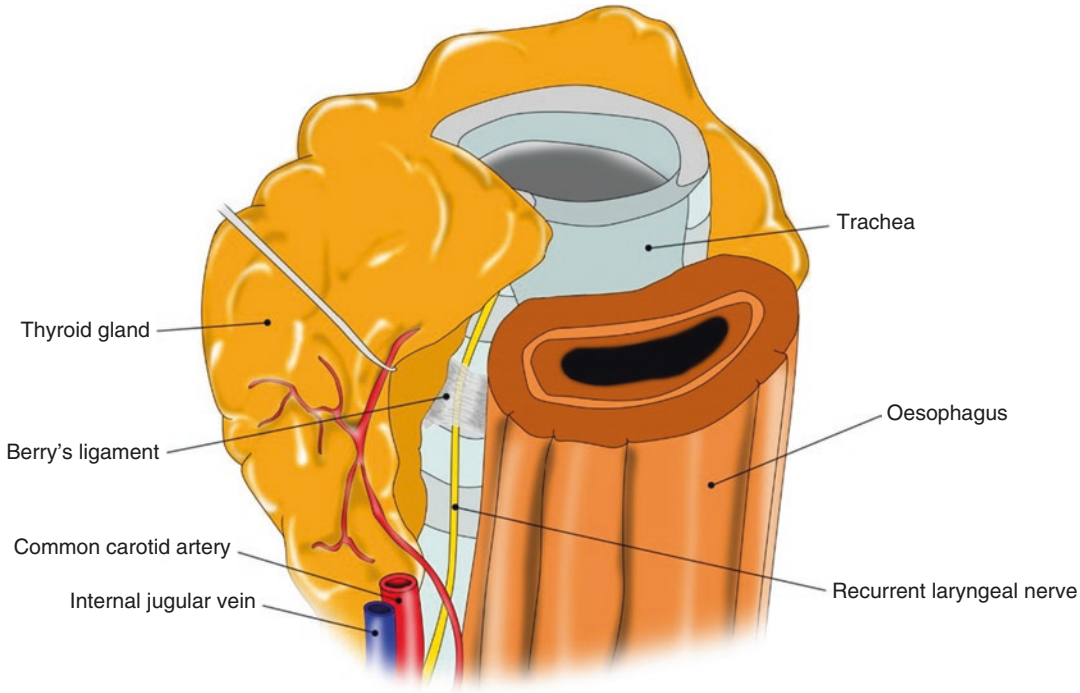

Fig. 9.4 Schematic drawing of the relation of recurrent laryngeal nerve with Berry's ligament

artery and the recurrent laryngeal nerve. Another point to highlight is that in most cases, parathyroids lie within 1 cm perimeter around the inferior laryngeal nerve and 1 cm cranial and 2.5 cm caudal to the Zuckerkandl tubercle (ZT), plane. At the level of the cricoid cartilage, the position of the superior parathyroid gland is usually dorsal of the thyroid gland, below the upper pole. The inferior parathyroid gland location is more variable. In most cases, they are located towards the inferior pole of thyroid gland or along the thyroid ligament [21].

Nevertheless, ectopic parathyroid glands may be present in about 16% of cases. Intraoperative techniques employed to identify these glands such as methylene blue staining or near-infrared imaging help to locate these glands [21]. The parathyroid glands are essentially supplied by the ITA. However, they receive additional supply from the superior thyroid artery. In about 8% of cases, parathyroids receive their blood supply directly from the thyroid gland, in which case the thyroidectomy could not avoid sacrificing their blood supply [21].

9.2.5 Inferior Thyroid Artery

The ITA commonly arises from the thyrocervical trunk. There are several reports describing the relations between the ITA and the RLN. In a systematic review study carried out by Ling et al. (2016), it has been shown that the most common relation between RLN and ITA is type C (51%), where the RLN runs posterior to the ITA (Fig. 9.5) [22]. In 21% of cases, the RLN runs anterior to the ITA, and in 28% of cases, the RLN runs between the branches of ITA. However, in a conflicting result, there are occasions where the RLN was most commonly found to course anterior to the ITA on the right-hand side and posterior to the ITA on the left side. In a small number of cases, the RLN was found to course between the branches of ITA [4]. The consistent relationship between RLN and ITA was that the artery and nerve intersect. The right RLN was below the ITA in 76.67% of the patients, and the left RLN was below it in 75.81%. There were no statistically significant differences in the relationship between RLN and ITA on the two sides,

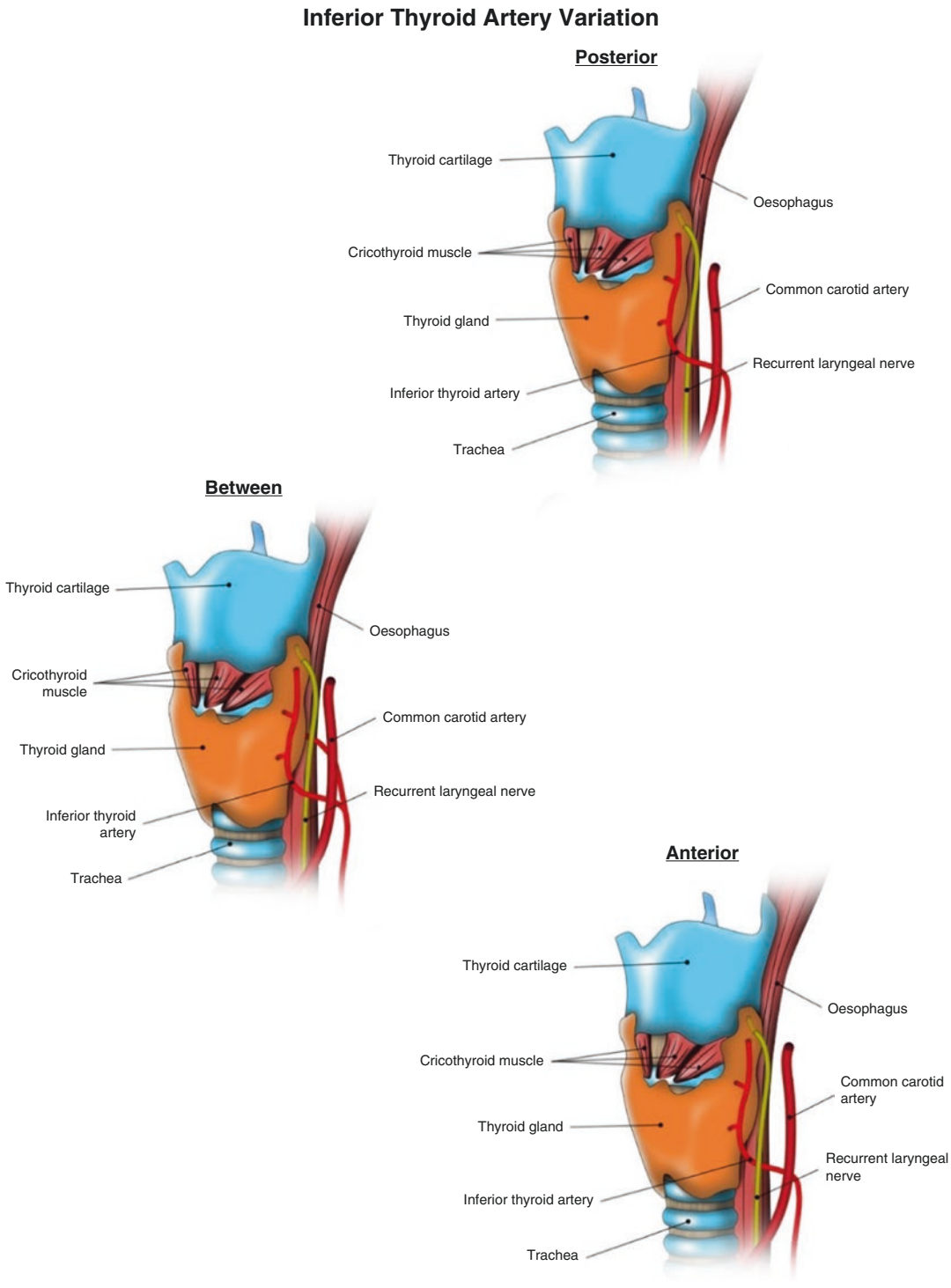

Fig. 9.5 Schematic drawing of variation in inferior thyroid artery

and gender did not significantly influence the relationship between the RLN and ITA on either side [19].

The results showed that the most prevalent form of RLN was later than the ITA. The heterogeneity of the studies, however, was statistically quite high. The link between the ITA and the RLN is quite variable. To try to eliminate the risk of injury to the nerve during thyroidectomy, anatomical knowledge of the region is vital [4]. There is a highly variable anatomical relationship between recurrent laryngeal nerve (RLN) and inferior thyroid artery (ITA). It is necessary to have sound anatomical knowledge of these variable relationships between the recurrent laryngeal nerve and inferior thyroid artery for all head and neck surgeons to perform a safe thyroid surgery [23]. The relationship between recurrent laryngeal nerve and ITA was studied. It revealed that mostly the ITA is anterior to RLN (in 71%) and posterior to RLN in 29% [3].

The nerve was found to be anterior to the inferior thyroid artery in 55.27% of cases, while in 34.67% of cases, it was posterior to the artery. The nerve was observed to pass within the branches of the inferior thyroid artery in the remaining 10.05% of instances [23]. Seventy-nine studies (n = 14,269 nerves) reported data on the RLN-to-ITA relationship. The comparison of left versus right revealed strong differences: on the left and right sides, RLNs were predominantly posterior (62.6% vs. 37.0%) and anterior (17.2% vs. 37.1%) [14].

Prior to entering the thyroid gland, most of the ITAs were derived from the thyrocervical trunk and divided into two or three branches. Three ITAs gave off the oesophageal branch, one ITA gave off the tracheal branch, and one abnormally derived right ITA. On the left side, the RLN was behind the ITA in 86.25% of cases, the nerve was between artery branches in 2.5%, the artery was between nerve branches in 1.25%, it was among the combined group in 2.5%, and it was in front of the artery in 7.5%. On the right side, the RLN was 75.0% in front of the artery, 10.0% behind the artery, and 5.0% between the branches of the artery [24].

9.2.6 Zuckerkandl Tubercle

Zuckerkandl tubercle (ZT) refers to the posterior extension of the thyroid tissue on the lateral lobe. In the 1980s, the identification of ZT became very important after its consideration as an anatomical landmark for safe identification of RLN [24]. It is an inconsistent anatomical structure with variable incidence. It has been identified in almost 88% of cases of thyroidectomy patients [3]. In this study, the incidence of ZT was slightly greater on the right side (85%) compared to the left (81%). It is present bilaterally in about 15% of cases. In some patients, ZT appears as a pointing structure for the RLN and neurovascular crossing point. If medially mobilized, ZT would allow the RLN to be easily identified before it turns deep to the lower articulation of the cricothyroid [3]. In most cases (around 90%), the RLN was found to course medially to ZT. Only in a small number of cases (approximately 7–10%), RLN passes laterally to ZT [17, 25, 26].

9.3 Clinical Presentation of Thyroid Tumours

The most common presentation of thyroid tumour is a midline neck mass, which is located overlying the thyroid cartilage. Others may also present as left lobe enlargement or right lobe enlargement (Fig. 9.6). On further examination, the mass is firm to hard in consistency and moves superiorly on swallowing. The mass can sometimes be larger on either side, left or right, and the patient presents with asymmetric swelling. The thyroid mass is always mobile supero-inferiorly and latero-medially. The features of a huge mass with hard characteristics and fixation to underlying structures imply high-grade malignant tumours.

Locally advanced thyroid cancer can often be relatively asymptomatic but may present with symptoms related to structures that are specifically involved or infiltrated. These include haemoptysis, dysphagia, altered voice, and difficulty breathing. Airway obstruction, stridor, and haemoptysis can be a sign of the trachea's direct invasion by the tumour. This airway infiltration is

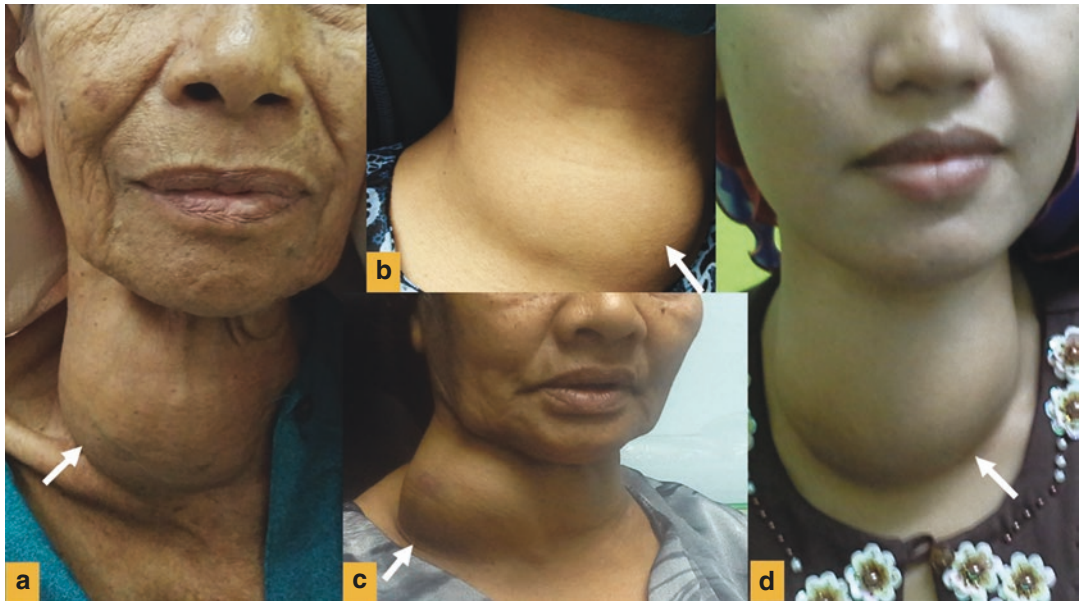

Fig. 9.6 Various neck mass presentation of thyroid tumour. Patient can present with a right solitary mass (**a**), mass on the left lobe (**b**), mass on the right lobe (**c**), or symmetrical midline thyroid mass (**d**). Clinically, the mass is confirmed to be arisen from the thyroid gland if it moves superiorly with swallowing

serious and can result in death if poorly managed. Similarly, hoarseness typically indicates involvement of the RLN, or direct invasion to the cricoarytenoid joint, which results in fixation of the vocal cord by the malignant tumour [27]. In a long-standing multinodular goitre case, the patient can also present with hoarseness due to compression of the RLN by the mass. Normally, this is transient, where surgical removal will relieve compression on the nerve and the hoarseness improves.

In symptomatic patients, clinical compression of the trachea and oesophagus by the thyroid mass is often the cause of complaints. Compressive symptom often exacerbates when the patient lies supine. This may result in globus sensation, dysphagia, and dyspnoea. Occasionally, large-vessel venous compression may manifest as superior vena cava syndrome in severe cases. The patient can have facial oedema with distended superficial neck veins. Active treatment is required when the patient has sustained serious compressive symptoms with a history of progressive enlargement of the mass in combination with a confirmed FNAC diagnosis of malignancy [28]. In benign tumour like multinodular goitre with evidence of compressive symptoms, surgery is also indicated. Similarly, in case of malignant tumour like PTC or follicular carcinoma, surgery, i.e. total thyroidectomy, is indicated, and in selected cases in combination with central compartment neck dissection.

Neck node metastases, even though rare, can occur in the setting of aggressive, high-grade, long-standing malignant tumour. The patient may present with multiple neck mass, especially at central compartment and levels II, III, and V, in addition to the thyroid mass. If the patient is deemed fit for surgery, neck dissection should be performed together with total thyroidectomy at the initial surgery.

In case of a retrosternal goitre, the patient may present with more sinister symptoms and complications, especially if the retrosternal extension is extensive. Previous studies have shown that retrosternal goitre can compress the surrounding structures, causing compression of the airway, difficulty swallowing, superior vena cava obstruction, and hoarseness. Surgery with sternotomy is the treatment of choice for extensive retrosternal

goitre. The compression of the surrounding structures, malignant risk, and intrathoracic extension are typical reasons for surgery [8]. In this case, a multiteam management with the cardiothoracic team and orthopaedic team for sternotomy and clavicle osteotomy is paramount.

Other critical symptoms should be considered in case where malignant thyroid tumours have spread to a distant site. The patient may present with haemoptysis and shortness of breath due to pulmonary metastases, bony tenderness due to bony metastases, hepatomegaly due to liver metastases, and so forth. All these symptoms need to be treated conservatively. The palliative care is crucial to optimize end-stage cancer patients, so that they can live as comfortable as possible.

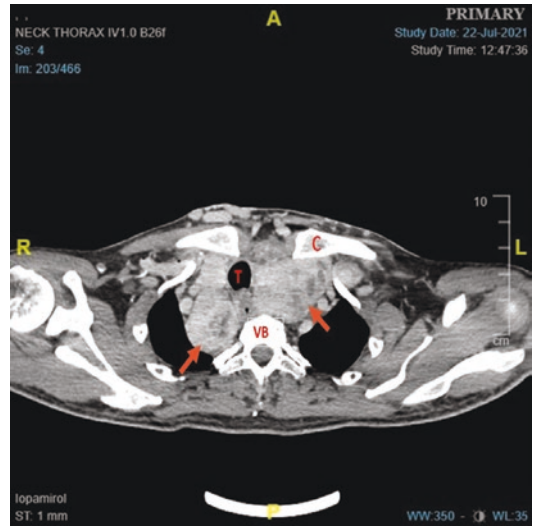

Fig. 9.7 A CT scan image of a retrosternal thyroid mass (arrows), which extends well below the clavicle (C). The trachea (T) is patent as evident by its circular ring

9.4 Imaging Modalities for Assessment of Thyroid Malignancy

During the initial assessment of thyroid glands, ultrasound is the primary imaging of choice in case of small-to-moderate size of thyroid mass. The ultrasound features which include solid and cystic areas, calcification, heterogeneity, relation to vascular structures, i.e. the IJV and carotid, and presence of lymph nodes are critical in distinguishing the benign and malignant features of thyroid mass.

The risk stratification systems like AGES, AMES, DAMES, and MACES are based on the characteristic findings from imaging of thyroid glands. In a huge multilobulated thyroid mass suspicious of malignancy, CT scan of the neck and thorax is critical for staging of the disease.

The CT scan assessment includes the size of the mass; accurate location of the mass; heterogeneity; adjacent structures' involvement like SCM, strap muscles, inferior constrictor muscle, oesophagus, and carotid sheath; neck nodes; and distant metastases. Critically, the CT scan is able to delineate neck node metastases that are not detected by ultrasound imaging. The features of neck node metastases include:

1. A rounded and concentric node
2. Nodes larger than 2.0 cm
3. Extracapsular extension of the nodes
4. Heterogeneity of the nodes
5. Presence of central necrosis on the nodes

These imaging findings are pivotal in planning details of the surgery, i.e. surgical mapping, in order to perform a safe surgery with effective oncology outcomes. For instance, in case the neck node is not palpable clinically but on CT scan imaging showed features of neck node metastases, then the surgery should include central compartment neck dissection during total thyroidectomy at the very first surgery done for the patient. Similarly, if on the CT scan imaging there is evidence of retrosternal extension in the setting of an extensive multinodular goitre case with compressive symptoms, the sternotomy is necessary for extirpation of retrosternal tumour (Fig. 9.7).

The choice of a surgical approach often depends on the detailed findings of the CT scan. These include the relation of mass to the clavicles, the depth of goitre expansion in the mediastinum, and the extension beyond the aortic arch. Several studies have also suggested CT as the most valuable radiological examination for

retrosternal goitre evaluation because it can evaluate the location of the mass, the mediastinum sternum, and the anatomical relationship between adjacent structures [8]. If the clavicle presents a barrier or difficult access for a complete tumour removal, clavicular osteotomy can be done, most commonly by an orthopaedic surgeon. Thus, the extensive malignant thyroid tumour with multiple adjacent structures' involvement that are critical for a free margin tumour removal should be discussed in a multidisciplinary tumour board.

9.5 Retrosternal Thyroid Tumour

Depending on the criteria used to define this type of goitre, the incidence of retrosternal goitre varies considerably, ranging from 0.2% to 45% of all thyroidectomies. In general, the symptoms are related to the compressive nature of the mass on the adjacent structures, and most patients report some form of goitre-associated respiratory manifestation. An evaluation of thyroid function, chest radiography, and computed tomography are usually included in a diagnostic evaluation. Due to the limited visibility and location of vital structures in this region, fine needle aspiration biopsy in substernal areas of the goitre should be avoided [29]. In selected cases, however, the CT scan-guided biopsy can be performed safely in an experienced interventional radiologist's hand. This is, for example, in case where there is no diagnosis available for urgent medical or more commonly surgical intervention necessary to acutely manage the patient, in case the patient is progressively deteriorating.

Substernal goitre is defined as a thyroid growth beyond the thoracic inlet. Using the cross-sectional imaging CT system, it can be classified into three grades (Table 9.2).

Technically, surgery for substernal goitre may be demanding. Extensive mediastinal extension brings the thyroid gland and vital intrathoracic structures into close quarters. To determine the potential need for an extracervical approach, proper preoperative planning is required. Typically, assessing the risk of requiring an extracervical approach is based on findings from cross-sectional neck and chest imaging [28].

Most substernal goitres can be resected through a cervical approach, with relatively low morbidity. Although the dictum for considering median sternotomy is well taught and widely published in the surgical approach to SSG, over 90% of these lesions can now be safely and adequately excised through a cervical incision. This is true especially in the setting of a small-to-moderate retrosternal extension, where through a common incision for total thyroidectomy, with good neck extension and meticulous dissection, the retrosternal segment can be safely excised together with the main primary thyroid tumour.

The bimodal technique (cervical incision and sternotomy) has an excellent result, achieving a safe resection, particularly in large thyroid masses extending to the mediastinum, closely related to the mediastinal structures. Postoperative mortality and morbidity are very low. Other surgical approaches reported in the literature for retrosternal thyroid excision are VATS techniques for the removal of ectopic intratho-

Table 9.2 The classification of retrosternal goitre based on CT scan findings

	Type I	Type II	Type IIA and B	Type III
Location	Anterior mediastinum	Posterior mediastinum	IIA: Ipsilateral extension IIB: Contralateral extension IIB1: Extension posterior to both trachea and oesophagus IIB2: Extension between trachea and oesophagus	Isolated mediastinal goitre
Anatomy	Anterior to trachea, RLN, and great vessels	Posterior to trachea, RLN, and great vessels		No connection to main gland. May have isolated mediastinal blood supply
Percentage	73	20	3	3

Modified from Abdelrahman H et al. (2020) [30]

racic goitre and robot-assisted techniques for the removal of substernal thyroid goitre with posterior mediastinum extension [31].

Many retrosternal goitres can be removed by a cervical incision alone surgically, although manubriotomy or sternotomy incision may be required in some specific cases. Previous studies have shown factors such as recurrent goitres, superior vena cava obstruction, malignant thyroid tumours, and depth of aortic arch tumour invasion to increase the likelihood of a thoracic surgical approach [32]. The most common complications after thyroidectomy were tracheomalacia (13%), transient hypocalcaemia (10%), and hypoparathyroidism (7%).

9.6 Choices and Types of Thyroidectomy

Multiple critical factors need to be considered in deciding the best thyroid surgery types of the patient. These include histology types and grades of the tumour, benign versus malignant features, lobe involvement of tumour, presence of neck nodes, presence of retrosternal extension, patient's comorbidity, social support, and patient consent for surgery.

In the past years, total thyroidectomy should be selected when the FNAC of thyroid mass is confirmative of malignancy. Recently, however, since higher cure rate can be achieved with thyroid malignancy, more conservative surgical approach has been advocated. Patients with PTC can still be offered hemithyroidectomy or lobectomy depending on the ultrasound features of the solid nodule's location. At our local centre, due to lacking nuclear medicine and oncology facility, we tend to be a little bit overtreated in a sense that all malignancy cases will be offered total thyroidectomy plus minus neck dissection. Majority of post-operative patients will receive adjuvant radioiodine ablation depending on the residual disease on serial follow-up thyroid scan.

Although early data supported that total thyroidectomy should be performed for all patients with >1 cm of well-differentiated thyroid cancer, more recent evidence in selected cases of low-risk patients shows lobectomy to be an alternative approach. A blanket statement that total thyroidectomy should be the treatment for all patients now has evolved to a more selective approach for addressing thyroid malignancy [2]. This is in relevance to better prognosis and survival of patients with thyroid carcinoma. The emergence of new guidelines for surgical approach for thyroid malignancy has improved patient's quality of life.

Despite selecting more conservative surgical types for well-differentiated thyroid carcinoma, there are several advantages of total thyroidectomy. The advantages of total thyroidectomy over lobectomy are the following:

1. The radioactive iodine ablation can only be performed for patients who had all thyroid glands removed, i.e. total thyroidectomy.
2. Total thyroidectomy will remove the multicentric tumour in contralateral lobe.
3. It will reduce the second surgery in future, i.e. completion thyroidectomy.

In centres with limited oncology facility and expertise, total thyroidectomy is probably a more practical and effective treatment option. This is good for patients with low socio-economic status as the majority of them had poor compliance to the follow-up schemes.

With the advancement in surgical techniques and instrumentation, the types of anaesthesia for thyroid surgery have also undergone rapid changes. Conventionally, thyroid surgery is performed under full general anaesthesia. Nowadays, in order to reduce patient's morbidity from general anaesthesia, thyroidectomy can also be performed under light sedation or awake anaesthesia. In properly selected patients, awake thyroidectomy is a well-tolerated and safe procedure, with many potential advantages over general anaesthesia [33]. In the majority of cases, only local anaesthesia is required with active monitoring of patient's vitals during the period of surgery. The increasing expertise among anaesthetists ensures that more patients can be selected for awake thyroidectomy, thus reducing the side effects from drugs used for general anaesthesia.

9.6.1 Endoscopic Thyroidectomy and Robotic Thyroidectomy

In a well-equipped centre, endoscopic and robotic thyroidectomy is practised depending on the patient selection criteria and the availability of expert surgeons in the field. Many factors need to be considered before embarking on this new refined technique of thyroid surgery. Because there is no visible neck scar with remote-access endoscopic thyroidectomy, it is becoming more popular. A number of specialized centres are presently evaluating this technically demanding surgery. At this juncture, the operation has earned worldwide acclaim and is now carried out in more than 50 locations [34].

The bilateral axillo-breast route, the transaxillary method, and the retro-auricular approach are examples of the remote-access thyroidectomy techniques that have been developed throughout the years. The thyroid gland is accessed using the bilateral axillo-breast approach, which involves four extremely small incisions: one in each axilla and one along the breast [35]. The transaxillary procedure uses a single incision to access the thyroid gland unilaterally. The gland is accessed through incisions behind the ear in the retro-auricular technique. All of these methods are better cosmetically than the traditional method of transferring the scar from the neck to other less visible sections of the body [35].

There are many terms to describe this scarless thyroid surgery, such as TOETVA or transoral endoscopic thyroidectomy with vestibular approach, which is one of the newly emerging scarless thyroid surgery techniques available [36]. Endoscopic thyroid surgery has been shown to have several advantages, including reduced post-operative swallowing problems, improved voice quality, less pain, faster recovery, and a lower incidence of wound-related complications, all while maintaining standard endocrine outcomes like complication rate and procedure completion [34].

9.7 Intraoperative Neural Monitoring

To avoid recurrent laryngeal nerve injury, intraoperative neural monitoring can be safely used in thyroid surgery. It allows the surgeon to identify the recurrent laryngeal nerve injury intraoperatively, in order to preserve the integrity of RLN and its function. The use of intraoperative neural monitoring also allows estimation of post-operative nerve function and modifies the surgical strategy to prevent bilateral paralysis of the vocal cord [37].

In re-operative thyroid and neck surgery, completion thyroidectomy, for patients with large goitres or Graves' disease, and in patients with a history of neck radiation, the recurrent laryngeal nerve anatomy may have changed and poses challenges during dissection. The RLN is more vulnerable to damage in the hands of less experienced surgeons. Extensive traction and manipulation during thyroid surgery also cause RLN paresis with resultant hoarseness.

Intraoperative neuromonitoring of the recurrent laryngeal nerve has been widely used in the identification and evaluation of RLN in order to prevent nerve injury that can be a medicolegal case, when we least expected. This is especially true for professional voice users who need normal voice post-surgery such as teachers and singers. This technique not only evaluates the function of the recurrent laryngeal nerve, but also helps to detect anatomical variations during surgery and to anticipate post-operative functions of the vocal cord [37]. The use of microscope or surgical loupes will assist in the identification of the RLN considerably as the nerve might be very fine in some cases. This surgical loupe allows magnification of the nerve during dissection and can be used for nerve grafting in case the nerve is accidently transected and needs to be primarily repaired with end-to-end anastomosis.

In case where the facial nerve monitor is lacking or does not work because of mechanical breakage, the surgeon may continue with thyroidectomy but needs to ensure to have good

knowledge of thyroid anatomy and landmarks in order to identify the RLN. More experienced surgeons will be able to do this. In junior surgeons, probably it is best to defer surgery until the nerve monitor is made available. This is applicable also if the surgery is performed for singers or teachers.

The most common and recommended surgical strategy in case of loss of signal during the planned total thyroidectomy with intraoperative neuromonitoring is to terminate the operation and leave the resection of the contralateral thyroid lobe to the second session, i.e. staged thyroidectomy [37]. This is also a good technique. The main purpose is to prevent bilateral vocal cord paralysis, which is very debilitating. The patient can have severe hoarseness and airway obstruction. It is logical that the second operation would be safer, and the risk of bilateral vocal cord paralysis would be avoided after the recovery of recurrent laryngeal nerve function in patients with visually intact nerves. Staged thyroidectomy can be performed in cases of selected thyroid cancer and benign thyroid disease. In benign thyroid tumour, there is no urgency to excise the tissue as it does not have the capacity to infiltrate and spread, so stage surgery would be ideal to consider if one-side RLN is suspiciously injured.

9.8 Total Thyroidectomy for Papillary Thyroid Carcinoma

Total thyroidectomy is performed for thyroid malignancy, namely papillary thyroid carcinoma, follicular carcinoma, or medullary thyroid carcinoma [38]. There are general routine steps commonly practised during thyroidectomy. However, some of the detailed steps might differ depending on the surgeon's expertise and preference as well as the availability of instruments.

The skin incision is normally placed at two finger breadths above to sternoclavicular joint or sternal notch (Figs. 9.8, 9.9, and 9.10). The other landmark for incision is midway between the cricoid cartilage and sternal notch. The skin incision

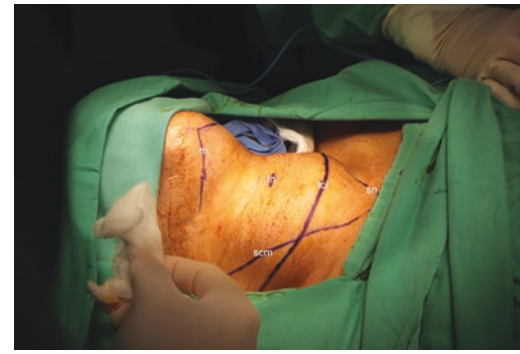

Fig. 9.8 Surgical landmarks are drawn before skin incision. These include mandible (m), thyroid cartilage notch (tn), anterior border of sternocleidomastoid muscle (scm), sternal notch (sn), and skin incision (tci)

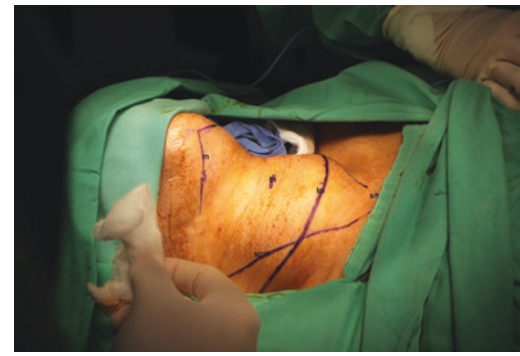

Fig. 9.9 The patient is made to lie supine with neck hyperextended. The surgical landmarks are drawn, which include thyroid notch (tn), cricoid cartilage, sternal notch (sn), inferior border of mandible (m), anterior border of sternocleidomastoid muscle (scm), and skin incision (tci). Skin incision follows the skin crease, two finger breadths above sternal notch, or midway between cricoid cartilage and sternal notch

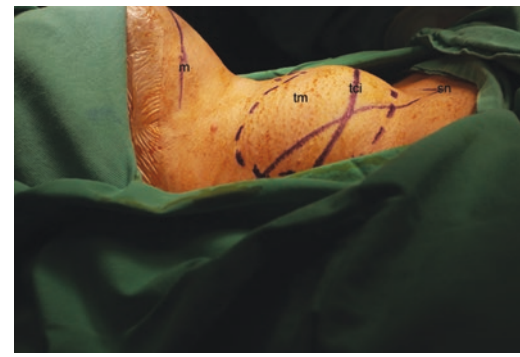

Fig. 9.10 Thyroid mass (tm) border is outlined (in dotted lines) together with other landmarks

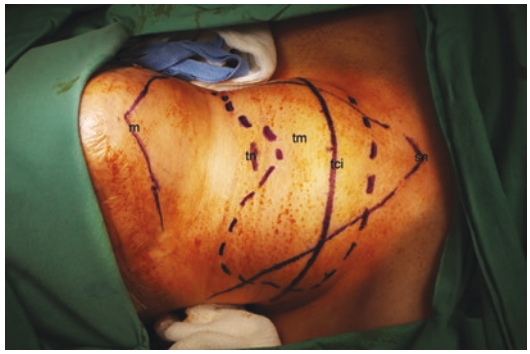

Fig. 9.11 The thyroid mass (tm) is also outlined. The border is palpated, and the margin is drawn with a sterile marker pen

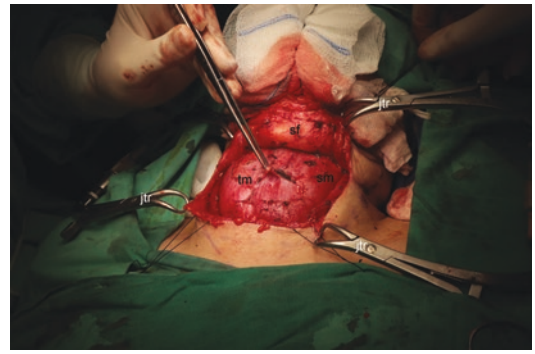

Fig. 9.13 Subplatysmal muscle flap (sf) is raised superiorly to hyoid bone and inferiorly to clavicle level or sternal notch

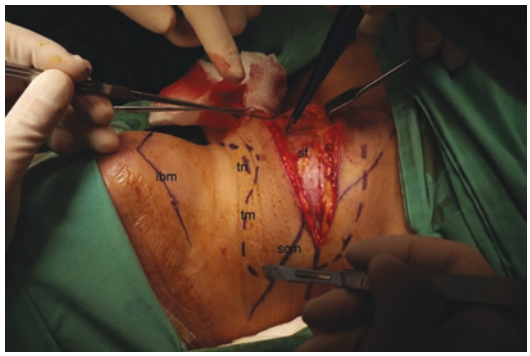

Fig. 9.12 The skin incision is infiltrated with local anaesthesia Marcaine-adrenaline mixture. The incision is carried out with blade size 11 after 5 min of LA infiltration to improve haemostasis. Sometimes, a fine-tip monopolar can also be used for skin incision

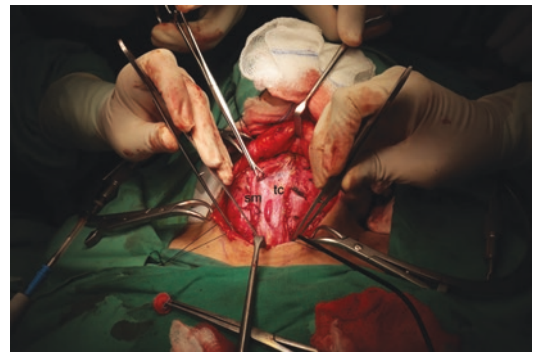

Fig. 9.14 The strap muscle (sm) is divided in the midline to expose the thyroid capsule (tc) and mass underneath

can be modified according to the tumour size. It should be designed not too low in malignant case, especially if tracheostomy has to be performed; the sternoclavicular joint can limit the surgical access.

The anterior border of SCM marks the lateralmost of the skin incision (Fig. 9.11). This skin incision is sufficient to address the thyroid mass removal and facilitate dissection around the carotid sheath. The skin incision can be lengthened if the surgeon finds it to be limited. In huge goitre, the SCM muscle can be transected to open up the surgical area.

The subplatysmal skin flap (Fig. 9.12) is raised superiorly to mandible and inferiorly to clavicle level. Subplatysmal muscle can be very thin in some cases. The strap muscles will be visible once the subplatysmal flap is reflected superiorly. It lies in the midline and consists of layers of sternohyoid, sternothyroid, and thyrohyoid muscle (Fig. 9.13). The midline fascia over the muscle can be cut in midline, and the muscle is retracted laterally (Fig. 9.14). This exposes the thyroid mass and its capsule. Layer of fascia over the thyroid mass needs to be cut and included together within the skin flap. This technique will lessen the risk of injury to RLN as capsular dissection is performed.

The dissection continues to expose all margins of the thyroid mass, superior pole, inferior pole, and lateralmost part of the mass. The dissection at inferior poles is carried out to slowly lift the mass while looking for inferior thyroid artery. If the inferior thyroid artery and vein are away from

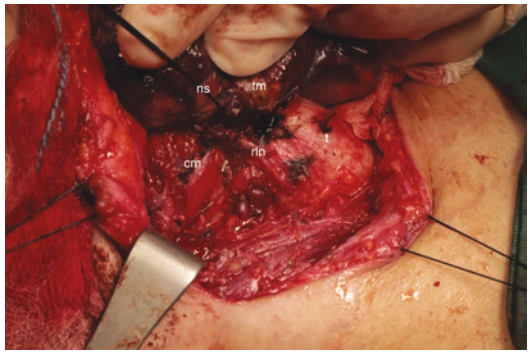

Fig. 9.15 The recurrent laryngeal nerve (rln) is visualized emerging from the tracheo-oesophageal groove and coursing superior-anteriorly to enter the cricothyroid muscle (cm) beneath the thyroid mass (tm). Nerve stimulator (ns) in situ is also shown

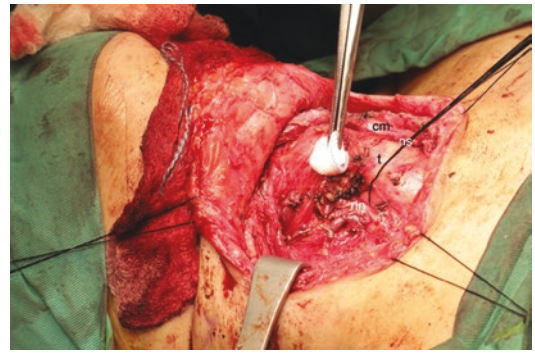

Fig. 9.16 The right recurrent laryngeal nerve (rln) is visualized going through the cricothyroid muscle (cm) and tested with a nerve stimulator (ns)

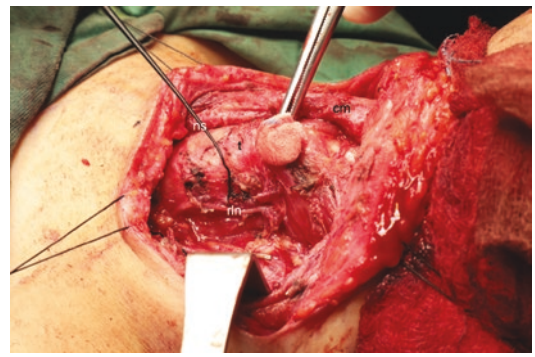

Fig. 9.17 The left recurrent laryngeal nerve (rln) is visualized going through the cricothyroid muscle (cm). The recurrent laryngeal nerve is tested with a nerve stimulator (ns) and is intact

the RLN, it can be safely ligated. The RLN can lie below the ITA, in between its branches or above the ITA. The RLN is traced, identified, and preserved (Fig. 9.15).

The same dissection techniques apply for the superior pole of the thyroid. The superior laryngeal nerve (SLN) should be identified together with the external laryngeal nerve. This nerve lies within 1.0 cm of the upper pole of thyroid glands.

There are several techniques of dissections: the superior-inferior direction approach, exploring the nerve where it enters the larynx, followed by superior pedicle ligation, and secondly the inferior-superior direction, following the inferior pedicle ligation, and identifying the nerve in the tracheo-oesophageal groove. These two techniques are used to identify the RLN in the majority of thyroidectomy cases [18]. In the thyroidectomies that localized the RLN using the superior-inferior approach, the rate of hypoparathyroidism was significantly lower. The superior-inferior approach was a safer technique in terms of preventing complications.

The RLN runs in the tracheo-oesophageal groove in relation to the ITA at the inferior lobe of thyroid glands. From here, it ascends superomedially to enter the cricothyroid muscle (Figs. 9.16 and 9.17).

1. Once the RLN is identified, the ITA is ligated. The dissection continues to the posterior aspect of thyroid glands.
2. The dissection continues superiorly, and middle thyroid artery and vein are also ligated.
3. The carotid artery and IJV are displaced laterally.
4. The dissection continues to the Berry's ligament.
5. The superior pole of thyroid glands is released. The external laryngeal nerve is identified and preserved.
6. Once the thyroid glands are removed, homeostasis is secured (Figs. 9.18 and 9.19).
7. The skin is closed in two layers, and a Redivac drain is secured in situ (Fig. 9.20, Table 9.3).

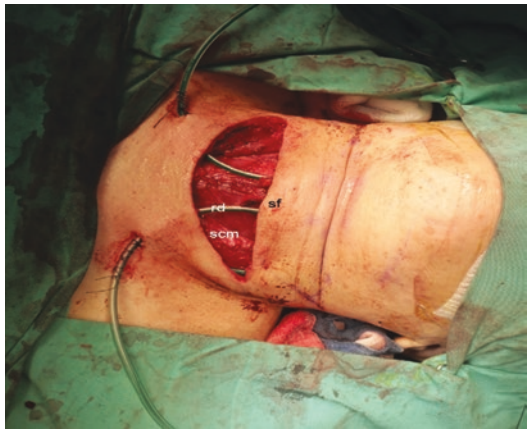

Fig. 9.18 After tumour removal, two Redivac drains (rd) are secured for drainage of the secretion or seroma. This is to prevent a haematoma formation that can compromise post-operative wound healing

Fig. 9.19 The excised thyroid gland comprised of both lobes and isthmus

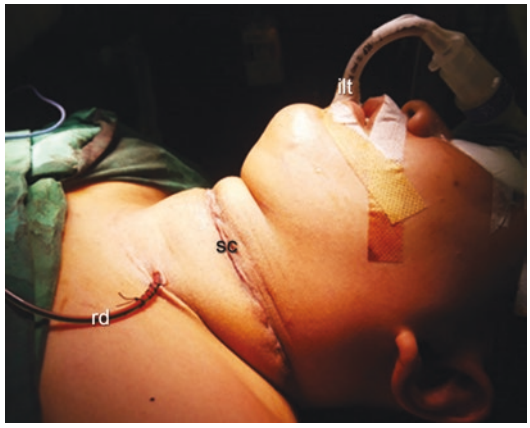

Fig. 9.20 The skin is closed in two layers (sc), and a Redivac drain (rd) is secured with a silk 3.0 suture to the skin

Table 9.3 A routine surgical step during total thyroidectomy

	Essential steps during total thyroidectomy
1.	Patient is made to lie supine with neck hyperextended, and nerve monitor for RLN is applied.
2.	The neck is cleaned and draped, and the landmarks are drawn on the neck. The LA is infiltrated along the skin incision (Fig. 9.6). The skin is incised with blade size 15, and the subplatysmal flap is raised using the blade or monopolar with Colorado tip.
3.	The superior flap is raised till hyoid bone and the inferior flap till sternal notch. The lateral flap is raised till the posterior border of sternomastoid muscle. The strap muscle is identified and separated midline and retracted laterally.
4.	The thyroid capsule is identified, and subcapsular dissection is performed.
5.	The dissection continues inferiorly. The landmarks for RLN and inferior thyroid artery are identified. The magnified loupe is used to identify the RLN with the aid of nerve stimulator.
6.	Once the RLN is identified, the ITA is ligated. The dissection continues to the posterior aspect of the thyroid glands.
7.	The dissection continues superiorly, and middle thyroid artery and vein are also ligated.
8.	The carotid artery and IJV are displaced laterally. The dissection continues to the Berry's ligament.
9.	The superior pole of thyroid glands is released. The external laryngeal nerve is identified and preserved.
10.	Once the thyroid glands are removed, homeostasis is secured.
11.	The wound bed is irrigated with warm saline.
12.	The parathyroid gland is thinly sliced and implanted into the sternomastoid muscle.
13.	The drain is secured.

9.9 Thyroid Lobectomy

Thyroid lobectomy is indicated for tumour or disease limited to one side of the thyroid lobe. The skin incision is smaller, and the risk of vocal cord morbidity is much less compared to total thyroidectomy. Only one recurrent laryngeal nerve is exposed during dissection and at risk of injury (Figs. 9.21 and 9.22).

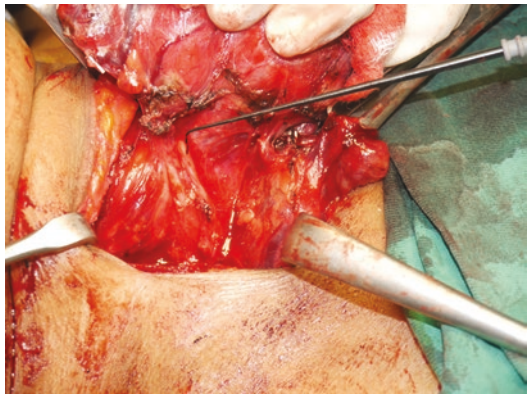

Fig. 9.21 The recurrent laryngeal nerve is passing obliquely on the trachea and adherent at Berry's ligament posterior to the thyroid mass

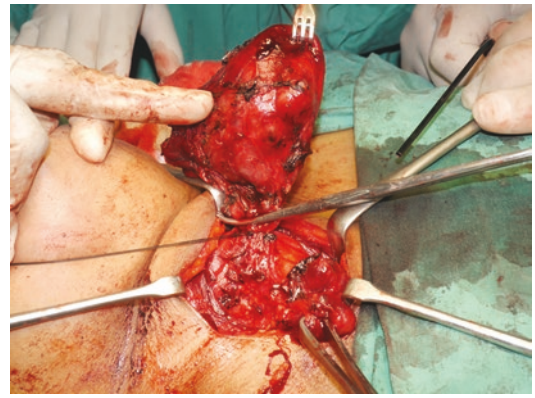

Fig. 9.23 The area of Berry's ligament which consists of a dense tissue which poses difficult dissection during thyroid surgery

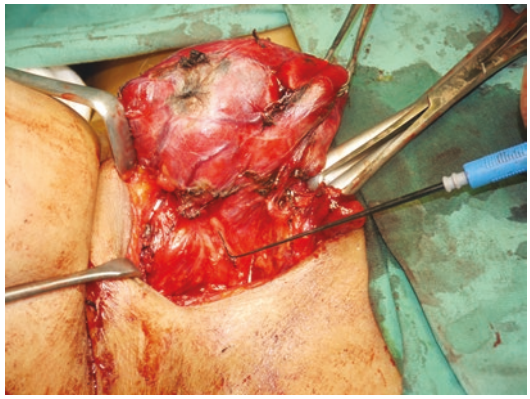

Fig. 9.22 Recurrent laryngeal nerve shown under the thyroid mass and is tested for its functionality with a probe of nerve stimulator

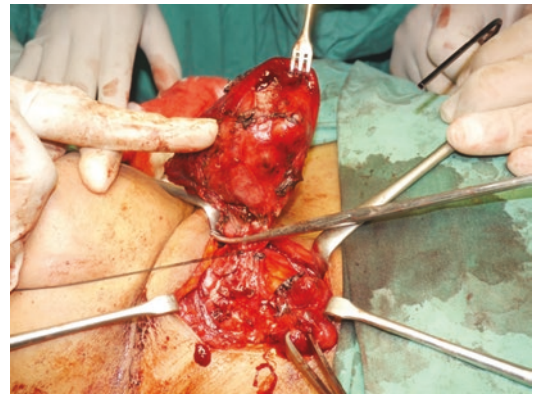

Fig. 9.24 Two separate masses are visualized, the bigger left thyroid lobes and smaller inferior part of thyroid isthmus

Similar techniques are used for lobectomy as in total thyroidectomy. Once the skin flap is elevated, strap muscle is identified and retracted laterally. This exposes the thyroid lobe. The lobe is dissected superiorly or inferiorly depending on the surgeon's decision on where to start the dissection around the glands. The ITA can be identified in a similar manner, as in total thyroidectomy. The Berry's ligament is the toughest tissue to dissect at the posterior part of the thyroid lobes (Figs. 9.23 and 9.24). Meticulous dissection is needed in order to avoid inadvertent injury to the RLN. Once the thyroid lobes are removed, the RLN is tested with the stimulator to assess its function (Figs. 9.25 and 9.26).

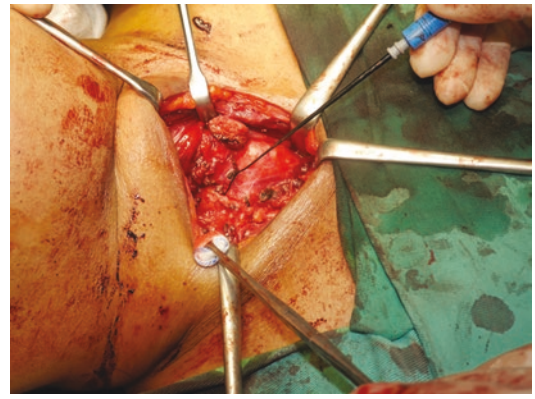

Fig. 9.25 Post removal of thyroid lobes, the recurrent laryngeal nerve is restimulated with nerve probe to ensure its patency

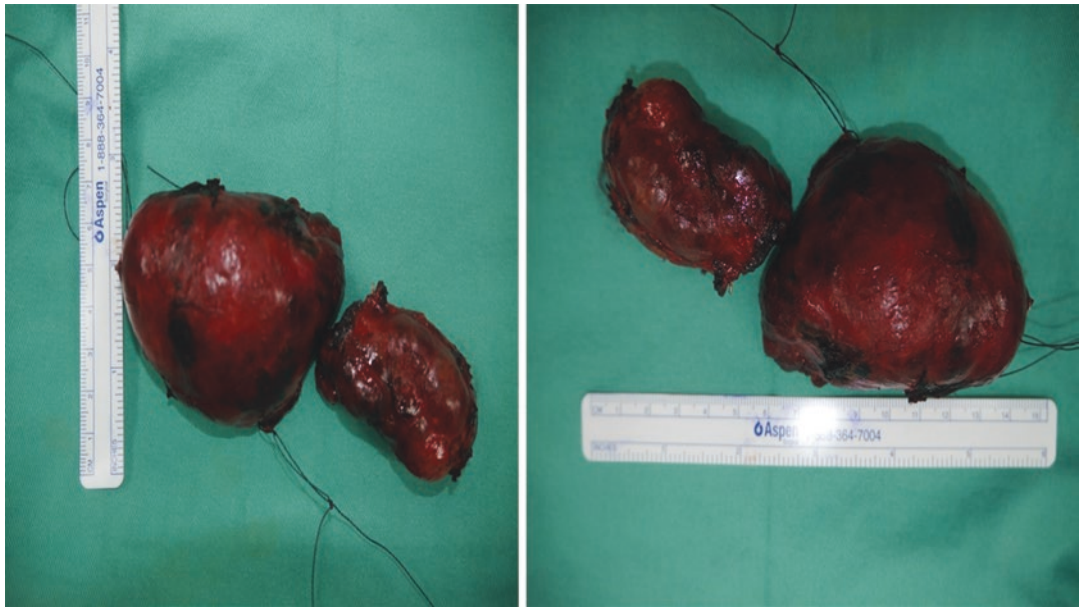

Fig. 9.26 Both of the thyroid lobes removed measuring 3.0 cm × 5.0 cm and 2.0 cm × 1.0 cm

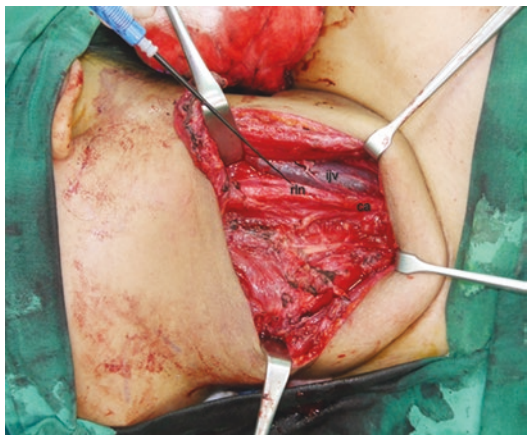

Fig. 9.27 The carotid sheath is exposed where recurrent laryngeal nerve (rln) is located more medially than carotid artery (ca). The vagus nerve is in between IJV and carotid artery

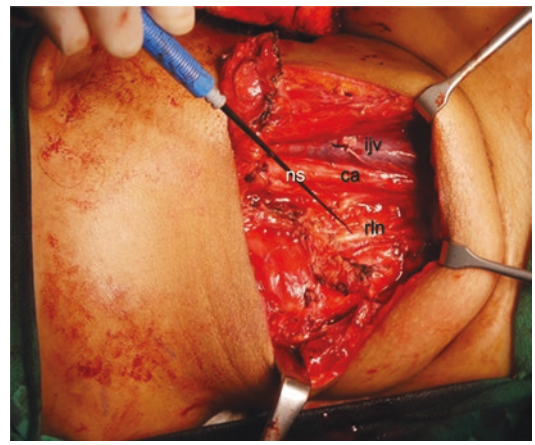

Fig. 9.28 The carotid sheath is exposed where recurrent laryngeal nerve (rln) is located more medially than carotid artery (ca). The vagus nerve is in between IJV and carotid artery. The recurrent laryngeal nerve is tested with a nerve stimulator (ns) and is intact

Once the surgical bed is irrigated with warm saline, a whitish colour of the nerve becomes more visible. The RLN lies medial to the carotid sheath, i.e. the carotid artery and IJV (Figs. 9.27 and 9.28).

9.9.1 Case Illustration 1: Completion Hemithyroidectomy

This is the case of a young lady with a history of thyroidectomy 15 years ago, represented with left

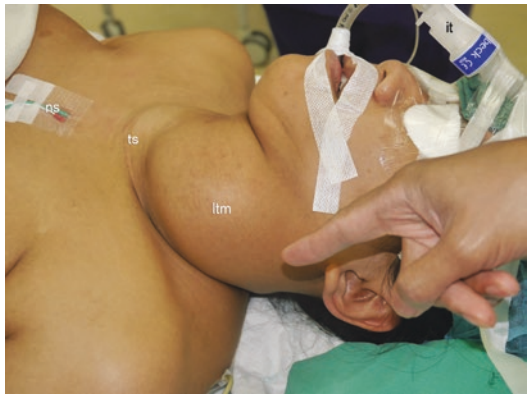

Fig. 9.29 Patient lies supine with oral intubation tube (it) in situ for anaesthesia. The nerve monitoring (ns) has been applied. Previous thyroid scar (ts) is visible, and left thyroid mass (ltm) is visualized

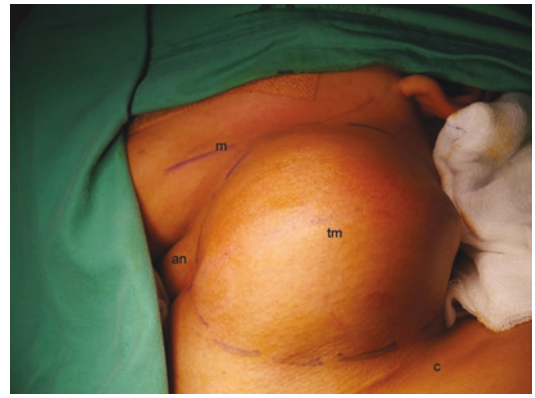

Fig. 9.30 The outermost margin of thyroid mass (tm) has been outlined, which abuts mandible (m) superiorly and close to midline (an) anteriorly

thyroid mass mimicking a branchial cyst (Fig. 9.29). A FNAC evaluation and CT scan confirmed that it was a recurrent benign thyroid tumour. The case indicated for a completion thyroidectomy.

A normal preparation for total thyroidectomy is intubation with the EMLT tube that is designed for recurrent laryngeal nerve monitoring (Fig. 9.29). This tube should be inserted where the marker for electrode monitoring is at the level of glottic. If the tube is inserted too inferiorly below the glottic level, the nerve monitoring will not be functioning.

A common skin incision is midway between the sternal notch and cricoid cartilage. In this case, however, since the recurrent tumour is lateral and more superiorly located at the left level II, III, and IV neck node region (Fig. 9.30), the designed skin incision is at the epicentre of the mass, following the normal skin crease, and placed below two finger breadths of the angle of mandible.

The subplatysmal skip flap is elevated, superiorly to the level of hyoid bone and inferiorly to the inferior-most border of the mass (Fig. 9.31). This will facilitate better dissection with wide surgical access. It is critical to anticipate the carotid artery, IJV, and vagus nerve deep to the

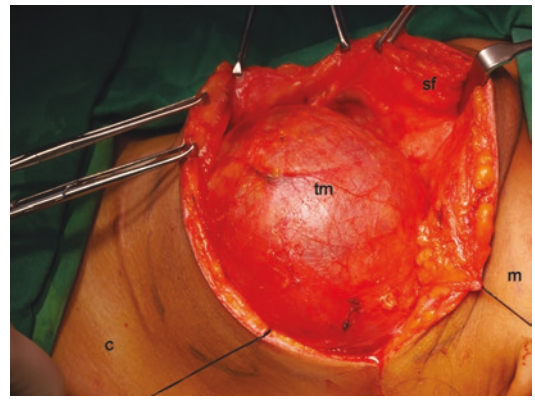

Fig. 9.31 The subplatysmal skin flap (sf) has been raised exposing the thyroid mass (tm) and its capsule. Superior flap is retracted towards mandible (m), and the inferior flap is raised down to the inferior border of the mass

mass, which need to be identified and preserved. A wide surgical access will allow safer dissection in the carotid sheath area and ensure the preservation of the carotid sheath and its content.

Retraction of the mass superomedially with meticulous dissection of tissue around the carotid sheath ensures preservation of IJV, vagus nerve, and carotid artery (Fig. 9.32). The dissection should be continued on the mass capsule, so as to avoid unnecessary tissue trauma to adjacent tissue.

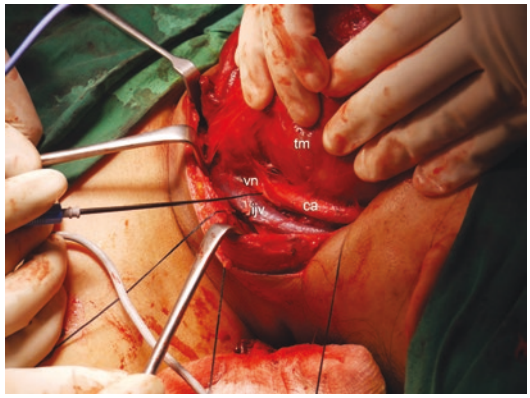

Fig. 9.32 The lateral dissection of the mass (tm) has been completed, and retraction of mass medially exposed the carotid artery (ca), vagus nerve (vn), and internal jugular vein (ijv). The mass is able to be dissected away from the carotid sheath as it has a well-formed capsule

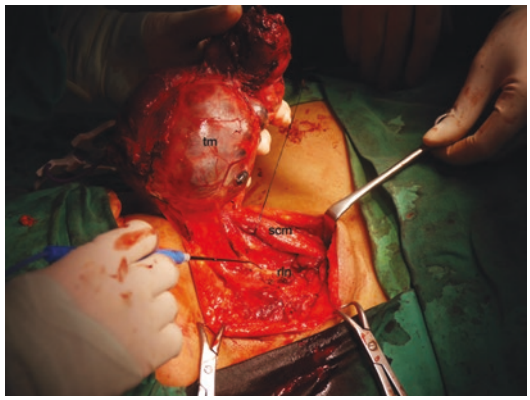

Fig. 9.33 The mass (tm) is retracted superiorly while deep dissection continues. The recurrent laryngeal nerve (rln) is tested with a nerve stimulator and is intact. The sternocleidomastoid muscle (SCM) is also shown

Further dissection deep to the mass and traction on the mass superiorly will allow a safe tumoural mass removal (Fig. 9.33). Any residual bleeding can be controlled with bipolar diathermy. Irrigation of tumour bed with warm normal saline allows bleeding control better.

The mass is excised in total together with its capsule which is intact (Fig. 9.34). The specimen is labelled and sent to the histopathology for analysis.

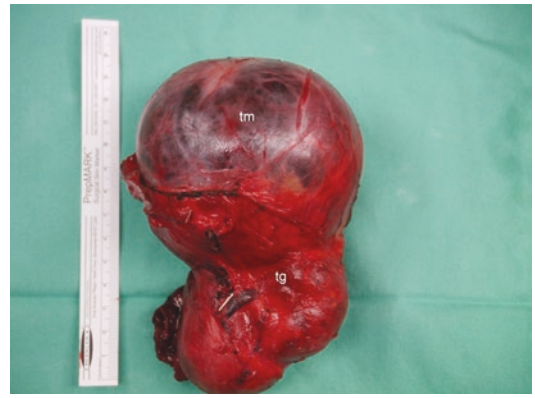

Fig. 9.34 The left thyroid mass (tm) which is removed measuring 8.0 cm × 5.0 cm. The dissected thyroid gland (tg) tissue is also shown

9.10 Conclusion

Thyroid gland surgery can cause significant morbidity to the patient. The complication of recurrent laryngeal nerve paralysis and hypocalcaemia poses critical management challenges. Sufficient knowledge of the anatomy and surgical landmarks together with experience ensure a safe and effective thyroidectomy. The surgeon also needs to understand the factors that underpin the types of thyroidectomy and their indication for the patients. Each patient has distinct tumour factors and preference that need to be considered meticulously during surgical planning.

References

1. Chmielik E, Rusinek D, Oczko-Wojciechowska M, Jarzab M, Krajewska J, Czarniecka A, et al. Heterogeneity of thyroid cancer. Pathobiology. 2018;85(1–2):117–29.
2. Asimakopoulos P, Nixon IJ. Surgical management of primary thyroid tumours. Eur J Surg Oncol. 2018;44(3):321–6. https://doi.org/10.1016/j.ejso.2016.12.015.
3. Singh P, Sharma K, Agarwal S. Per operative study of relation of Zuckerkandl tubercle with recurrent laryngeal nerve in thyroid surgery. Indian J Otolaryngol Head Neck Surg. 2017;69(3):351–6.

4. Noussios G, Chatzis I, Konstantinidis S, Filo E, Spyrou A, Karavasilis G, et al. The anatomical relationship of inferior thyroid artery and recurrent laryngeal nerve: a review of the literature and its clinical importance. J Clin Med Res. 2020;12(10):640–6.
5. Henry BM, Sanna B, Graves MJ, Sanna S, Vikse J, Tomaszewska IM, et al. The reliability of the tracheoesophageal groove and the ligament of berry as landmarks for identifying the recurrent laryngeal nerve: a cadaveric study and meta-analysis. Biomed Res Int. 2017;2017:1.
6. Sukumaran V, Teli B, Avula S, Pavuluru J. Effect of dissection of the recurrent laryngeal nerves on parathyroid insufficiency during total thyroidectomy for multinodular goitre. J Clin Diagn Res. 2016;10(2):PC01–3.
7. Kim DW, Jung SL, Baek JH, Kim J, Ryu JH, Na DG, et al. The prevalence and features of thyroid pyramidal lobe, accessory thyroid, and ectopic thyroid as assessed by computed tomography: a multicenter study. Thyroid. 2013;23(1):84–91.
8. Wang LJ, Liu CM, Chen X, Zhang L, Zhou HW. An intracardiac accessory thyroid gland mimicking cardiac tumor: a case report and literature review. Medicine (United States). 2017;96(51):6–8.
9. Zatoński T, Bolanowski M, Jędrzejuk D, Zatońska K, Kręcicki T. Intralaryngeal ectopic thyroid. Otolaryngologia polska (Pol Otolaryngol). 2014;68(1):46–9.
10. Jacobsen B, VanKampen N, Ashurst JV. Anatomy, head and neck, thyrohyoid membrane. In: StatPearls. Treasure Island, FL: StatPearls Publishing; 2021. Available from: https://www.ncbi.nlm.nih.gov/books/NBK532995/.
11. Chin J, Zhou Y, Wan PJ, Lomiguen CM. The prevalence of thyroid ima artery and its clinical significance. Int J Otorhinolaryngol Head Neck Surg. 2019;5(4):845.
12. Chiang FY, Lu IC, Chen HC, Chen HY, Tsai CJ, Hsiao PJ, et al. Anatomical variations of recurrent laryngeal nerve during thyroid surgery: how to identify and handle the variations with intraoperative neuromonitoring. Kaohsiung J Med Sci. 2010;26(11):575–83.
13. Asgharpour E, Maranillo E, Sañudo J, Pascual-Font A, Rodriguez-Niedenführ M, Valderrama FJ, et al. Recurrent laryngeal nerve landmarks revisited. Head Neck. 2012;34(9):1240–6. https://doi.org/10.1002/hed.21882.
14. Henry BM, Vikse J, Graves MJ, Sanna S, Sanna B, Tomaszewska IM, et al. Variable relationship of the recurrent laryngeal nerve to the inferior thyroid artery: a meta-analysis and surgical implications. Head Neck. 2017;39(1):177–86.
15. Rajabian A, Walsh M, Quraishi NA. Berry's ligament and the inferior thyroid artery as reliable anatomical landmarks for the recurrent laryngeal nerve (RLN): a fresh-cadaveric study of the cervical spine. The RLN relevant to spine. Spine J. 2017;17(3):S33–9. https://doi.org/10.1016/j.spinee.2017.01.011.
16. Ngo Nyeki AR, Njock LR, Miloundja J, Evehe Vokwely JE, Bengono G. Recurrent laryngeal nerve landmarks during thyroidectomy. Eur Ann Otorhinolaryngol Head Neck Dis. 2015;132(5):265–9. https://doi.org/10.1016/j.anorl.2015.08.002.
17. Uludag M. A review of methods for the preservation of laryngeal nerves during thyroidectomy. SiSli Etfal Hastanesi Tip Bulteni (Med Bull Sisli Hosp). 2018;52(2):79–91.
18. Serpell JW. New operative surgical concept of two fascial layers enveloping the recurrent laryngeal nerve. Ann Surg Oncol. 2010;17(6):1628–36. https://doi.org/10.1245/s10434-010-0928-0.
19. Wojtczak B, Kaliszewski K, Sutkowski K, Bolanowski M, Barczyński M. A functional assessment of anatomical variants of the recurrent laryngeal nerve during thyroidectomies using neuromonitoring. Endocrine. 2018;59(1):82–9.
20. Henry BM, Sanna S, Graves MJ, Vikse J, Sanna B, Tomaszewska IM, et al. The non-recurrent laryngeal nerve: a meta-analysis and clinical considerations. PeerJ. 2017;2017(3):1–17.
21. Burger F, Fritsch H, Zwierzina M, Prommegger R, Konschake M. Postoperative hypoparathyroidism in thyroid surgery: anatomic-surgical mapping of the parathyroids and implications for thyroid surgery. Sci Rep. 2019;9(1):1–11. https://doi.org/10.1038/s41598-019-52189-3.
22. Ling XY, Smoll NR. A systematic review of variations of the recurrent laryngeal nerve. Clin Anat. 2016;29(1):104–10. https://doi.org/10.1002/ca.22613.
23. Zada B, Anwar K, Malik SA, Niamatullah KN, Salam F. Anatomical relationship between recurrent laryngeal nerve and inferior thyroid artery in thyroidectomy patients. J Ayub Med Coll Abbottabad (JAMC). 2014;26(3):380–3. Available from: http://europepmc.org/abstract/MED/25671953.
24. Tang W-J, Sun S-Q, Wang X-L, Sun Y-X, Huang H-X. An applied anatomical study on the recurrent laryngeal nerve and inferior thyroid artery. Surg Radiol Anat (SRA). 2012;34(4):325–32.
25. Irawati N, Vaish R, Chaukar D, Deshmukh A, D'Cruz A. The tubercle of Zuckerkandl : an important landmark revisited. Indian J Surg Oncol. 2016;7(3):312–5. https://doi.org/10.1007/s13193-015-0482-0.
26. Yun JS, Lee YS, Jung JJ, Nam KH, Chung WY, Chang HS, et al. The Zuckerkandl's tubercle: a useful anatomical landmark for detecting both the recurrent laryngeal nerve and the superior parathyroid during thyroid surgery. Endocr J. 2008;55(5):925–30.
27. Janjua N, Wreesmann VB. Aggressive differentiated thyroid cancer. Eur J Surg Oncol. 2018;44(3):367–77. https://doi.org/10.1016/j.ejso.2017.09.019.
28. Hanson MA, Shaha AR, Wu JX. Surgical approach to the substernal goiter. Best Pract Res Clin Endocrinol Metab. 2019;33(4):101312.
29. Knobel M. An overview of retrosternal goiter. J Endocrinol Investig. 2020;44:679. https://doi.org/10.1007/s40618-020-01391-6.
30. Abdelrahman H, Al-Thani H, Al-Sulaiti M, Tabeb A, El-Menyar A. Clinical presentation and surgical treat-

ment of retrosternal goiter: a case series study. Qatar Med J. 2020;2020(1):1–8.
31. di Crescenzo V, Vitale M, Valvano L, Napolitano F, Vatrella A, Zeppa P, et al. Surgical management of cervico-mediastinal goiters: our experience and review of the literature. Int J Surg. 2016;28:S47–53. https://doi.org/10.1016/j.ijsu.2015.12.048.
32. Wang X, Zhou Y, Li C, Cai Y, He T, Sun R, et al. Surgery for retrosternal goiter: cervical approach. Gland Surg. 2020;9(2):392–400.
33. Haugen TW, Andera LN, LaMadrid AB. Awake thyroidectomy. Laryngoscope. 2020;130(3):685–90. https://doi.org/10.1002/lary.28196.
34. Zhang D, Park D, Sun H, Anuwong A, Tufano R, Kim HY, et al. Indications, benefits and risks of transoral thyroidectomy. Best Pract Res Clin Endocrinol Metab. 2019;33(4):101280.
35. Fernandez-Ranvier G, Meknat A, Guevara DE, Inabnet WB 3rd. Transoral endoscopic thyroidectomy vestibular approach. J Soc Laparoendosc Surg (JSLS). 2019;23(4):e2019.00036.
36. Jongekkasit I, Jitpratoom P, Sasanakietkul T, Anuwong A. Transoral endoscopic thyroidectomy for thyroid cancer. Endocrinol Metab Clin N Am. 2019;48(1):165–80.
37. Gür EO, Haciyanli M, Karaisli S, Haciyanli S, Kamer E, Acar T, et al. Intraoperative nerve monitoring during thyroidectomy: evaluation of signal loss, prognostic value and surgical strategy. Ann R Coll Surg Engl. 2019;101(8):589–95.
38. Chávez Tostado KV, Velázquez-Fernandez D, Chapa M, Pantoja Millán JP, Salazar MS, Herrera MF. Substernal goiter: correlation between grade and surgical approach. Am Surg. 2018;84(2):262–6. Available from: http://europepmc.org/abstract/MED/29580356.

10 Endoscopic Nasal and Paranasal Sinus Surgery

Ramiza Ramza Ramli, Sakinah Mohamad, and Norasnieda Md Shukri

10.1 Introduction

The endoscopic sinus surgery (ESS) has greatly evolved over the past few decades. It was originally started with the attempt at nasal endoscopy in 1901 by Hirschman by using a modified cystoscope to assess the nasal cavity [1]. Following that, Reichert introduced a 7 mm endoscope through an oro-antral fistula, and this was regarded as the first endoscopic procedure [1]. Later on, in 1925, the term 'sinuscopy' was coined by Maltz. The turning point in nasoendoscopy was when Hopkins introduced the rod optic endoscope system together with the inventions of a fibre-optic gastroscope and zoom camera lens [1]. Subsequently, Messerklinger utilized this innovation and performed a cadaveric study on mucociliary clearance [1]. From his observation, the mucociliary clearance in the paranasal sinuses was draining towards their respective natural ostium. Then, Stammberger and Kennedy popularized the philosophy of widening the natural ostium of the diseased paranasal sinuses [2]. Following that onwards, with the advancement in the instrumentation and technological progress, the use of the endoscopic technique is extended to other procedures such as endoscopic dacryocystorhinostomy, orbital/optic nerve decompression, and anterior skull base surgery via transsphenoidal route.

10.2 Surgical Anatomy

It is of utmost importance to thoroughly know and understand the surgical landmarks involved during the endoscopic sinus surgery for surgical planning to achieve complete clearance of the disease and to avoid complications. The nose is divided internally into two nasal cavities by the nasal septum. The nasal septum is composed of membranous, cartilaginous, and bony components as shown in Fig. 10.1 [3].

The membranous component consists of connective tissues located between the columella and the caudal part of the cartilaginous septum. The cartilaginous septum is comprised of septal cartilage or also known as quadrilateral cartilage. On the other hand, the bony septum is composed of superiorly the perpendicular plate of the ethmoid bone and inferiorly the vomer, crest of maxilla bone, and crest of palatine bone. The Little's area is located at the anterior part of the nasal septum and supplied by branches from the anterior ethmoid artery, sphenopalatine artery, greater palatine artery, and superior labial artery, which anastomose forming the Kiesselbach's plexus. This region is the commonest site of anterior epistaxis as it is very rich in capillary loops and

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N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_10

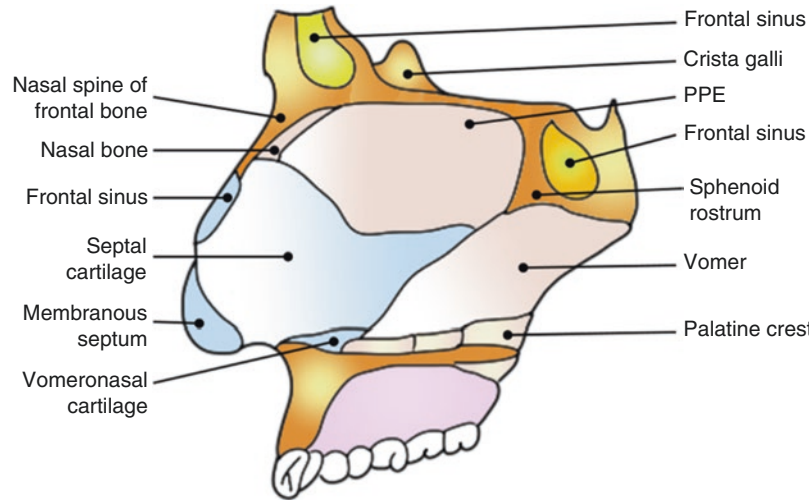

Fig. 10.1 Components of nasal septum

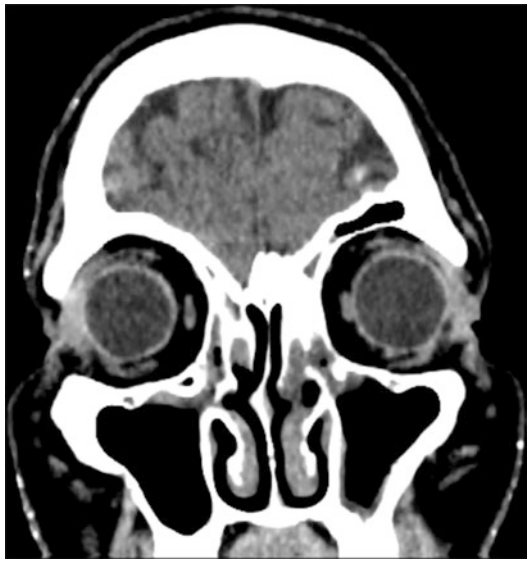

Fig. 10.2 Coronal view of the CT scan of the paranasal sinuses showed some degree of bony septal deviation to the right. The septal deviation in this case is not in contact with the mucosa of the structures in the lateral wall of the nose

susceptible to injury such as digital trauma. The nasal septum deviation may cause narrowing of the nasal airway passage leading to some degree of nasal blockage for the patient (Fig. 10.2).

Along the lateral nasal wall, there are 3–4 types of turbinates, namely inferior turbinate, middle turbinate, superior turbinate, and supreme turbinate occasionally. These turbinates play some role in the regulation of the inhaled nasal airflow, humidification, and filtration. The nasal passage inferior to each turbinate is called the meatus. The nasolacrimal duct drains into the inferior meatus via some mucosal folds named Hasner's valve, which is about 1 cm posterior to the caudal end of the inferior turbinate. The middle meatus is a complex region whereby it acts as a common drainage from the maxillary sinus, anterior ethmoid sinus, and frontal sinus. Meanwhile, the posterior ethmoid air cells drain into sphenoethmoidal recess of the superior meatus.

From anterior to posterior, there are a series of 4–5 bony partitions or lamellae separating the ethmoid sinuses, namely uncinate process (first lamella), bulla ethmoidalis (second lamella), ground or basal lamella of the middle turbinate (third lamella), superior turbinate (fourth lamella), and occasionally supreme turbinate (fifth lamella) [4]. The basal lamella of middle turbinate marks the division between anterior and posterior ethmoid sinuses. Posterior ethmoid air cells are fewer in number but larger in size compared to anterior ethmoid air cells. The uncinate process is a boomerang-shaped bone that runs from anterosuperior to posteroinferior direction. Superiorly, it can attach to the lamina papyracea (85% of cases), middle turbinate, or skull base (both account for 15% of cases). Interestingly, in more than 50% of cases, it has multiple

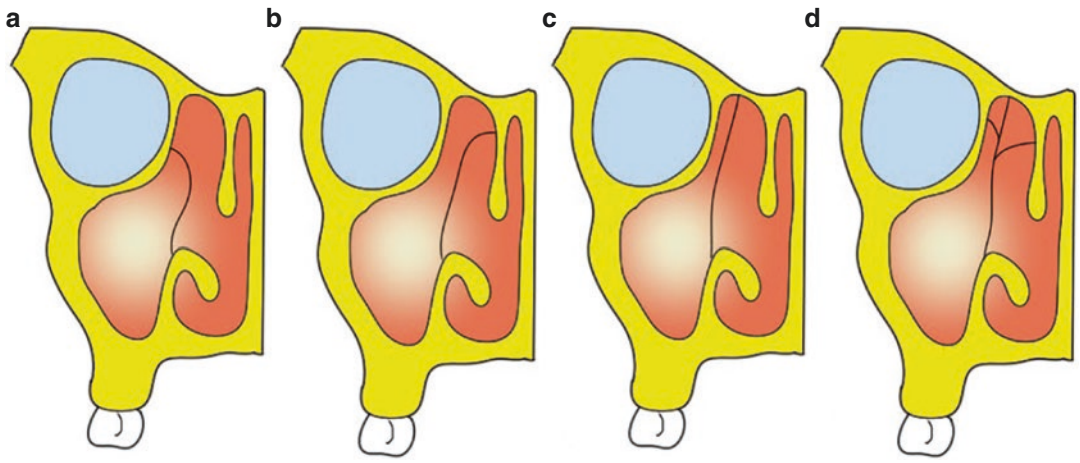

Fig. 10.3 Different attachment of uncinate process: (**a**) single attachment to lamina papyracea, (**b**) middle turbinate, (**c**) skull base, or (**d**) multiple attachment

attachments in the nasal cavity. Figure 10.3 shows different attachment of the uncinate process in the nasal cavity [3].

The uncinate process has a horizontal and a vertical component, whereby the latter is closely related to the frontal recess. When the uncinate process attaches to the lamina papyracea, the frontal recess will drain medially to the uncinate process into the middle meatus, and vice versa; if the uncinate process attaches to the middle turbinate or skull base, then the drainage pathway of the frontal recess will be lateral to the uncinate process, hence draining into the ethmoid infundibulum. The ethmoid infundibulum is a three-dimensional space located lateral to the uncinate process. Bulla ethmoidalis is the largest and the most prominent anterior ethmoid air cell on the lateral nasal wall. It is bounded anteriorly by the frontal recess and uncinate process, posteriorly by the basal lamella of the middle turbinate, medially by the lamina papyracea, and laterally by the middle turbinate.

The outflow tract of the frontal sinus resembles an hourglass appearance in the sagittal plane. The wider upper part of the hourglass (floor of the frontal sinus) drains into the wider lower part (frontal recess) via the narrowest segment in the middle (frontal ostium). Frontal recess is bounded anteriorly by the agger nasi cell, posteriorly by the bulla ethmoidalis and supra bulla air cells, laterally by lamina papyracea, and medially by the middle turbinate. Agger nasi cell is the most anterior ethmoid air cell. If it enlarges, it can encroach the frontal recess resulting in a narrower frontal recess drainage pathway. Besides that, the size of the drainage pathway of frontal recess is also determined by other cells. According to the International Frontal Sinus Anatomy Classification, there are three types of cells related to the frontal recess [5]:

1. Anterior cells (push the drainage pathway of frontal sinus medially, posteriorly, or posteromedially): agger nasi cell, supra agger cell, and supra agger frontal cell
2. Posterior cells (push the drainage pathway anteriorly): supra bulla cell, supra bulla frontal cell, supraorbital ethmoid cell
3. Medial cells (push the drainage pathway laterally): frontal septal cells

The maxillary sinus is bounded by orbital floor superiorly, alveolar process inferiorly, facial surface of the maxilla anteriorly, infratemporal fossa posteriorly, and lateral wall of nasal cavity medially. The infraorbital nerve runs in the roof of maxillary sinus to exit via infraorbital foramen at the anterior surface of maxilla. About 14% of cases have a dehiscent infraorbital canal, which may increase the risk of nerve injury intraoperatively [4]. The natural maxillary sinus ostium

opens into the posterior third of the ethmoid infundibulum on the superior part of the medial wall of the maxillary sinus. On the other hand, the accessory sinus ostium can be found in either anterior or posterior nasal fontanelle. It is important to differentiate between the true and the accessory sinus ostium so that we can enlarge the true ostium and restore the drainage pathway of the maxillary sinus. Occasionally, the anterior ethmoid air cells can expand laterally into the maxillary sinus, known as infraorbital ethmoid cells or Haller cells.

Sphenoid sinus ostium can be found within 1 cm behind the posteroinferior end of the superior turbinate, and most of the time the sphenoid ostium (SO) is medial to it [6]. Besides that, the roof of the maxillary sinus can be used as a reference point when looking for the SO. A horizontal imaginary line is drawn at the level of the roof of the maxillary sinus to the nasal septum [7], and the SO is usually within 1 cm medial to the nasal septum [6]. Posterior choana can also be one of the landmarks for SO as the SO is located about 1.5 cm above the posterior choana. Sphenoid sinuses are surrounded by important neurovascular structures, namely internal carotid arteries (ICA), optic nerves, cavernous sinuses, and other nerves such as oculomotor, trochlear, maxillary, vidian, and abducens nerves. Bony canal dehiscence for ICA and optic nerve were found to be in approximately 25% and 6% of cases, respectively [8]. Onodi cells or sphenoethmoidal cells, which are located at the superolateral part of sphenoid sinuses, can also be seen occasionally.

10.3 Indications

The term 'functional' in functional endoscopic sinus surgery (FESS) refers to the restoration of the function of the sinonasal cavity, i.e. trying to preserve as much mucosa as possible. The most common indication for FESS is for chronic rhinosinusitis with or without polyp when maximal medical therapy has failed. The goals for this procedure are to remove the diseased sinonasal mucosa, allow adequate sinus drainage and ventilation, facilitate topical drug deliverance, and facilitate the surveillance of disease recurrence post-operatively.

Other indications include:

- Sphenopalatine artery ligation
- Orbital/optic nerve decompression
- Mucocele
- Invasive and non-invasive fungal rhinosinusitis
- Benign and malignant sinonasal tumour
- Cerebrospinal fluid leaks
- Lesions involving pituitary fossa, petrous apex, and pterygomaxillary fossa

10.4 Preoperative Evaluation and Surgical Preparation

Optimizing the surgical field in patients prior to endoscopic sinus surgery increases the chances for a safe and efficient surgery. Preoperative medical management, anaesthetic choice, patient positioning, and topical vasoconstrictors are methods currently used to mitigate cumbersome bleeding during surgery. Decreased bleeding improves the quality of the optical cavity, thereby enhancing visualization of nearby critical structures.

10.4.1 Patient Preparation

Before we proceed with endoscopic sinus surgery, one of the most crucial aspects that we need to deal with is stabilizing the patient's current medical condition. We need to optimize patient health, especially for those who had diabetes and hypertension. Early referral to physician for blood sugar monitoring and blood pressure control is mandatory.

The patient was also advised to stop smoking for at least 1 month before the surgery. A study on smoking habits in endoscopic sinus surgery found an association between exposure to cigarette smoke and potentially severe surgical site infections in the 30-day post-operative period after ESS [9].

All the blood-thinning products such as garlic and ginkgo biloba need to be stopped. Blood

thinner medication such as aspirin also needs to be withheld before surgery.

10.4.2 Informed Consent

Informed consent is also another important issue that needs to be highlighted before we proceed with the surgery. A good, informed consent should include several important issues:

- Thorough explanation about the disease
- Indication for endoscopic sinus surgery
- Patient's expectation and surgeon's expectation
- The procedure itself in general
- Complication of the surgery
- Post-operative care

10.4.3 Preoperative Planning/ Evaluation

Prior to the surgery, the nasal anatomy is re-evaluated, and any significant abnormalities are noted. It is helpful to repeat the nasal endoscopy to detect the presence of reactive nasal mucosa identified by marked congestion, sneezing, and hypersecretion during diagnostic endoscopy despite maximum medical therapy. In this situation, if the oedematous mucosa is not treated preoperatively, bleeding will be increased intraoperatively.

It is essential that the patient's CT scan be re-reviewed again prior to the surgery. Preoperative planning requires careful evaluation and conceptualization of the anatomy based upon the preoperative CT scan. This requires a systematic review of the CT scan so as to provide not only an understanding of the anatomy of the skull base and the medial wall of orbit, but also the surgeon's conceptualization of the frontal sinus drainage pathway and the relevant anatomy of the ethmoid pneumatization.

A checklist of anatomic landmark and variants should be reviewed (Table 10.1), including the presence of Onodi (sphenoethmoidal) cell and integrity of the ethmoid. The vertical height of the ethmoid sinus as well as the slope of the roof of the ethmoid should also be carefully assessed.

Table 10.1 Systematic CT scan review

		Yes/ No
Patient ID	Is this the correct CT scan for the patient?	
Previous surgery	Has the patient had another sinus surgery before?	
Anterior ethmoid root	Slope, height	
	Keros classification	
	Anterior ethmoidal artery course	
	Any asymmetries	
Medial wall of orbit	Uncinate; superior attachment	
	Middle turbinate; attachment	
	Concha bullosa	
Posterior ethmoid	Vertical height	
	Dehiscence lamina papyracea	
Sphenoid sinus	Sphenoethmoidal cells	
	Pneumatization	
	Intersinus septa	
	Dehiscence carotid artery	
Frontal recess/sinus	Frontal sinus drainage pathway	
	Frontal cell	
	Agger nasi	

Failure to recognize a sloping pattern of skull base will end up the surgeon entering the cranial cavity.

When evaluating the frontal sinus for preparation of endoscopic frontal sinusotomy, the surgeon needs to conceptualize the frontal sinus drainage pathway and the adjacent cells as they will be encountered intraoperatively. Failure to do so will lead to a more disastrous problem post-operatively. It may be helpful if the surgeon can draw the drainage pathway in relation to middle turbinate, ethmoid bulla, agger nasi, supraorbital cells, and uncinate process. The presence of any septal deformity is important to be addressed also.

As the CT scan is reviewed, sphenoid skull base, bony optic and carotid canal, size and pneumatization pattern of the sphenoid sinus, integrity of the bony medial wall of orbit in case of dehiscence of lamina papyracea, and orbital apex should also be addressed. Careful attention is also paid to the position of anterior ethmoidal artery and veins as these may lead to torrential bleeding intraoperatively if not recognized prior to it.

It is best to view the CT scan in all planes, coronal images, sagittal images, and axial images. Even though most of these landmarks can be recognized on coronal images, the axial and sagittal images can provide important supplemental anatomic perspective. For example, axial images are best viewed for sphenoid ostium and sagittal images of the sphenoid can easily demonstrate Onodi cells.

MRI becomes important when there is opacification adjacent to the erosion of the skull base or when there is tumour. Besides that, presence of midline pulsatile mass seen during nasoendoscopy should warn the otorhinolaryngologists of the possibility of meningoencephalocele. MR allows the identification of meningoencephalocele and their differentiation from other tumours or inflammatory disease.

10.4.4 Preoperative Measure to Reduce Intraoperative Bleeding

10.4.4.1 Antibiotic

In patients with acute infection, reducing the inflammation with antibiotic will help to reduce intraoperative bleeding. However, in a case where there is no acute infection, the use of antibiotic preoperatively is controversial as it is considered as one of the regimes in maximal medical therapy for chronic rhinosinusitis. Most surgeons do not advocate starting antibiotic prior to the surgery. Usage of antibiotic usually depends on intraoperative findings of the patients [10].

10.4.4.2 Systemic Corticosteroid

The use of preoperative systemic corticosteroids in endoscopic sinus surgery (ESS) has been a topic of debate among otolaryngologists for many years now. Until recently, most of the evidence to support its use in ESS was largely anecdotal and based on expert opinion. In the presence of reactive mucosa or polyposis, the use of systemic corticosteroid preoperatively is controversial. Most of the surgeons prefer the usage of steroid during the initial part of therapy as one of the regimes in maximal medical therapy for CRS where the inflammatory loads are still not in control.

A systematic review and meta-analysis on the preoperative use of local and/or systemic corticosteroids in FESS concluded that it had significantly reduced blood loss, shortened operative time, and improved surgical field quality [11]. Studies are limited on the intraoperative use of corticosteroids to reduce post-operative pain. Post-operative corticosteroids improve post-operative endoscopic scores in CRS and recurrence rates in cases of CRSwNP. In their review on the usage of systemic steroid, Carlton and Chiu [12] had pointed out that there are known risks of administration of systemic corticosteroids, and clinicians must take these into account when evaluating an individual patient. In view of the adverse effect of systemic steroid, Harvey et al. (2018) suggested the usage of steroid irrigation post-operatively in the setting of diffuse or patchy CRS disease, compared to simple nasal spray in postsurgical patients [13].

10.4.4.3 Topical Decongestants

Usage of topical oxymetazoline has been advocated as one of the measures to reduce bleeding intraoperatively as it has also been a common practice among otolaryngologists. The justification is that alpha-receptor agonist can help to reduce bleeding during surgery if used before the operation. However, simple decongestants like oxymetazoline are not ideal for pre-op decongestion as these are partial, mainly alpha-1 agonist, and while they do have an effect in causing vasoconstriction on the arteriole side, they are less or not effective on the venous side. Furthermore, they are competitive agonists at the same receptors that adrenaline works at. So why use these partial agonists when they can only compete with adrenaline and diminish the effects of adrenaline, which is going to be part of our topical preparation and infiltration intraoperatively?

10.4.4.4 Adrenaline

It stimulates both alpha-1 and -2 receptors. Furthermore, the degree of vasoconstriction is

dose dependent. Adrenaline can accurately achieve optimal local vasoconstriction while minimizing the systemic effects. Topical vasoconstriction of adrenaline via gauze or cotton pledges with a concentration of 1:1000 in children or 1:2000 in at-risk patients has been demonstrated to be safe [14].

10.4.4.5 Moffett's Solution

In our centre, we advocate the use of Moffett's solution as topical decongestion and local anaesthetic prior to endoscopic sinus surgery. It is a combination of cocaine, adrenaline, bicarbonate, and 0.9% sodium chloride, which was first described by Major A.J. Moffett of the Royal Army Medical Corps in 1941 [15]. The combination of cocaine and adrenaline synergistically acts on both alpha-1 and alpha-2 adrenoreceptors in nasal vasculature. When applied topically to the nasal mucosa, it produces profound vasoconstriction and anaesthesia, reducing blood loss and improving visualization in the operative field for sinonasal surgery [16]. The solution consists of a mixture of 2 mL of 10% cocaine solution (200 mg), 1 mL of 1:1000 adrenaline, 2 mL of sodium bicarbonate, and 5 mL of 0.9% sodium chloride solution, 10 mL in total with 5 mL applied to each side.

10.4.5 Anaesthesia

Endoscopic sinus surgery can be performed satisfactorily under either local anaesthesia with sedation or general anaesthesia. With the advancement in anaesthetic drugs, less blood loss was encountered in endoscopic sinus surgery. Hypotensive anaesthesia has been used to reduce bleeding intraoperatively. The mean arterial pressure (MAP) is aimed to be in between 50 and 70 mmHg. To have a good surgical field in endoscopic sinus surgery, it usually relies on good vasoconstriction and good clotting mechanism. This is when the term hypotensive anaesthesia is coined. Neither vessel ligation nor extensive diathermy is needed once a clear surgical field is achieved.

Surgical field improves with bradycardia anaesthesia [17]. With this finding, bradycardia anaesthesia is achieved by using total intravenous anaesthesia (TIVA) with either propofol or remifentanil. Meta-analysis study on total intravenous anaesthesia (TIVA) vs. inhalational anaesthesia indicates that TIVA has the potential to confer superior surgical field visibility and reduce intraoperative blood loss compared to inhalational anaesthesia in ESS [18]. TIVA has been demonstrated to be associated with less blood from prior inhalational agents [19].

10.4.6 Positioning of Patient

The reverse Trendelenburg position (RTP), a head-up, feet-down tilt varying from 10° to 30°, is also commonly used during ESS [20]. The RTP reduces venous return and cardiac output by retaining blood in the lower parts of the body. The 15° RTP improves the endoscopic field of view and reduces blood loss during ESS [21].

10.4.7 Image-Guided System (IGS)

Image-guided systems (IGS) have gained widespread use in endoscopic sinus surgery (ESS) and have been thoroughly analysed. The use of IGS in ESS and anterior skull base surgery is predicated on the notion that its ability to aid in anatomic identification during surgery will lead to fewer complications and improved surgical outcomes. Based on the best available evidence in the literature, the use of IGS has not clearly been shown to decrease surgical complications or improve surgical outcomes [22].

Level 2A evidence from systematic reviews suggests that in certain cases IGS may be associated with decreased major and total surgical complications, though the potential for bias and confounding exists in these conclusions. The choice to use IGS in any endoscopic procedure remains best determined by the operating surgeon based on factors including case complexity and surgeon comfort [23].

10.5 Operative Techniques

10.5.1 Endoscopic Sinus Surgery

After topical decongestion with Moffett's solution, by using a 0° Hopkins telescope, a local infiltration with Scandonest 2% (adrenaline 0.001% and mepivacaine HCl 2%) is placed at the body and axilla of the middle turbinates, and lateral wall of the nasal cavity as shown in Fig. 10.4. Then, the middle turbinate is 'relaxed' by gently medializing it with utmost precaution to avoid injury to the lateral lamella of the cribriform plate (Fig. 10.5). In a case of a bulky concha bullosa or paradoxical middle turbinate, surgical access is widened by resection of the lateral part of the middle turbinate. Again, care is to be taken to have a clean sharp cutting edge and avoid unnecessary mucosal injury surrounding this area to prevent synechia formation (Fig. 10.6).

10.5.1.1 Uncinectomy

The free edge of the uncinate process is identified and probed in an upward-downward direction and teased out anteromedially. There are two approaches for uncinectomy: antegrade and retrograde approach. We prefer to use a retrograde approach as the antegrade approach may increase

Fig. 10.4 Positioning of patient in reverse Trendelenburg position

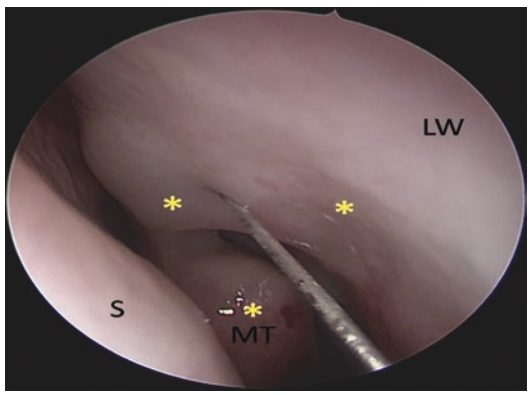

Fig. 10.5 Injection sites for the local anaesthesia (*marked with asterisks* *). Axilla and body of left middle turbinate (MT), lateral wall of nasal cavity (LW). Septum, S

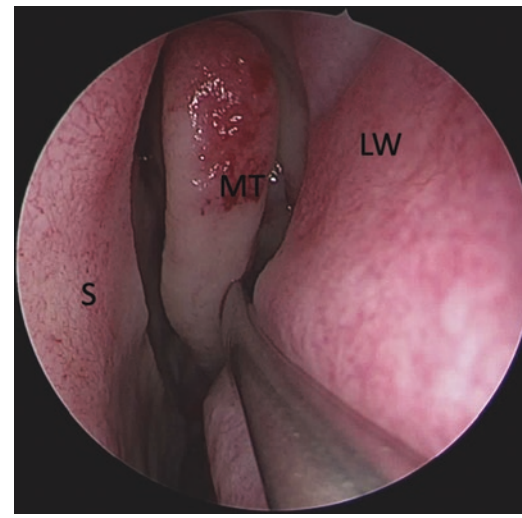

Fig. 10.6 Relaxation of the left middle turbinate (MT) by gently medializing it from inferoposterior to inferomedial direction. Septum (S) and Lateral wall (LW) of the nasal cavity

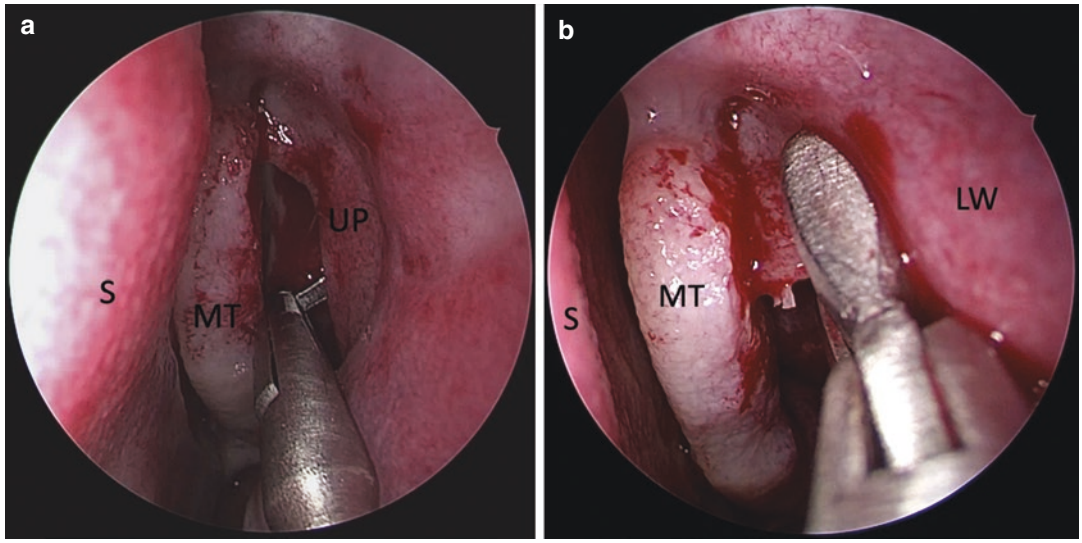

Fig. 10.7 Left uncinate process (UP) was removed by using (**a**) a backbiting forceps and (**b**) an upturned through-cutting Blakesley forceps. Septum, S; middle turbinate, MT; and lateral wall of nasal cavity, LW

the risk of penetrating the lacrimal sac or breaching lamina papyracea, especially in the case of an atelectatic uncinate process, hence injuring the orbit. By using a retrograde approach, both vertical and horizontal parts of the uncinate process are removed by cutting with a backbiting forceps at the middle of the vertical component of the uncinate process, whereby usually 2–3 bites are needed (Fig. 10.7). Then the rest of the uncinate process can be removed with the backbiter forceps angled 45° cutting in upwards direction or using an upturned through-cutting Blakesley forceps or a microdebrider to trim it.

10.5.1.2 Middle Meatal Antrostomy (MMA)

The true maxillary sinus ostium is usually visualized after uncinectomy. Sometimes, mucus or mucopus discharge with some debris can be seen flowing out of the sinus ostium when the medial wall of the maxillary sinus is pressed. It can also be identified by using a right-angled ball-tipped probe, curved curette, or sinus suction tube. Then the posterior fontanelle is removed with a straight Blakesley forceps and a backbiting forceps as shown in Fig. 10.8. The MMA can also be performed by using a microdebrider. If a Haller cell is encountered, the inferomedial part of the Haller cell is removed first and the dissection continued until the surgeon can engage where the posterior wall and roof of the maxillary sinus are. Careful dissection is necessary to avoid injury to the orbit. Palpation of the eye globe helps to guide

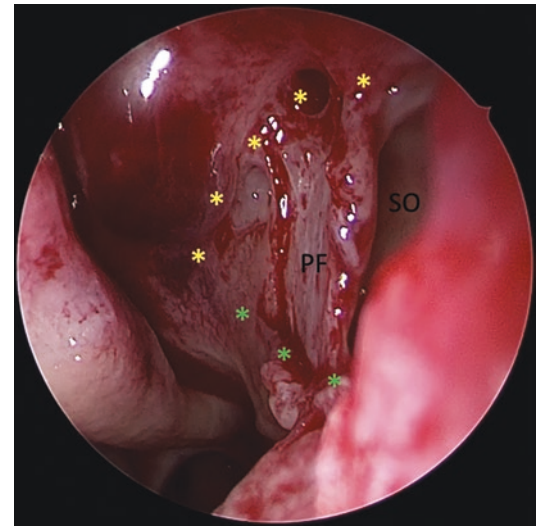

Fig. 10.8 Left middle meatal antrostomy performed by removing the posterior fontanelle (PF), using a straight Blakesley forceps in a backward direction (along the yellow asterisks) and a backbiting forceps in a forward direction (along the green asterisks). True left maxillary sinus ostium (SO)

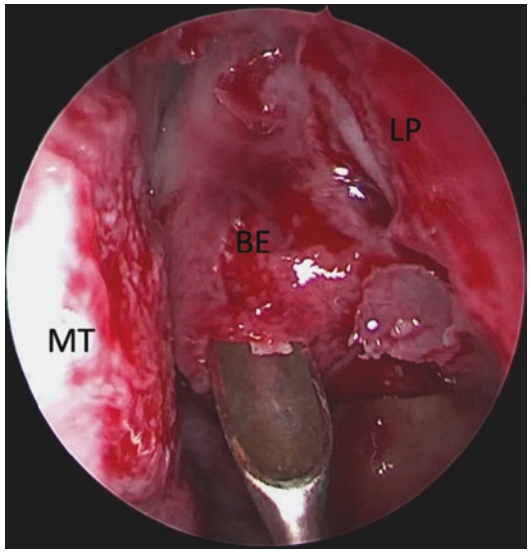

Fig. 10.9 Left bulla ethmoidalis (BE) was opened with a straight curette at the inferomedial part of the bulla. *MT* middle turbinate, *LP* lamina papyracea

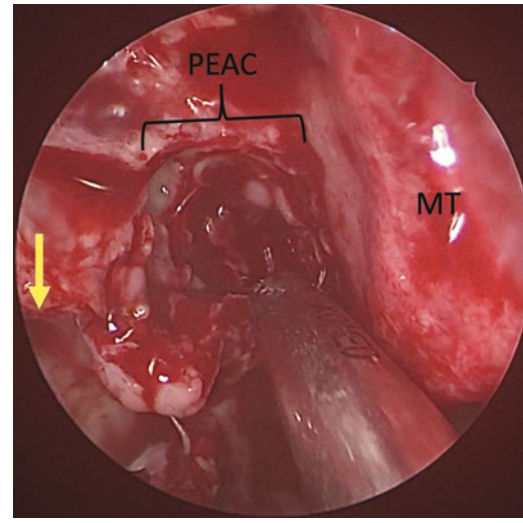

Fig. 10.10 After penetrating the basal lamella of right middle turbinate (MT), posterior ethmoidectomy was performed by using a microdebrider. *PEAC* posterior ethmoid air cells. The roof of right maxillary sinus is shown by the *yellow arrow*

the surgeon if the lamina papyracea has been breached.

10.5.1.3 Ethmoidal Bullectomy

The bulla ethmoidalis is identified, and a straight curette is used to open the inferomedial part of the bulla as seen in Fig. 10.9. Then the rest of the bulla is removed by using a straight through-cutting Blakesley forceps and a microdebrider. In a case of anterior ESS or mini-ESS, uncinectomy and opening of the anterior face of the bulla are done with retention of 3–4 mm mucosa from the edge of the anterior and inferior part of the bulla [5]. If proceeding to posterior ethmoidectomy, all the anterior wall of the bulla is removed to gain better access.

10.5.1.4 Posterior Ethmoidectomy

After uncapping the bulla, the posterior ethmoid sinus region is entered by opening up the basal lamella of the middle turbinate with a straight curette, ball probe, or straight Blakesley forceps at its inferior and medial part, at the same level with the roof of the maxillary sinus. Then the posterior ethmoid air cells are removed with a straight through-cutting Blakesley forceps, a straight curette, or a microdebrider (Fig. 10.10). Keep in mind that the base of the skull runs in a downward sloping fashion as it goes more posteriorly. The base of the skull is also recognized by its pale ivory-coloured mucosa.

10.5.1.5 Sphenoidotomy

During the posterior ethmoidectomy, landmarks of the sphenoid sinus ostium are identified, i.e. the superior turbinate, the roof of maxillary sinus, and the posterior choana, which have been discussed earlier in the 'surgical anatomy section'. The sphenoid sinus ostium can be identified by either transnasal or transethmoid approach. In a transethmoid approach, once the basal lamella is breached, the superior turbinate is identified. The sphenoid ostium is more clearly visualized when one-third up to half of the inferior part of the superior turbinate is removed with a straight through-cutting Blakesley forceps or microdebrider (Fig. 10.11). It is most of the time medial to the superior turbinate. The ostium can be enlarged adequately by removing part of the anterior face of the sphenoid sinus with a Kerrison punch or microdebrider. The maximum border for removal of the anterior face of the sphenoid will be the base of the skull superiorly, the floor

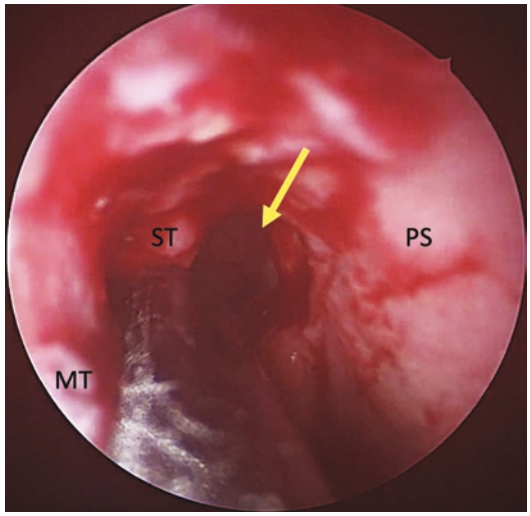

Fig. 10.11 Right sphenoid sinus ostium is shown by the yellow arrow. The right superior turbinate (ST) was trimmed with a microdebrider. Posterior nasal septum, PS and right middle turbinate, MT

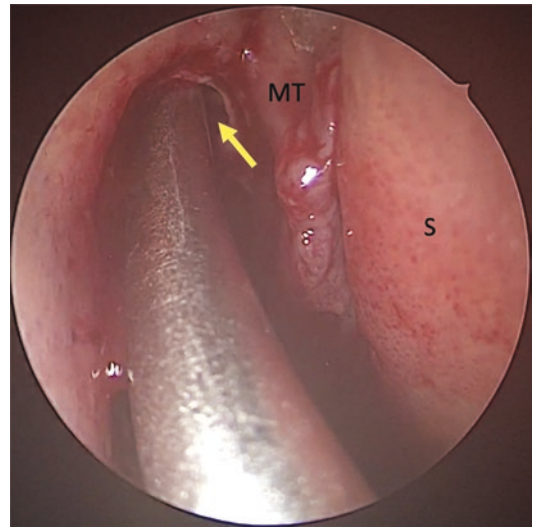

Fig. 10.12 A long curved sinus suction tube was inserted into the right frontal recess as shown by the *yellow arrow*. Right polypoidal middle turbinate, MT, and septum, S

of the sphenoid sinus inferiorly, the posterior part of the nasal septum medially, and the lamina papyracea laterally. Important neurovascular structures such as internal carotid artery and optic nerve should be kept in mind during the dissection, especially when Onodi cell is encountered. The optic nerve may lie freely within the Onodi cell; hence, extra precaution is needed.

10.5.1.6 Frontal Sinusotomy

The frontal sinus is usually addressed last due to its complex anatomy, and that bleeding from the frontal sinus work may drip down obscuring the surgical field when working more posteriorly. A 45° or 70° Hopkins telescope can be used for a better visualization during the dissection. The frontal recess can be identified by probing with a frontal seeker or sinus suction tube (Fig. 10.12).

The cells obstructing the frontal sinus outflow should be studied thoroughly preoperatively and removed carefully. A navigation system with a registered frontal probe will be helpful in this frontal sinus work. The obstructed cells can be removed using a curved curette, Stammberger upward-cutting forceps, or frontal giraffe forceps to widen the frontal recess. Endonasal frontal sinusotomy can be classified into Draf I–III (Table 10.2).

Table 10.2 Types of frontal sinusotomy according to Draf [24]

Type	Extent of surgery
I	Anterior ethmoidectomy with drainage of the frontal recess without touching the frontal sinus outflow tract
IIa	Removal of ethmoid cells protruding into the frontal sinus, creating an opening between the middle turbinate medially and lamina papyracea laterally
IIb	Removal of the floor of frontal sinus between the nasal septum medially and lamina papyracea laterally
III	Bilateral Draf type II drainage with removal of the superior part of nasal septum and lower part of intersinus septum

The Draf type I is achieved by clearing the anterior ethmoid cells without manipulation of frontal sinus outflow. The Draf IIa–b are usually performed in case of mucocoele or complication of acute rhinosinusitis. Endoscopic modified Lothrop procedure or Draf III is commonly reserved for revision cases or resection of anterior skull base tumours [24].

Endoscopic sinus surgery has come a long way since its maiden application in the late 1800s. It was first introduced as a procedure to be

applied to organs 'down-south' examining the urinary tract and the bladder. That was the first time the word *endoscope* was used. Nowadays, endoscopic sinus surgery (ESS) is almost synonymous with rhinology as more surgeons are adapting well with ESS in their practice. The technique in ESS is fine-tuned as time progresses, where surgeons learn and modify steps in ESS to improve the outcome. The number of otorhinolaryngology head and neck surgery (ORL-HNS) surgeons has increased as well as the number of ESS procedures. With that said, one must consider the learning curve of these surgeons in expecting the possibility of ESS complications.

Like all surgical procedures, the risk and possibility of complications will have to be addressed. Besides the importance of explaining before surgery the indications and the basic steps of the ESS to the patient, the risk and complications must also be explained in detail so that patients will understand and be aware of all the issues before the surgery. Equally important is that the surgeon himself/herself must understand the risk and complication thoroughly if not more than the patient must as well as how to avoid and solve if one encounters such complications. Complications in ESS can be categorized into minor and major complications, by location, procedure, and timing of the procedure, i.e. intraoperative vs. post-operative. Recognising and anticipating complications is as important as preventing and managing them. Below are the complications and suggestions on how to manage them.

10.6 Intraoperative Complication

Intraoperative complications during ESS can be further divided into intranasal, intraorbital, and intracranial.

10.6.1 Intranasal Complications

10.6.1.1 Haemorrhage from Mucosa

The nasal airway is a vascular area, with its main supply coming from two main arteries, which are the internal and the external carotid arteries (ICA and ECA). The ICA branches into the ophthalmic artery, which then supplies the anterior and the posterior ethmoid arteries. The branches of ECA, i.e. the facial and the internal maxillary arteries, supply the rest of the nasal airway.

Bleeding from the mucosal surface of the nasal airway while doing ESS is sometimes unavoidable but only to be considered cumbersome when it hinders the view in ESS. According to Rem et al. (2011), about 0.8% and 5% of the minor bleeding were perioperative and post-operative haemorrhages, respectively [25]. It can be localized or diffuse. The bleeding can be procedure, surgical, or patient related. It usually occurs in circumstances such as the following:

1. Multiple or inappropriate instruments used in ESS which when in contact with the surrounding structure will cause injury and bleeding.
2. Inflamed mucosa in active diseases such as chronic rhinosinusitis with or without nasal polyposis: Therefore, the pre- and intraoperative preparation is important to avoid diffuse mucosal bleeding [26, 27].

Statistics
1. Epistaxis requiring intervention is 0.6–1.6%, whereas major haemorrhage that requires transfusion is 0.76% [28, 29].
2. Endoscopic sinus surgery is affected by diffuse bleeding in about 5% of cases, and about 1.4% of the procedures are cancelled [27, 30].
3. Two percentage of bleeding complications occur during and post operation, and only 0.2% of cases need transfusion [31, 32].
4. Post-operative haemorrhage following endoscopic nasal sinus surgery occurs in 2.7% of patients [33].
Prevention
Preoperative measures
1. Preoperative systemic steroid (e.g. 30–60 mg/day prednisone for 7–14 days before surgery) can reduce bleeding, therefore reducing the duration of surgery.
2. Position the patient in a reverse Trendelenburg, i.e. lifting the head and the upper part of the patient's body for about 10–20° can be successful in reducing intraoperative bleeding [34, 35].

Prevention

Intraoperative measures

1. Appropriate instruments for each procedure, i.e. sharp through-cutting forceps for thin bony removal and sharp soft-tissue cutting (Blakesley forceps) to remove or mobilize polyps or tissue. Polyps or tissue should be cut not pulled when using the tissue-cutting forceps, to avoid excessive mucosal bleed [36].
2. When inserting a sharp instrument, it is advisable that the scope follows the instrument. The instrument should be in front of the scope so that you can see the instrument as it is manoeuvred through the nasal cavity. This way you avoid injury to the surrounding mucosa and thus unnecessary bleeding.
3. Study has shown that local injection of vasoconstrictors, i.e. epinephrine, has no significant benefit over topical vasoconstrictors [37]. However, Fokkens et al. reported that preoperative injections of local anaesthetic (1:80,000 adrenaline) and vasoconstrictor into the greater palatine canal effectively reduce intraoperative bleeding in ESS [34]. Topical vasoconstrictors suggested include the following:
   (a) 1:2000 adrenaline has been shown to have better haemostatic effect over much lower concentrations [34]. The risk of optic nerve damage and blindness after the application of local adrenaline has been reported in 0.05% [38].
   (b) Oxymetazoline 0.05% or epinephrine 1:2000 may be used for children [39].
4. EPOS 2020 concluded that there is a level I evidence that the usage of propofol in achieving hypotension improved surgical field, but it is less superior when compared to the usage of alpha-2-adrenergic agonists. Fokkens et al. show that total intravenous anaesthetic (TIVA) is more superior to inhalation anaesthetic (IA) in reducing blood loss, hence improving the surgical field [34]. The recommended pulse rate is 60 min^{-1} [40].
5. Using warm saline of up to 50 °C to irrigate the surgical area has significantly reduced blood loss and duration of surgery, therefore enhancing the visibility of the surgical site and improving the outcome of functional endoscopic sinus surgery and septorhinoplasty [41]. Irrigating with hot saline improves the view of the surgical field in FESS after 2 h of operating time [42]. Solares et al. showed that rinsing the surgical field with 40 °C water is also helpful [26].
6. The use of tranexamic acid: Kim et al. showed that the operative time and the intraoperative time were statistically lower in the tranexamic group, and it shows no significant effect on thrombotic events compared to placebo [43]. Similar findings by El Shah et al. were shown when intravenous tranexamic acid was given to the patient [44]. The suggested dosage is IV tranexamic acid 10 mg/kg diluted in 100 mL saline administered during 10-min infusion [44, 45].

10.6.1.2 Arterial Injury

The arteries that are commonly dreaded in ESS are the sphenoidal artery and its branches, the anterior ethmoidal artery, and finally the internal carotid artery.

10.6.1.2.1 Sphenopalatine Artery

The commonly injured artery would be the sphenoidal artery at its branches. It emerges from the sphenopalatine foramen, which is identified by elevating a mucoperiosteal flap and identifying the crista ethmoidalis, at the posterior aspect of the middle meatus within the superior meatus [46]. It branches into posterior septal branch (PS) supplying the anterior wall of the sphenoid sinus and the septum, and to the lateral wall via posterior lateral nasal branch (PLN) [47] (Figs. 10.13 and 10.14, Table 10.3).

Prevention

- Identify the bleeding source and secure it via cauterization and surgical clip. Rarely, extension is done laterally at the posterior wall of the maxillary sinus if the SPA is retracted laterally.

10.6.1.2.2 Anterior Ethmoidal Artery (AEA)

Besides causing significant bleeding during surgery, a complete transection of the AEA may result in retraction of the lateral stump end into the orbit causing orbital haematoma, which is a major complication.

The anterior ethmoidal artery (AEA) is supplied by the ophthalmic artery, which is the branch of the

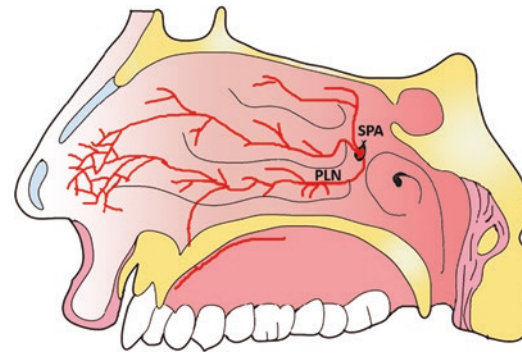

Fig. 10.13 Illustration showing the posterior lateral nasal wall and the branches of the sphenopalatine artery (SPA). *PLN* posterior lateral nasal branch

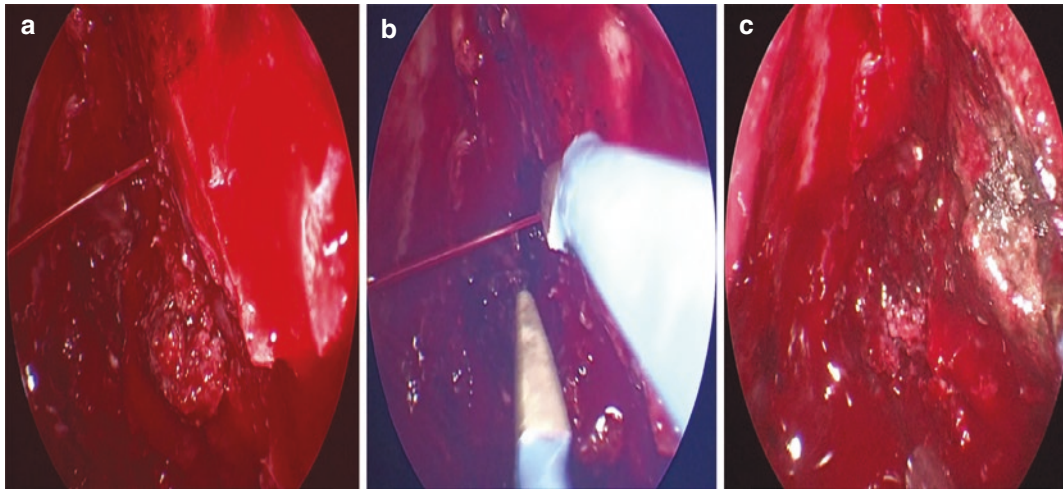

Fig. 10.14 Bipolar cauterization of a bleeding sphenoid artery (SPA). (**a**) Bleeding (sputter) from sphenoid artery. (**b**) Bipolar cauterization used to stop the SPA bleed. (**c**) Charred area post cauterization

Table 10.3 Procedures that may injure the SPA and its branches

Branches	Procedure
PLN	Bleeding due to aggressive debridement of the posterior Fontanelle during posterior extension of the medial maxillary antrostomy
PS	In transnasal sphenoidal approach, i.e. pituitary surgery. Widening of the sphenoid ostium inferiorly will cause bleeding from the PS branch of the SPA
Branches of SPA at the SPF	Several ostia may be present at the SPF 13% [48]. Bleeding may occur while locating the SPF due to the branches that emerge from extra ostia

internal carotid artery. From the orbit, it traverses medially through the lamina papyracea and enters the anterior ethmoid sinus. The artery may be identified endoscopically running along the skull base, i.e. the roof of the ethmoidal sinuses, just posterior to the anterior face of the bulla ethmoidalis. It then pierces through the lateral wall of the olfactory recess. In-between its lateral entrance and medial exit is the area of vulnerability for AEA.

Floreani et al., in their cadaveric studies, showed that 20% of AEA that runs in a bony mesentery was able to be clipped effectively [49]. Another important anatomy feature of AEA is that the blood flow through the anterior ethmoid artery comes from a posterolateral to an anteromedial direction, at 60° angle [35] (Fig. 10.15).

In the majority of cases, the AEA can be adequately cauterized using endoscopic bipolar instruments, thus avoiding transmitting the electrical current to the skull base and orbit.

Prevention
1. Preoperative imaging Identification of the position of the AEA through imaging is important to determine if AEA is 'hanging' in the ethmoid roof or within the bony mesentery. AEA can be best seen as a pinch or 'nipple' between the medial rectus and superior oblique muscles in the coronal view of the computed tomography (CT) scan (Fig. 10.16). 2. Instrument precaution Always have in view whatever you want to cut. Usage of powered instrument, i.e. microdebrider, must be with extra precaution. Once unsure, gentle usage of upturned tissue-cutting forceps is advisable.

10.6.1.2.3 Posterior Ethmoidal Artery (PEA)

The posterior ethmoidal artery is a branch of the ophthalmic artery and runs symmetrical, and it is much smaller than the AEA. The bone overlying it, in most cases, is approximately 60% dehiscence. PEA is most commonly injured during sphenoid sinus surgery or during posterior ethmoidectomy [40]. If bleeding occurs due to injury to the PEA, a bipolar cautery is a preferable measure to control the bleeding, thus avoiding transmitting of the electrical current to the

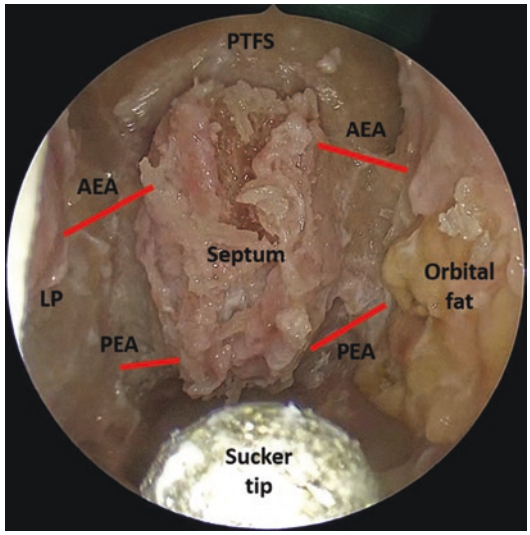

Fig. 10.15 Cadaveric dissection illustrating the anatomy of the anterior skull base following partial resection of both middle turbinates and nasal septum. The lateral margins are the lamina papyracea (LP). *AEA* anterior ethmoidal artery which runs from posterolateral to anteromedial, *PEA* posterior ethmoidal artery (*red line*)

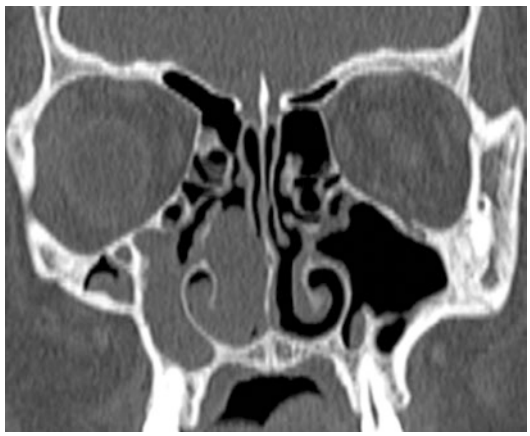

Fig. 10.16 Anterior ethmoidal artery exiting the orbit into the nasal cavity: 'nipple sign'

skull base and orbit when using a monopolar cautery.

10.6.1.2.4 Internal Carotid Artery (ICA)

The injury to the ICA is very rare, and the exact incidence of the injuries in ESS is unknown.

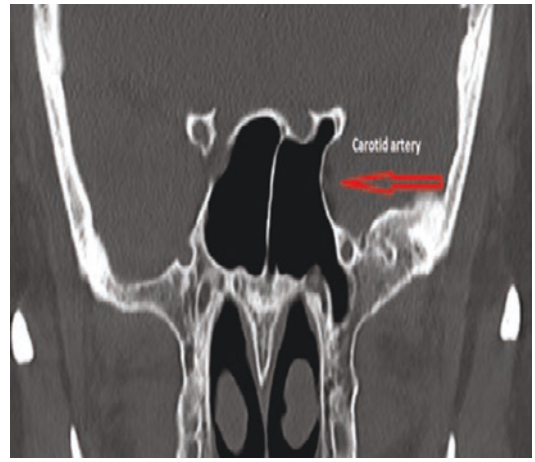

Fig. 10.17 CT scan coronal section showing the carotid artery relation to the lateral wall

Dalziel (2006) reported that 0.3% of ICA injuries occurred in ESS of diffuse CRS cases and 1% in pituitary surgery [32, 50]. Hosemann et al. showed that approximately 0.3–0.9% of ICA injuries occurred in sinoneurosurgical procedures with a mortality rate of 17% [40].

The ICA can be seen indented on the lateral wall of the sphenoid sinus and is reported to be dehiscent in 75% of cases. Welch et al. also reported that 1% of intersinus (sphenoid) septum is inserted at the bone overlying the ICA [51]. Therefore, it is of utmost importance, especially for the beginners, to take extra precautions when removing the intersinus septum so that it will not break at the lateral attachment. A through-cutting bone forceps may be used to remove the bone, and try not to twist or rotate the intersinus septum so that the bone segment will not pierce the ICA. Staying medially and inferiorly is the best option, so as to avoid going too laterally in the sphenoid sinus, thus increasing the risk of penetrating the ICA (Fig. 10.17).

Powered drills should be used with precautions, but if one is unsure do resort to using through-cutting forceps.

If one is unfortunate enough to have injured the ICA, a summary of recommended steps should be followed (Fig. 10.18).

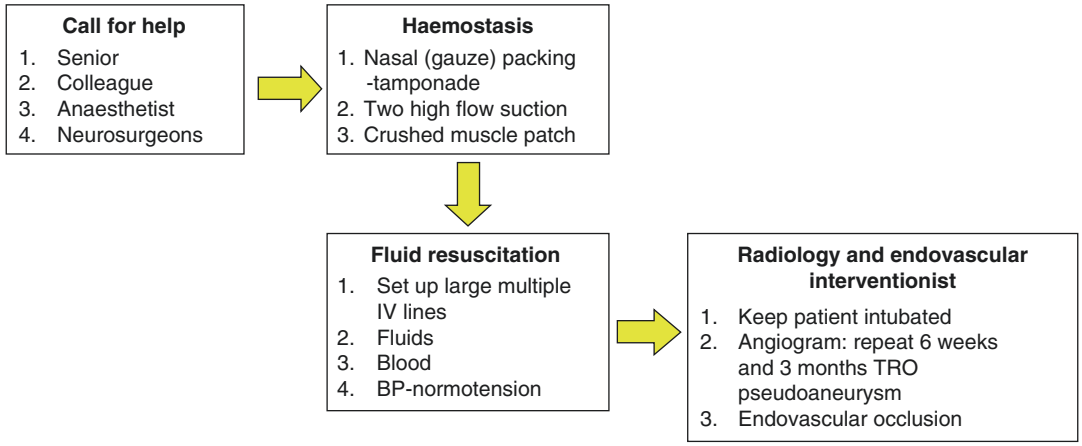

Fig. 10.18 Summary of management of ICA injury

The steps include the following:

Call for Help

Here, *too many cooks spoil the broth* does not apply. The presence of a senior surgeon or a second set of hands will help in overcoming the complication. The assistance from the anaesthetist is vital in resuscitating the patient by keeping the blood pressure under control, i.e. the systolic pressure, thus maintaining a sufficient cerebral blood flow from the contralateral ICA. Give a heads-up to the neurosurgeons and the interventional radiologist about the case, where the latter will assess the location and the extent of the vascular injury.

Secure the Bleeding

The surgeon needs to immediately halt the bleeding with nasal and pharyngeal packing, i.e. with gauze [52]. The idea here is not to panic; thigh packing in a calmly and orderly fashion will ensure that the gauze counts are correct and the location of packing is precise. Multiple IV lines should be established as well as several suctions should be prepared. Initiation of an aggressive fluid resuscitation and emergency blood transfusion should begin to help maintain cerebral perfusion.

Having said that, a tight packing may cause stenosis, partial occlusion or even complete occlusion of the affected ICA [53]. Examples of packing agents [54–56] that have been suggested and discussed in the literature include:

1. Teflon (Medox Medical, Oakland, NJ) and methyl methacrylate patch
2. Fibrin glue
3. Gelfoam (Pfizer, New York City, NY)
4. Oxidized cellulose packing thrombin-gelatin matrix
5. Oxygel
6. Glue and muslin gauze

In 2011, Valentine et al. compared the haemostatic and biocompatible haemostats' efficacy in an animal model of carotid bleeding using various absorbables such as oxidized cellulose, thrombin-gelatin matrix, and a crushed muscle patch and concluded that crushed muscle succeeded in gaining the optimum haemostasis regardless of the type of vascular injury, i.e. linear, stellate, or punch injuries. The long-term complications of crushed muscle patch also maintain the patency of the vessels with low risk of pseudoaneurysm [55].

Muscles that can be harvested are [52, 57–59]:

(a) Quadriceps muscle
(b) Sternocleidomastoid muscle
(c) Thigh muscle
(d) Temporalis muscle
(e) Nasopharyngeal muscle-longus capitis muscle

The suggested measurement for the muscle is about 1.5 by 1.5 cm. It should be crushed, usually between two metal kidney dishes [52]. Two surgeons with a four-hand technique would be preferable. While the second surgeon is diverting the bleeding using a high-flow sucker, the main surgeon with a much clearer surgical field and using some forceps, i.e. Blakesley, will gently place the crushed muscle directly on the bleeding site and maintain pressure on the patch for 5–10 min. Neurosurgical patties may be applied onto the muscle patch, while the Blakesley forceps can be slowly lessened. Once the bleeding subsides, the patties may be removed and replaced with a few squares of Surgicel (Ethicon Inc., Somerville, NJ, USA), which is placed over the patch [52]. A pedicle septal flap may also be used. The flap is rotated to cover the muscle patch. This is then glued into place and covered with Gelfoam and a pack, i.e. Merocel or ribbon gauze, which is placed over the flap to allow a continuous pressure to be applied to the flap and muscle patch. The pack is then removed under general anaesthesia 5–7 days later [52].

Interventional Radiologist/Endovascular

An angiogram is then performed to reconfirm the location and to ensure that the bleeding is secured. In a situation where the bleeding is not controlled, endovascular intervention is required, and the vessel can be either stented or coiled. The angiogram should be repeated at 6 weeks and 3 months to ensure that no pseudoaneurysm has formed [35].

10.6.1.3 Injury to Surrounding Structures

The mucosa of the nasal airway is very vascular. The vascularity is very important to humidify the respiratory air coming in and out. Injury to the nasal mucosa is usually due to the instruments introduced through the narrow space. Besides bleeding to the mucosa, the structure could be injured. The injuries can be divided according to the location. Below are the injuries according to the location and measures to prevent the injuries (Table 10.4).

10.6.2 Intraorbital Complications

Intraorbital complications in ESS are rare. The complications may occur due to the proximity of the paranasal sinuses to the orbit and its contents. The majority of orbital complications are minor ranging from 0.5% to 5%, mostly during maxillary antrostomy or ethmoidectomy [60, 61]. Only less than 0.3% causes permanent disabilities. Examples of factors that may contribute to the complications are disease extension, changes from previous endoscopic surgery, and coexisting medical comorbid and certain medications such as anticoagulant treatment.

Siedek et al. classified ophthalmic complications into [62]

1. **Grade I**: Minor, e.g. injury to the lamina papyracea
2. **Grade II**: Major, e.g. injury to the lacrimal duct
3. **Grade III**: Serious, e.g. retroorbital haemorrhage, injury to the optic nerve or any reduction of vision or blindness, and injury of orbital muscle

10.6.2.1 Breach of the Lamina Papyracea and Orbital Fat Injury (Grade I)

The lamina papyracea is usually breached through the medial orbital wall during ESS, i.e. during ethmoidectomy, maxillary antrostomy, or uncinectomy (anterograde more likely than retrograde uncinectomy) [63]. The recognition of this area and a cautious approach are pivotal in avoiding any permanent sequelae [38, 61, 64]. Therefore, it is routine to ask the assistants to palpate the globe while operating in the area, to see any movement [40]. Once you see orbital fat (confirm by floating test in water-filled gallipot), manipulation of the fat should be avoided to prevent further injury. Furthermore, powered instruments should be avoided as well as rigorous suctioning. Regular assessment of the eye during and post-surgery should be done to ensure no intraorbital haematoma. A nasal packing should be avoided in such cases; rather, a silicon sheet can be placed temporarily on the area of the

Table 10.4 Procedure, types of injuries, and preventive measures

Procedure	Location and injury	Prevention
Uncinectomy	1. Middle turbinate (MT) (a) Laceration (b) Fracture the attachment of the MT 2. Lacrimal duct injuries	1. Use appropriate instrument. Avoid multiple instruments. Gentle medialization of MT at the inferior and anterior edge of the MT, thus avoiding the risk of fracturing the MT at its superior attachment 2. In the anterograde uncinectomy, identify the maxillary line and locate the attachment of the uncinate to the lacrimal bone before dissecting it using a sharp sickle blade. In retrograde uncinectomy, only 1–2 bites using the back bitter or Kerrison punch to avoid injury to the lacrimal bone housing the lacrimal sac and duct
Medial maxillary antrostomy	1. Middle turbinate (MT) (a) Laceration (b) Mucosa	1. Use appropriate instrument. Avoid multiple instruments at the same time. Good visualization. Avoid stripping the mucosa. Remove the intended mucosa with sharp cutting instruments
Anterior ethmoidectomy	1. Middle turbinate (MT) (a) Laceration (b) Medialized MT, i.e. flappy MT 2. Lamina papyracea 3. Anterior and posterior ethmoidal arteries 4. Skull base	1. Use appropriate instrument. Avoid multiple instruments at the same time. Good visualization. Gentle medialization of MT at the inferior and anterior edges of the MT, thus avoiding the risk of fracturing the MT at its superior attachment 2. Identify the lateral boundaries of the anterior ethmoidal sinus air cells, which is the lamina papyracea. For the beginners, avoid using the powered instruments; rather use a sharp bone-cutting forceps to remove the ethmoidal sinus bones from the lamina papyracea 3. The anatomical location is paramount in order to avoid injuries to these structures. Once the area is located, use upturned bone-cutting forces to remove the remaining bony partition 4. Always remember that the skull base has a sloping descent posteriorly from the roof of the ethmoidal air cells to the sphenoidal sinus roof. The fixed landmark that can be used is the roof of the maxillary where an imaginary line is drawn horizontally to the septum. Ethmoidal air cells below this line can be safely removed until the roof of the sphenoid is identified
Posterior ethmoidectomy	1. Middle turbinate (MT) (a) Laceration (b) Medialized MT, i.e. flappy MT 2. Lamina papyracea 3. Posterior ethmoidal artery	Similar to the precautions during anterior ethmoidectomy, the possibility of complications is the same
Sphenoidectomy	1. Superior turbinate 2. Lateral wall and its adjacent structures in the sphenoid lateral and posterior walls 3. Skull base	1. In locating the sphenoid ostium, the superior turbinate might be injured. ST is used to locate the sphenoid ostium, which is medial to its posterior end 2. Indented on the lateral wall of the sphenoid are important structures such as optic nerve and ICA. Anatomical knowledge is paramount to avoid injuries to these structures. Study the CT scan before surgery
Frontal sinusotomy	1. Axilla of the MT 2. Superior attachment of uncinate and the anterior part of the MT 3. Frontal recess 4. AEA 5. Olfactory fibres	1. The landmark to identify the frontal recess is the axilla of the MT. in these procedures, sometimes it is inevitable that the axilla is injured; therefore, one of the fixed landmarks in ESS will be missing for future reference. Therefore, careful with probing and only dissect whenever necessary, i.e. Draf IIb 2. Overzealous and aggressive manipulation of the region can also cause injuries to the superior attachment of the anterior part of the MT and uncinate process. 10% of the attachment is to the skull base, and these will have a higher risk of CSF leak. Study the CT scan and avoid twisting and rotating the attachments when removing it 3. At the frontal recess, avoid circumferential stripping of the mucosa so as to avoid stenosis at the recess 4. Be aware of the AEA proximity, which is usually located just posterior to the frontal recess 5. In Draf III or modified Lothrop, the posterior limit is the first olfactory fibres. These fibres may be injured

defect if needed. Usually, no repair of the defect is necessary [35].

10.6.2.2 Orbital Emphysema (Grade I)

Orbital emphysema, i.e. periorbital and subcutaneous emphysema post ESS, is rare. Postoperative orbital emphysema may occur following excessive nose blowing or sneezing [65]. The most common site of emphysema would be the upper eyelid. The management is usually conservative, and it will subside within a week, but, although very rare, it may require urgent intervention because of the risk of increased intraocular pressure, impaired blood supply to the globe, and even blindness [61, 66].

10.6.2.3 Intraorbital Haematoma (Grade I)

The incidence of intraorbital haematoma is rare at around 0.1% [63, 67]. The normal intraocular pressure is 12–22 mmHg, and the average orbital volume is 26 cc. A 4.0 cc increase in volume will result in 6 mm proptosis [51]. Retrobulbar haematoma with accompanying loss of vision has 50% risk of permanent blindness [52]. Intraorbital haematoma occurs from injury to the anterior or posterior ethmoid arteries, which retract laterally, therefore causing an acute increase in the intraorbital pressure resulting in retinal ischemia; however, injury to orbital or ophthalmic veins results in a slower process of accumulation of blood. The window of opportunity to intervene is about 90 min, where the retina can tolerate the ischemia before irreversible damage happens (Table 10.5) [68]. The treatment approach is determined by the severity and is outlined in Fig. 10.19.

Table 10.5 Signs and symptoms of intraorbital haemorrhage [69]

1. Tense globe
2. Increased intraocular pressure
3. Progressive proptosis with chemosis
4. Conjunctival vessel congestion and subconjunctival haemorrhage
5. Pupillary dilation
6. Loss of pupillary reflex
7. Eye pain
8. Limitation of eye mobility
9. Visual field loss and loss of vision

Note

- Lateral canthotomy and cantholysis will reduce intraorbital pressure (IOP) by approximately 14 mmHg and 30 mmHg, respectively. These procedures are indicated when [51]
  1. The intraocular pressure is more than 40 mmHg
  2. There is loss of pupillary reflex
  3. There is cherry red macula
- Endoscopic medial orbital wall decompression will reduce IOP by approximately 10 mmHg. The bleeding can also be controlled through endoscopic or external artery ligation

10.6.2.4 Injury to the Lacrimal Duct (Grade II)

Injury to the nasolacrimal duct can occur during uncinectomy or enlarging the maxillary ostium, i.e. when the back-biting forceps is used too far anteriorly. Symptoms include epiphora and dacryocystitis.

10.6.2.5 Extraocular Muscle Injury (Grade III)

The medial rectus muscle is the most susceptible muscle to injury during endoscopic sinus surgery due to its proximity to the lamina papyracea. The injury may occur during posterior ethmoidectomy. Injury to the medial rectus muscle will cause diplopia and exotropia [72]. Huang et al. reported that the incidence of extraocular muscle injury is rare accounting for about 0.00014% [38]. Other eye muscles are less often injured, i.e. inferior rectus muscle (maxillary sinus surgery) [73]. The use of microdebriders in ESS is the main culprit for injury to the extraocular muscle [63]. Besides muscle transection, several other types of injury have been described, including muscle entrapment, contusion or haematoma, and oculomotor nerve branch injury [38]. Symptoms may vary across exotropia, ocular adduction deficits, and abduction deficit, which only occur during muscle entrapment [69]. Management will have to offer a prompt referral to the ophthalmology team, and the surgical option is strabismus surgery. A primary surgical reanastomosis, interposition grafting, or use of adjustable sutures may be attempted depending on the amount of tissue loss. The surgical option is not always successful in restoring the full range

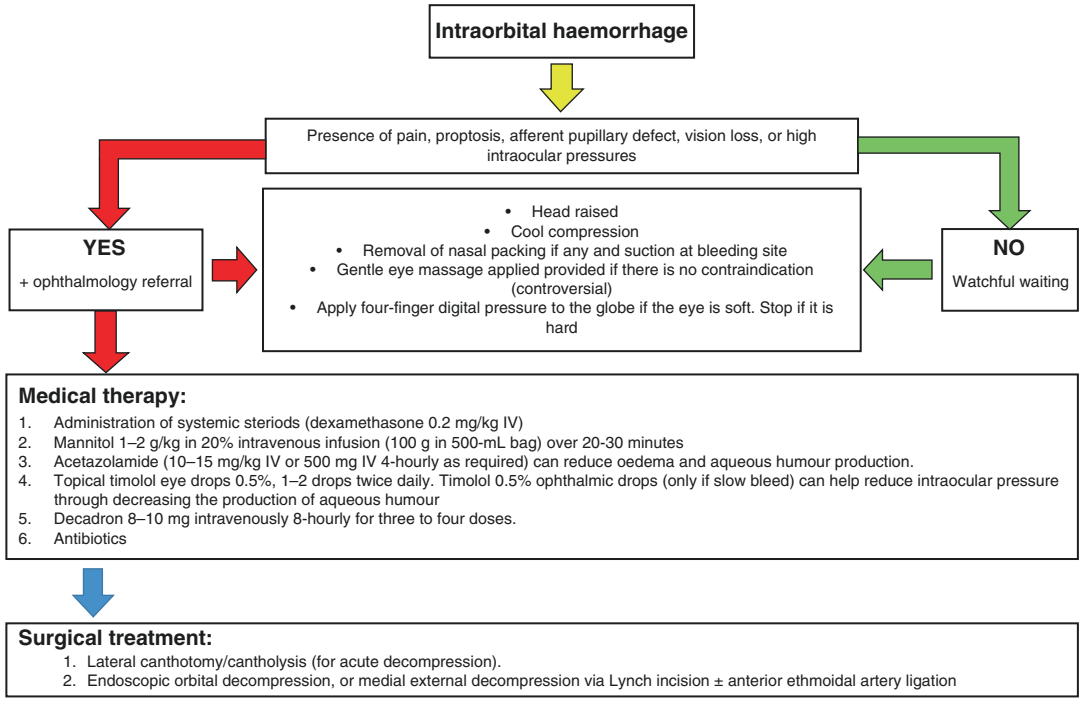

Fig. 10.19 Outline of the management of intraorbital haemorrhage [35, 69]

of motion of the globe and should be performed within 2–3 weeks from injury, i.e. after the resolution of the oedema. Hong et al. advocated the administration of systemic corticosteroid and the use of Botox injection in the ipsilateral lateral rectus muscle as a useful adjunct in the first few weeks after repair to reduce tension across the anastomosis site [74].

10.6.2.6 Optic Nerve Injury (Grade III)

The injury to the optic nerve is very rare and may occur in sphenoid surgery since its location usually can be identified as an indentation in the superolateral sphenoid sinus wall. About 5% of the optic nerve can be dehiscence [35]. The presence of Onodi cells, which are present in about 8–14% of the general population, may also increase the risk of optic nerve injury [75]. Ali et al. found a prevalence of 42.8% of Onodi cells, which is higher than the prevalence found in a recently reported study [76, 77]. The high percentage of Onodi cells may be contributed by the usage of the cone beam computed tomography (CBCT) scan, which is more precise in the recognition of bony structures of the paranasal sinus [76]. Optic nerve injury might cause a partial loss of vision or blindness. The initial step when an injury to the optic nerve is suspected is to normalize the blood pressure, refer to the ophthalmology team, and immediately start a high-dose systemic corticosteroid (dexamethasone 0.5–1 mg/kg body weight IV). By using the CT scan to evaluate the location and extent of this injury, optic nerve decompression may be considered [35].

10.6.3 Intracranial Complications

Intracranial complication due to ESS is a dreadful complication but fortunately is a very rare complication, which is about 0.47–0.54% [78]. Common among the complications is cerebral spinal fluid (CSF) leak. Other complications include direct intracranial injury evidenced by pneumocephalus—the presence of gas (air) in the cranial cavity and obviously damage to cerebral vasculature or to the brain itself. For intracranial complication, the immediate sign includes intracranial haemorrhage, but the majority of signs

and symptoms occur post-operatively, i.e. persistent headache, neurologic deficit, intracranial infection, and meningoencephalocele [69]. All intracranial complications must be referred to and managed with the neurosurgery team.

10.6.3.1 CSF Leak

Once a persistent watery rhinorrhoea, which is usually unilateral post-endoscopic sinus surgery, is seen and documented, CSF leak should be ruled out. The incidence of iatrogenic endoscopic sinus surgery injury to the skull base resulting in CSF leak is 0.5% [34]. The most liable regions to injury which are the weakest (0.05–1 mm thin) areas of the skull base are:

1. At the junction of the anterior ethmoid artery and the middle turbinate along the anterior ethmoid roof
2. At the lateral lamella of the olfactory fossa which is susceptible for injury [79]

The best management of CSF leak due to ESS is immediate repair, which has a 90% good outcome according to Banks et al. (2009) [80]. Intraoperative localization can be facilitated by intrathecal instillation of fluorescein, which will colour the CSF fluorescent green. Studies have suggested that a low dose of intraoperative or post-operative intrathecal fluorescein administration is a safe and sensitive method for localization of CSF leakage sites. The protocol in our centre is to withdraw 10 mL of CSF from the lumbar puncture and add 0.1 mL of filtered 10% fluorescein, creating a 0.1% final concentration that is slowly infused intrathecally 30–60 min before the procedure [69]. Nevertheless, appropriate informed consent must be obtained before using fluorescein due to the fact that studies have showed that intrathecal administration of fluorescein has been associated with some severe side effects including seizures, flash pulmonary oedema, headache, and distal lower extremity numbness [80, 81].

A CSF leak may be detected after surgery if the patient complains of a clear, watery, salty-tasting nasal discharge. Known tests that can be performed at the bedside include: positive glucose in the fluid, halo sign, handkerchief sign and reservoir sign, i.e. an exacerbation of CSF rhinorhea when bending over or using the Valsalva monuver. However, the gold standard test would be the biochemical confirmation via a β2-transferrin assay [69]. The integrity of the skull base, location of the bony defect, and any sign of other intracranial injury and complication, i.e. pneumocephalus, should be assessed via a CT scan. The area of importance as described above, which is the area most common to sustained injury, should be examined thoroughly as well as the assessment of the skull base should be done via the Keros classification (Fig. 10.4). Some surgeons also describe the asymmetry of the skull base as Keros type IV, which occurs in approximately 10% of the population [40]. Management of CSF leak has a 90% greater outcome if it is identified during surgery and managed at the same setting [80, 82]. If the leak was detected after surgery, prophylactic antibiotics can be started. The patient has a more than 90% success if the repair was done via transnasal endoscopic approach [82, 83]. Techniques of repair are shown in Fig. 10.20.

Generally, the patient will have nasal packing to secure the flaps for at least 3–7 days. The patient is also advised for bed rest with the head-end elevation (40–70°) when sleeping, prescribed antibiotics as a prophylaxis, and asked to avoid strenuous activity and sneezing with an open mouth. Laxatives may be prescribed for patients with constipation. Large defect repair and revision cases with increased intracranial pressure almost always require lumbar drains.

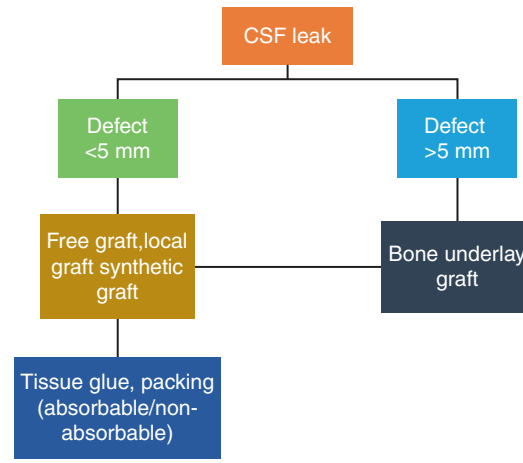

Fig. 10.20 Flow chart of CSF leak repair depending on the size of the defect [84]

10.6.4 Post-operative Complication

10.6.4.1 Epistaxis

Epistaxis can occur due to inadequate haemostasis or about a week post operation when the crust starts to peel or dislodge. It may also occur during the first visit after surgery when the surgeons are inspecting the nasal cavity and removing the dry crust. If the bleeding occurs at home, the basic compression can be applied with the patient in the Trotter's position while applying cold pack over the forehead or soaking the head with cold water or towel. The bleeding should subside within 10–15 min. If the bleeding persists, then it should be managed at the nearest clinic with proper nasal packing. Ideally, an examination with nasoendoscopy should be done to locate the bleeding site. A simple but effective method to prevent post-op epistaxis is not to pack the nose if, at the end of the ESS, excessive bleeding is absent.

10.6.4.2 Nasal Synechia

Synechia is a very common complication in ESS occurring in about 10% of cases, but more than half of the cases do not impair the nasal function [32]. The synechia usually occurs between the injured mucosa between the lateral wall and the septum and also in between the medial side of the middle turbinate and the lateral wall (Fig. 10.21). It can also occur due to infections post ESS. Henriquez et al. found that more synechia occurs in revision cases, and although both groups improve, the degree of QoL improvement appears to be less in those who form post-operative synechia after surgery compared to those who do not [85].

Basic measures that can prevent and reduce the risk of synechia include the following:

1. Nasal packing to be removed within 48 h (for the non-absorbable packing).
2. Silastic sheet: A temporary soft, thin silicone sheet placed between raw mucosa and held in place by suture of nasal packing. Preferably, the sheet is lubricated with topical antibiotics cream, i.e. chloramphenicol 1% ointment.

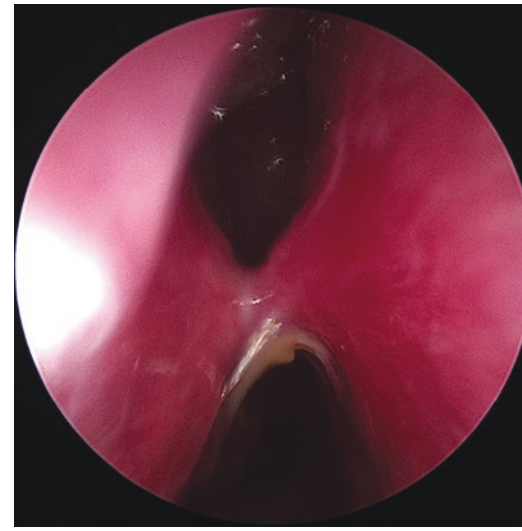

Fig. 10.21 Synechia between the middle turbinate and septum

3. Nasal irrigation with saline 24–48 h post operation. A gentle douching is advised for the first few douching.
4. Removing crusting 5–7 days post operation. Mechanically cleaning the nasal cavity of crust will reduce the risk of infection that may lead to synechia.
5. Prophylactic antibiotics.
6. Nasal decongestant and nasal steroid sprays.

In cases of a floppy middle turbinate occurring when the vertical part of the middle turbinate is detached from the second part of the middle turbinate (basal lamella), the medial surface of the middle turbinate is scored as well as the septal area opposite to it induced adhesion medializing the middle turbinate. Lateralized floppy middle turbinate will sometimes obstruct the drainage area of the ostiomeatal complex (OMC). It is also known as Bolgerization or middle turbinate medialization. Other methods of middle turbinate medialization include application of fibrin glue to the medial surface of the middle turbinate and suturing the middle turbinate to the nasal septum.

10.6.4.3 Other Complications

These are the complications that may occur post ESS (Table 10.6).

Table 10.6 Other complications of ESS

No.	Complications	Description and management
1.	Infection	1. Post-op ESS infection may present as sinusitis, which is usually due to the injury to the nasal mucosa, therefore exposing it to bacterial infection especially within 24–48 h of surgery (Fig. 10.22). At this critical time, the mucociliary clearance of nasal secretions is affected, thus making it prone to infection. Management: Prophylactic antibiotics in ESS cases as well as early nasal irrigation and nasal toileting to remove crust. 2. Atrophic rhinitis occurring post ESS especially in revision cases where there is a significant amount of mucosa removed, including the turbinates, i.e. inferior and middle turbinates. Iatrogenic atrophic rhinitis is categorized as secondary atrophic rhinitis and the symptoms including merciful ozaena and paradoxical nasal obstruction where the foul smell is not detected by the patient and the nasal blockage complaint although the nasal cavity is roomy, respectively. The reported incidence of atrophic rhinitis is less than 1% [40]. Management: Mucosal sparing procedures and avoid removing the turbinates as well as prophylactic antibiotics, nasal irrigation, and nasal toileting. 3. Meningitis has been reported to occur between 1% and 3% as reported by Ranson et al., post rhino-neurosurgical procedures and CSF leak should be ruled out [70]. The practice of giving prophylactic antibiotics has not reduced the risk of meningitis in skull base surgery. Whether it is congenital or post-traumatic, direct extension via osteomyelitis of the sinus walls or bony defects is uncommon [71].
2.	Smell disturbances	Hyposmia occurs post ESS due to inflammation and nasal congestions. Occurring about 24–48 h post-op, patient should be warned about this and nasal irrigation with nasal decongestion will help to reduce the symptoms. Some patients will experience anosmia. The smell disturbances should progressively improve within 2–6 weeks.

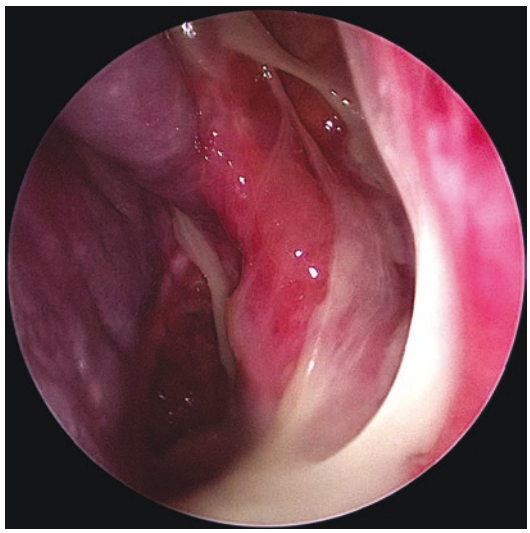

Fig. 10.22 Sinusitis post endoscopic sinus surgery

References

1. Tajudeen BA, Kennedy DW. Thirty years of endoscopic sinus surgery: what have we learned. World J Otorhinolaryngol Head Neck Surg. 2017;3(2):115–21.
2. Gendeh BS. Extended applications of endoscopic sinus surgery and its reference to cranial base and pituitary fossa. Indian J Otolaryngol Head Neck Surg. 2010;62(3):264–76.
3. Watkinson JC, Clarke RW, editors. Scott-Brown's otorhinolaryngology and head and neck surgery: anatomy of the nose and paranasal sinuses, vol. 1. London: CRC Press; 2018.
4. Bailey BJ, Johnson JT, Newlands SD, editors. Head & neck surgery—otolaryngology: sinonasal anatomy, function and evaluation, vol. 1. Philadelphia, PA: Lippincott Williams & Wilkins; 2006.
5. Wormald PJ, Hoseman W, Callejas C, Weber RK, Kennedy DW, Citardi MJ, et al. The international frontal sinus anatomy classification (IFAC) and classification of the extent of endoscopic frontal sinus surgery (EFSS). Int Forum Allergy Rhinol. 2016;6(7):677–96.
6. Gupta T, Aggarwal A, Sahni D. Anatomical landmarks for locating the sphenoid ostium during endoscopic endonasal approach: a cadaveric study. Surg Radiol Anat. 2013;35(2):137–42.
7. Lee JM, Woods T, Grewal A. Preoperative evaluation of the maxillary sinus roof as a guide for posterior ethmoid and sphenoid sinus surgery. J Otolaryngol Head Neck Surg. 2012;41(5):361.
8. Homsi MT, Gaffey MM. Sinus endoscopic surgery. In: StatPearls; 22 Sept 2020. https://www.ncbi.nlm.nih.gov/books/NBK563202/.
9. Teitelbaum JI, Grasse C, Quan D, et al. General complications after endoscopic sinus surgery in smokers: a 2005-2016 NSQIP analysis. Ann Otol Rhinol Laryngol. 2021;130(4):350–5. https://doi.org/10.1177/0003489420952481.
10. Patel PN, Jayawardena ADL, Walden RL, Penn EB, Francis DO. Evidence-based use of perioperative antibiotics in otolaryngology. Otolaryngol Head Neck Surg. 2018;158(5):783–800. https://doi.org/10.1177/0194599817753610.

11. Pundir V, Pundir J, Lancaster G, Baer S, Kirkland P, Cornet M, Lourijsen ES, Georgalas C, Fokkens WJ. Role of corticosteroids in functional endoscopic sinus surgery—a systematic review and meta-analysis. Rhinology. 2016;54(1):3–19. https://doi.org/10.4193/Rhino15.079.
12. Carlton DA, Chiu AG. Do preoperative corticosteroids benefit patients with chronic rhinosinusitis with nasal polyposis. Laryngoscope. 2019;129(4):773–4. https://doi.org/10.1002/lary.27411.
13. Harvey RJ, Snidvongs K, Kalish LH, Oakley GM, Sacks R. Corticosteroid nasal irrigations are more effective than simple sprays in a randomized double-blinded placebo-controlled trial for chronic rhinosinusitis after sinus surgery. Int Forum Allergy Rhinol. 2018;8(4):461–70. https://doi.org/10.1002/alr.22093.
14. Valdes CJ, Bogado M, Rammal A, Samaha M, Tewfik MA. Topical cocaine vs adrenaline in endoscopic sinus surgery: a blinded randomized controlled study. Int Forum Allergy Rhinol. 2014;4(8):646–50. https://doi.org/10.1002/alr.21325.
15. Moffett A. Postural instillation: a method of inducing local anaesthesia in the nose. J Laryngol Otol. 1941;56(12):429–36. https://doi.org/10.1017/S0022215100006782.
16. Benjamin E, Wong DK, Choa D. Moffett's' solution: a review of the evidence and scientific basis for the topical preparation of the nose. Clin Otolaryngol Allied Sci. 2004;29(6):582–7. https://doi.org/10.1111/j.1365-2273.2004.00894.x.
17. Wormald PJ, van Renen G, Perks J, Jones JA, Langton-Hewer CD. The effect of the total intravenous anesthesia compared with inhalational anesthesia on the surgical field during endoscopic sinus surgery. Am J Rhinol. 2005;19(5):514–20.
18. Lu VM, Phan K, Oh LJ. Total intravenous versus inhalational anesthesia in endoscopic sinus surgery: a meta-analysis. Laryngoscope. 2020;130(3):575–83. https://doi.org/10.1002/lary.28046.
19. Yuki K, DiNardo JA, Koutsogiannaki S. The role of anesthetic selection in perioperative bleeding. Biomed Res Int. 2021:5510634. https://doi.org/10.1155/2021/5510634.
20. Ko MT, Chuang KC, Su CY. Multiple analyses of factors related to intraoperative blood loss and the role of reverse Trendelenburg position in endoscopic sinus surgery. Laryngoscope. 2008;118(9):1687–91. https://doi.org/10.1097/MLG.0b013e31817c6b7c.
21. Hathorn IF, Habib AR, Manji J, Javer AR. Comparing the reverse Trendelenburg and horizontal position for endoscopic sinus surgery: a randomized controlled trial. Otolaryngol Head Neck Surg. 2013;148(2):308–13. https://doi.org/10.1177/0194599812466529.
22. Ramakrishnan VR, Orlandi RR, Citardi MJ, Smith TL, Fried MP, Kingdom TT. The use of image-guided surgery in endoscopic sinus surgery: an evidence-based review with recommendations. Int Forum Allergy Rhinol. 2013;3(3):236–41. https://doi.org/10.1002/alr.21094.
23. Beswick DM, Ramakrishnan VR. The utility of image guidance in endoscopic sinus surgery: a narrative review. JAMA Otolaryngol Head Neck Surg. 2020;146(3):286–90. https://doi.org/10.1001/jamaoto.2019.4161.
24. Kountakis SE, Senior BA, Draf W, editors. The frontal sinus, vol. 14. Berlin: Springer; 2005. p. 294.
25. Re M, Massegur H, Magliulo G, et al. Traditional endonasal and microscopic sinus surgery complications versus endoscopic sinus surgery complications: a meta-analysis. Eur Arch Otorhinolaryngol. 2012;269(3):721–9.
26. Solares CA, Ong YK, Carrau RL, et al. Prevention and management of vascular injuries in endoscopic surgery of the sinonasal tract and skull base. Otolaryngol Clin N Am. 2010;43(4):817–25.
27. Nguyen QA, Cua DJ, Ng M, Rice DH. Safety of endoscopic sinus surgery in a residency training program. Ear Nose Throat J. 1999;78(12):898–902, 904.
28. Dalgorf DM, Sacks R, Wormald PJ, et al. Image-guided surgery influences perioperative morbidity from endoscopic sinus surgery: a systematic review and meta-analysis. Otolaryngol Head Neck Surg. 2013;149(1):17–29.
29. Castillo L, Verschuur HP, Poissonnet G, Vaille G, Santini J. Complications of endoscopically guided sinus surgery. Rhinology. 1996;34(4):215–8.
30. Aletsee C, Deglmann M, Dieler R. Chirurgische Eingriffe an den Nasennebenhöhlen bei Sinusitiden und benignen Tumoren. Indikationen, Konzepte und Komplikationen einer Weiterbildungseinrichtung [Paranasal sinus surgery in chronic sinus disease and benign tumors indications, concepts and complications at a teaching institution]. Laryngorhinootologie. 2003;82(7):508–13. https://doi.org/10.1055/s-2003-40898.
31. Vleming M, Middelweerd RJ, de Vries N. Complications of endoscopic sinus surgery. Arch Otolaryngol Head Neck Surg. 1992;118:617–23.
32. Dalziel K, Stein K, Round A, Garside R, Royle P. Endoscopic sinus surgery for the excision of nasal polyps: a systematic review of safety and effectiveness. Am J Rhinol. 2006;20(5):506–19. https://doi.org/10.2500/ajr.2006.20.2923.
33. Akita K, Hayama M, Tsuda T, et al. Factors impacting postoperative haemorrhage after transnasal endoscopic surgery. Rhinol Online. 2020;3(3):141–7. https://doi.org/10.4193/rhinol/20.059.
34. Fokkens WJ, Lund VJ, Hopkins C, et al. European position paper on rhinosinusitis and nasal polyps 2020. Rhinology. 2020;58(Suppl S29):1–464. Published 20 Feb 2020. https://doi.org/10.4193/Rhin20.600.
35. Shanmugam G, Emad AD, Hamad AS, Mansour AS, Maryam A, Rafia Z, Ahmed S. Chapter 27: Complications of functional endoscopic sinus surgery. In: Al-Qahtani A, et al., editors. Textbook of clinical otolaryngology. Cham: Springer; 2021. p. 299–316.
36. Minovi A, Brors D. Instrumentation for endonasal sinus surgery. From basic to advanced. In: Stucker F, de Souza C, Kenyon G, Lian T, Draf W, Schick B,

editors. Rhinology and facial plastic surgery. Berlin: Springer; 2009.
37. Alsaleh S, Manji J, Javer A. Optimization of the surgical field in endoscopic sinus surgery: an evidence-based approach. Curr Allergy Asthma Rep. 2019;19(1):8. Published 2 Feb 2019. https://doi.org/10.1007/s11882-019-0847-5.
38. Huang TW, Liu CM, Cheng PW, Yang CH. Posterior ischemic optic neuropathy following endoscopic sinus surgery. Otolaryngol Head Neck Surg. 2003;129:448–50.
39. Higgins TS, Hwang PH, Kingdom TT, Orlandi RR, Stammberger H, Han JK. Systematic review of topical vasoconstrictors in endoscopic sinus surgery. Laryngoscope. 2011;121:422–32.
40. Hosemann W, Draf C. Danger points, complications and medico-legal aspects in endoscopic sinus surgery. GMS Curr Top Otorhinolaryngol Head Neck Surg. 2013;12:Doc06.
41. Amjad AI, Hazem AK, Awni M, Nabiha KK. Effect of warm saline on bleeding during sinus and septum surgery. J Royal Med Serv. 2016;23(1):17–21.
42. Gan EC, Alsaleh S, Manji J, Habib AR, Amanian A, Javer AR. Hemostatic effect of hot saline irrigation during functional endoscopic sinus surgery: a randomized controlled trial. Int Forum Allergy Rhinol. 2014;4(11):877–84. https://doi.org/10.1002/alr.21376.
43. Kim DH, Kim S, Kang H, Jin HJ, Hwang SH. Efficacy of tranexamic acid on operative bleeding in endoscopic sinus surgery: a meta-analysis and systematic review. Laryngoscope. 2019;129:800–7.
44. El Shal SM, Hasanein R. Effect of intravenous tranexamic acid and epsilon aminocaproic acid on bleeding and surgical field quality during functional endoscopic sinus surgery (FESS). Egypt J Anaesth. 2015;31:1–7.
45. Tamil AP, Kodali VRK, Ranjith BK. Comparative study of two different intravenous doses of tranexamic acid with placebo on surgical field quality in functional endoscopic sinus surgery—a randomised clinical trial. J Clin Diagn Res. 2019;13(12):UC05–9.
46. Maxwell AK, Barham HP, Getz AE, Kingdom TT, Ramakrishnan VR. Landmarks for rapid localization of the sphenopalatine foramen: a radiographic morphometric analysis. Allergy Rhinol (Providence). 2017;8(2):63–6. https://doi.org/10.2500/ar.2017.8.0196.
47. Simmen DB, Raghavan U, Briner HR, Manestar M, Groscurth P, Jones N. The anatomy of the sphenopalatine artery for the endoscopic sinus surgeon. Am J Rhinol. 2006;20:502–5.
48. Midilli R, Orhan M, Saylam CY, Akyildiz S, Gode S, Karci B. Anatomic variations of sphenopalatine artery and minimally invasive surgical cauterization procedure. Am J Rhinol Allergy. 2009;23(6):e38–41.
49. Floreani SR, Nair SB, Switajewski MC, Wormald PJ. Endoscopic anterior ethmoidal artery ligation: a cadaver study. Laryngoscope. 2006;116(7):1263–7.
50. Gondim JA, Almeida JP, Albuquerque LA, Schops M, Gomes E, Ferraz T, Sobreira W, Kretzmann MT. Endoscopic endonasal approach for pituitary adenoma: surgical complications in 301 patients. Pituitary. 2011;14(2):174–83.
51. Welch KC, Palmer JN. Intraoperative emergencies during endoscopic sinus surgery: CSF leak and orbital hematoma. Otolaryngol Clin N Am. 2008;41(3):581–96.
52. Padhye V, Valentine R, Wormald PJ. Management of carotid artery injury in endonasal surgery. Int Arch Otorhinolaryngol. 2014;18(Suppl 2):S173–8. https://doi.org/10.1055/s-0034-1395266.
53. Raymond J, Hardy J, Czepko R, Roy D. Arterial injuries in trans-sphenoidal surgery for pituitary adenoma; the role of angiography and endovascular treatment. AJNR Am J Neuroradiol. 1997;18(4):655–65.
54. Padhye V, Valentine R, Paramasivan S, et al. Early and late complications of endoscopic hemostatic techniques following different carotid artery injury characteristics. Int Forum Allergy Rhinol. 2014;4(8):651–7.
55. Valentine R, Boase S, Jervis-Bardy J, Dones Cabral JD, Robinson S, Wormald PJ. The efficacy of hemostatic techniques in the sheep model of carotid artery injury. Int Forum Allergy Rhinol. 2011;1(2):118–22.
56. Inamasu J, Guiot BH. Iatrogenic carotid artery injury in neurosurgery. Neurosurg Rev. 2005;28(4):239–48.
57. Weidenbecher M, Huk WJ, Iro H. Internal carotid artery injury during functional endoscopic sinus surgery and its management. Eur Arch Otorhinolaryngol. 2005;262(8):640–5.
58. Duek I, Sviri GE, Amit M, Gil Z. Endoscopic endonasal repair of internal carotid artery injury during endoscopic endonasal surgery. J Neurol Surg Rep. 2017;78(4):e125–8.
59. Wang W, Lieber S, Lan M, Wang EW, Fernandez-Miranda JC, Snyderman CH, Gardner PA. Nasopharyngeal muscle patch for the management of internal carotid artery injury in endoscopic endonasal surgery. J Neurosurg (JNS). 2020;133(5):1382–7. Retrieved 30 Apr 2021.
60. Seredyka-Burduk M, Burduk PK, Wierzchowska M, Kaluzny B, Malukiewicz G. Ophthalmic complications of endoscopic sinus surgery. Braz J Otorhinolaryngol. 2017;83(3):318–23.
61. Han JK, Higgins TS. Management of orbital complications in endoscopic sinus surgery. Curr Opin Otolaryngol Head Neck Surg. 2010;18(1):32–6.
62. Siedek V, Pilzweger E, Betz C, Berghaus A, Leunig A. Complications in endonasal sinus surgery: a 5-year retrospective study of 2,596 patients. Eur Arch Otorhinolaryngol. 2013;270(1):141–8.
63. Bhatti MT, Stankiewicz JA. Ophthalmic complications of endoscopic sinus surgery. Surv Ophthalmol. 2003;48:389–402.
64. Rene C, Rose GE, Lenthall R, Moseley I. Major orbital complications of endoscopic sinus surgery. Br J Ophthalmol. 2001;85:598–603.

65. Çınar E, Yüce B, Fece M, Küçükerdönmez FC. Periorbital emphysema after endoscopic nasal polyp surgery. Turk J Ophthalmol. 2019;49(1):47–50.
66. Rubinstein A, Riddell CE, Akram I, Ahmado A, Benjamin L. Orbital emphysema leading to blindness following routine functional endoscopic sinus surgery. Arch Ophthalmol. 2005;123(10):1452.
67. Ramakrishnan VR, Palmer JN. Prevention and management of orbital hematoma. Otolaryngol Clin N Am. 2010;43(4):789–800.
68. Graham SM, Nerad JA. Orbital complications in endoscopic sinus surgery using powered instrumentation. Laryngoscope. 2003;113:874–8.
69. Tewfik MA, Wormald PJ. Section II Rhinology and skull base. Complications in endoscopic sinus surgery. In: Tewfik MA, editor. Complications in otolaryngology—head and neck surgery. Stuttgart-New York: Thieme Publishing; 2013. p. 89–115.
70. Ransom ER, Chiu AG. Prevention and management of complications in intracranial endoscopic skull base surgery. Otolaryngol Clin N Am. 2010;43(4):875–95.
71. Koizumi M, Ishimaru M, Matsui H, Fushimi K, Yamasoba T, Yasunaga H. Outcomes of endoscopic sinus surgery for sinusitis-induced intracranial abscess in patients undergoing neurosurgery. Neurosurg Focus. 2019;47(2):E12.
72. Jang DW, Lachanas VA, White LC, Kountakis SE. Supraorbital ethmoid cell: a consistent landmark for endoscopic identification of the anterior ethmoidal artery. Otolaryngol Head Neck Surg. 2014;151:1073–7.
73. Thacker NM, Velez FG, Demer JL, Wang MB, Rosenbaum AL. Extraocular muscle damage associated with endoscopic sinus surgery: an ophthalmology perspective. Am J Rhinol. 2005;19(4):400–5.
74. Hong S, Lee HK, Lee JB, Han SH. Recession–resection combined with intraoperative botulinum toxin A chemodenervation for exotropia following subtotal ruptured of medial rectus muscle. Graefes Arch Clin Exp Ophthalmol. 2007;245(1):167–9.
75. Onodi A. The optic nerve and the accessory sinuses of the nose. New York: William Wood & Co.; 1910.
76. Ali IK, Sansare K, Karjodkar F, Saalim M. Imaging analysis of Onodi cells on cone-beam computed tomography. Int Arch Otorhinolaryngol. 2020;24(3):e319–22. https://doi.org/10.1055/s-0039-1698779.
77. Chmielik LP, Chmielik A. The prevalence of the Onodi cell—most suitable method of CT evaluation in its detection. Int J Pediatr Otorhinolaryngol. 2017;97:202–5.
78. May M, Levine HL, Mester SJ, Schaitkin B. Complications of endoscopic sinus surgery: analysis of 2108 patients—incidence and prevention. Laryngoscope. 1994;104(9):1080–3.
79. Kainz J, Stammberger H. The roof of the anterior ethmoid: a place of least resistance in the skull base. Am J Rhinol. 1989;3:191–9.
80. Banks CA, Palmer JN, Chiu AG, O'Malley BW Jr, Woodworth BA, Kennedy DW. Endoscopic closure of CSF rhinorrhea: 193 cases over 21 years. Otolaryngol Head Neck Surg. 2009;140(6):826–33.
81. Javadi SA, Samimi H, Naderi F, Shirani M. The use of low-dose intrathecal fluorescein in endoscopic repair of cerebrospinal fluid rhinorrhea. Arch Iran Med. 2013;16(5):264–6.
82. Hegazy HM, Carrau RL, Snyderman CH, Kassam A, Zweig J. Trans-nasal endoscopic repair of cerebrospinal UID rhinorrhea: a meta-analysis. Laryngoscope. 2000;110(7):1166–72.
83. Lanza DC, O'Brien DA, Kennedy DW. Endoscopic repair of cerebrospinal fluid fistulae and encephaloceles. Laryngoscope. 1996;106:1119–25.
84. Mantravadi AV, Welch KC. Chapter 26: Repair of cerebrospinal fluid leak and encephalocele of the cribriform plate. In: Chiu AG, Palmer JN, Adappa ND, editors. Atlas of endoscopic sinus and skull base surgery. 2nd ed. Elsevier; 2019. p. 223–32.
85. Henriquez OA, Schlosser RJ, Mace JC, Smith TL, Soler ZM. Impact of synechiae after endoscopic sinus surgery on long-term outcomes in chronic rhinosinusitis. Laryngoscope. 2013;123(11):2615–9.

11 Surgical Approaches to the Maxilla, Maxillary Sinus, Pterygopalatine Fossa, and Infratemporal Fossa for Malignant Tumors

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11.1 Introduction

The maxillary sinus is the site of the sinonasal tract most frequently affected by cancer (60% of cases), followed by nasal cavity (20%) and ethmoid sinus (15%). Tumors in sphenoid and frontal sinuses are extremely rare [1]. The reason why the maxillary sinus is the most affected by neoplasm has several explanations. First of all, since its big size, it has a larger surface for contact with inhalant carcinogens. Then, its position, more accessible by inhalant pollutants, and associated with a slower clearance of mucus compared to other sinuses, allows a prolonged contact between mucosa and carcinogenic agents, easing mutagenesis and tumor development. Also, pathologic conditions, such as complete or partial obstruction of the ostium, such as in case of chronic rhinosinusitis, or alterations in the ventilation pattern (e.g., in case of septal deviation, often associated with contralateral inferior turbinate hypertrophy) further prolong the contact time between the carcinogenic agents and the mucosa [2, 3].

Sinonasal cancers are generally slow growing and tend to remain asymptomatic till advanced stages. Their presentation is commonly with unilateral nasal respiratory obstruction, epistaxis, and nasal drip.

Squamous cell carcinomas (SCCs) constitute the majority of the maxillary sinus cancer followed by malignancies of salivary gland origin (adenoid cystic carcinomas first, adenocarcinomas and mucoepidermoid carcinomas second). Very rare are midline (NUT) carcinoma, neuroendocrine carcinoma, teratocarcinosarcoma, extranodal NK/T cell lymphoma (midline malignant granuloma), extraosseous plasmacytoma, and neuroectodermal and melanocytic tumors.

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N. Mat Lazim et al. (eds.), *Head and Neck Surgery: Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_11

The maxillary sinus offers several ways of neoplastic spread:

- The medial wall and the floor are the most fragile areas and, once these have been passed, the mass infiltrates the ipsilateral nasal cavity, the nasopharynx, and the hard palate.
- The lateral wall, so the cancer may emerge on the skin of the cheek.
- The posterior wall is very thick, so tumors that manage to overcome it typically show a very aggressive growth pattern: in this case, the tumor could invade infratemporal and pterygopalatine fossa and could infiltrate sphenopalatine ganglion and maxillary nerve. If V2 trigeminal branch has been involved, the mass may spread through it to the middle cranial fossa.
- The roof, through which the cancer reaches the orbit and may spread through its vascular and nervous structures.

Regional nodal and distant metastases are uncommon, occurring in less than 20% of patients, higher in advanced-stage tumors. In maxillary sinus non-squamous cell carcinomas, the rate of neck metastases at diagnosis is very low (6%) and metachronous nodal metastases are rare, whereas in squamous cell carcinomas the rate of neck metastases at presentation is 10.3% [3].

Nodal metastases worsen patient's prognosis, going from a 2-year survival of 70.3% for N0 patients to a survival of 48.5% for N+ patients with maxillary cancer [3].

Metastatic spread by blood has been documented in 1.5–18% of cases and usually occurs in very advanced stages of the disease [2, 3]. The diagnostic process of sinonasal malignant tumors consists of anamnesis, physical examination, videorhinoscopy, imaging, CT and MRI, and endoscopically guided biopsy. CT is superior to MR imaging for identifying bone erosion and for identifying involvement of the hard palate. MR imaging, especially with T2-weighted images, is helpful for tumor mapping and for distinguishing between tumor extension and obstructed secretions.

Staging of malignant sinonasal cancers, with the exception of lymphoma and sarcoma, is based on the 8th edition of TNM [4]. This new classification introduces the important prognostic role of location of the tumor inside maxillary sinus: cancers that arise below Ohngren's line (in the anteroinferior portion of the maxillary sinus) are associated with a good prognosis, while cancers that arise above that line (in the posterosuperior part) show a poorer prognosis due to early invasion of critical structures, including the orbit, skull base, pterygoid plates, and infratemporal fossa. Another important clinical factor introduced by the 8th edition of TNM [4] is the extranodal extension: tumor metastases invading beyond the lymph node capsule into the surrounding connective tissue, with or without associated stromal reaction.

Management of sinonasal cancers involving the maxillary sinus depends on the histology and tumor size as well as location in relation to the adjacent critical structures. The typical up-front locoregional treatment includes transfacial, transoral, or endoscopic maxillectomy, with or without neck dissection, followed by reconstruction and adjuvant radiation therapy, to optimize local control [2]. The use of postoperative RT and concomitant chemotherapy should be considered in patients with positive lymph nodes, particularly in cases of multiple metastatic lymph nodes or nodes with extracapsular spread [2]. The overall 5-year survival rates range from 30% to 60% [2, 3, 5].

11.2 Anatomical Landmarks

Before starting a surgical dissection of the maxillary region, it is necessary to deeply understand the complex morphology of this area. The maxillary bone forms most of the skeletal support of the midface, and part of the nasal cavities, by outlining the inferior border of the pyriform aperture and the inferior third of the lateral nasal wall. This bone has a main body, which contains the maxillary sinus (also called Highmore's antrum), whose superior and anterior plates, respectively, form the orbital floor and the infraorbital region and join each other at the level of the inferior orbital rim.

The infraorbital nerve (derived from V2 trigeminal branch) emerges from the infraorbital foramen, located within the canine fossa, a niche

on the anterior maxillary wall, just above and laterally to the prominence of the superior canine tooth root. The anterior maxillary wall articulates with the body of the zygomatic bone, and it is also in continuity with the posterolateral or infratemporal surface, which articulates with the pterygoid process of the sphenoid and forms, joining the medial endonasal maxillary wall, the apex of the maxillary sinus [6].

The frontal process of the maxillary bone stretches upwards to join the lacrimal bone at the level of the medial portion of the orbital rim, the nasal bones, and the frontal bone. The alveolar process of the maxilla extends inferiorly and forms half of the superior dentary arch. The palatine process, in continuity with the alveolar one, extends medially to form the anterior part of the hard palate and posteriorly joins the palatine bone. The pyramidal process of the palatine bone presents a groove, which articulates with the greater palatine groove of the maxilla, forming a canal for the descending palatine vessels and the palatine major nerve. The nasal crest arises in the suture between these two processes and articulates with the vomer. Anteriorly, the septal cartilage attaches to a thick protrusion called the anterior nasal spine. Behind the palatine process lies the horizontal process of the palatine bone (lamina horizontalis), completing the floor of the nasal cavity.

The medial endonasal maxillary face forms the lateral wall of the inferior meatus and gives insertion to the inferior turbinate. Anteriorly, it continues upward as the medial face of the frontal process, which articulates with the lacrimal bone and contributes to form the anterolateral half of the bony canal hosting the nasolacrimal duct. The frontal process also articulates with the middle turbinate in the ethmoidal crest and with the inferior turbinate in the conchal crest in the medial face. The maxillary sinus is usually the largest of all paranasal sinuses, with an average volume of 15 mL, and dimensions of about 34 × 23 × 33 mm in length, width, and height, respectively. It consists of a pyramid-shaped cavity, whose apex may also extend laterally into the zygomatic process of the maxilla or into the zygomatic bone itself.

Its boundaries are the anterior (facial) wall of the maxilla anteriorly, the infratemporal fossa posterolaterally, the pterygopalatine space postero-medially, the lateral wall of the nasal cavity medially, and the orbital floor superiorly. The maxillary sinus also gives origin to several niches, including the zygomatic and the alveolar recesses. The infraorbital nerve and vessels form a longitudinal prominence on the maxillary sinus roof, but they may also be dehiscent. The maxillary sinus may be partially divided by Schaeffer's septa, which may affect mucous drainage. In adults, the floor of the maxillary sinus may extend up to 5 mm below the level of the nasal cavity, whereas in children, with the sinus not completely developed, it is usually located above the nasal cavity floor.

The maxillary ostium (hiatus maxillaris), tough wide in the disarticulated maxilla, is greatly reduced in size in anatomical conditions, due to several complex spatial interactions with other bony and mucous structures. In particular, the uncinate process of the ethmoid diagonally crosses the ostium region to articulate with the ethmoidal process of the inferior turbinate, whose maxillary process covers the inferior margin of the maxillary hiatus itself. The vertical part (lamina perpendicularis) of the palatine bone hides the posterior notch of the maxillary, and a small portion of the lacrimal bone covers its anterosuperior angle. The remaining gap in the maxillary ostium is closed by connective tissue and mucosa, forming the *fontanelle*, which is divided into anterior and posterior *fontanelle* by the uncinate process. The natural ostium of the maxillary sinus is located in the anteroinferior angle of the fontanelle and constitutes the connection of the maxillary infundibulum with the ethmoidal infundibulum. It is hidden medially by the concave portion of the uncinate process [7].

Accessory ostia may be often seen as round holes in the region of the *fontanelle*. During endoscopy, they can be easily distinguished from the natural ostium, since they are round and can be visualized with a 0° endoscope, while the latter is oval shaped and cannot be seen unless an angled scope is employed or the uncinate has been removed or anteriorized. Posterior-superior and anterior-superior vessels and nerves, as well as infraorbital ones, provide innervation and blood

supply for the maxillary sinus. Small vessels from the inferior turbinate enter the maxillary sinus via the ostium region. Just postero-medially to the maxillary sinus lies the pterygopalatine fossa. It is a pyramid-shaped space, located medially to the pterygomaxillary fissure, and below the orbital apex. It is bounded by the posterior wall of the maxilla laterally, the base of the pterygoid process and the grater wing of the sphenoid posteriorly, and the perpendicular plate of the palatine bone medially. The latter shows the sphenopalatine foramen in its superior aspect.

The pterygopalatine fossa communicates with the surrounding regions via eight openings that give way to several neurovascular structures:

- Inferior orbital fissure (in which pass infraorbital, zygomatic nerve, infraorbital vessels, veins to pterygoid plexus, ophthalmic vein)
- Pterygomaxillary fissure (which connects pterygomaxillary and infratemporal fossae and is crossed by the internal maxillary vessels)
- Sphenopalatine foramen (located in the posterior part of the lateral nasal wall, just posteriorly to the end of the middle turbinate, and crossed by sphenopalatine artery)
- Foramen rotundum (which contains V2 branch)
- Pterygoid or vidian canal (located inferomedially to the foramen rotundum, and crossed by the vidian nerve in its route to the sphenopalatine ganglion)
- Pharyngeal canal (which opens into the lateral aspect of the roof of the choanae, and transmits pharyngeal branches of the sphenopalatine ganglion and of the internal maxillary artery)
- Greater pterygopalatine canal (crossed by the greater palatine vessels and nerves)
- Lesser pterygopalatine canal (crossed by the lesser palatine vessels and nerves)

The pterygopalatine fossa contains the third portion of the internal maxillary artery with its branches (posterosuperior alveolar artery, infraorbital artery, descending palatine artery, artery of the pterygoid canal, palatovaginal artery, sphenopalatine artery), pterygoid venous plexus, V2 nerve with its branches (zygomatic nerve, ganglionic branches, posterior-superior alveolar nerves, infraorbital nerve), vidian nerve, and sphenopalatine ganglion.

In relationship with the maxillary bone and the pterygopalatine fossa lies the infratemporal region. It is an anatomic space with irregular boundaries, encompassing the masticator and upper parapharyngeal spaces and located below the floor of the middle cranial fossa. In turn, the masticator space includes the medial and lateral pterygoid muscles, tendon of the temporalis muscle, internal maxillary artery, maxillary (V2) and mandibular (V3) branches of the trigeminal nerve, tensor and levator veli palatini muscles, and Eustachian tube. The styloid diaphragm, formed by the styloid aponeurosis, divides the UPPS into pre- and poststyloid compartments [6].

According to Li [8], the infratemporal region may be divided into five compartments in relationship with the endoscopic anatomy of the axillary sinus.

- Zone 1 (retromaxillary space) is defined as the space lying between the posterolateral wall of maxillary sinus and the complex of temporalis and pterygoid muscles. It may be accessed by removing the posterolateral wall of the maxillary sinus and its periosteum lateral to the infraorbital nerve down to the level of the floor of the maxillary sinus, to expose the buccal fat pad, beneath which the branches of the internal maxillary artery lie. Laterally to such vascular branches, the temporalis and pterygoid muscles can be observed.
- Zone 2 (superior interpterygoid space) is located at the superior part of the ITF and comprises the superior head of the lateral pterygoid muscle, V3, and foramen ovale. In anatomical dissection, approaching from the pterygopalatine fossa and using the maxillary nerve as a landmark to identify the pterygoid base and greater wing of the sphenoid bone, V3 and foramen ovale may be identified posterior to the origin of the lateral pterygoid plate, once the superior head of the lateral pterygoid muscle is elevated.
- Zone 3 (inferior interpterygoid space) includes the inferior head of the lateral pterygoid muscle, medial pterygoid, and temporalis muscles. The deep temporal nerve, located at the medial

border of the temporalis muscle, serves as a landmark to identify such region. Along the virtual space enclosed by the temporalis muscle and the medial and lateral pterygoid muscles in a posterolateral direction, the lingual and inferior alveolar nerves lie on the superior border of the medial pterygoid muscle, and the internal maxillary artery is detected to enter the posterior aspect of the infratemporal fossa. Additionally, the medial aspect of mandible ramus and the fascia of the deep head of masseter muscle could be through this corridor.

- Zone 4 (temporo-masseteric space) is defined as the space lateral to the temporalis muscle, and mainly contains fat, that leads to the medial aspect of the zygomatic arch and the superficial head of masseter muscle.
- Zone 5 (tubopharyngeal space) includes the Eustachian tube, the tensor and levator veli palatini muscles, and the structures within the upper parapharyngeal space. These structures may be exposed after elevation of the lateral pterygoid muscle off the lateral pterygoid plate and drilling of the pterygoid process, and lateral pterygoid plate. Along the superior border of the medial pterygoid muscle, in a posterior direction, the tensor veli palatini muscle at the anterolateral aspect of cartilaginous Eustachian tube and the levator veli palatini muscle at its anteroinferior aspect can be found. Behind these structures, the fat in the prestyloid compartment envelops the deep lobe of the parotid gland. Removal of the styloid aponeurosis leads to the exposure of the parapharyngeal internal carotid artery, the mixed cranial nerves (IX–XI), and the internal jugular vein. The hypoglossal nerve (XII) is placed posteriorly to the parapharyngeal internal carotid artery.

11.3 Background

The idea of maxillectomy was first described in 1826 by Lazars, whereas its first successful execution dates back to 1828 [9]. First pioneeristic maxillectomies were characterized by a high morbidity rate mostly due to important blood loss. This drawback led to the spread of radiation therapy for the treatment of maxillary tumors. After the Second World War, the innovations introduced in the fields of anesthesia, antibiotic therapy, and blood replacement contributed to a wider adoption of maxillectomy. Traditional approaches included transfacial incisions such as in the lateral rhinotomy or Weber-Ferguson technique [10, 11]. Modifications or additional procedures were subsequently added to maxillectomy, in order to better fulfill the needs of patients. Maxillectomies were performed together with resections of the pterygoid plates, the anterior skull base, or the nasopharynx, even including approaches through the infratemporal fossa [12]. In this way, lesions previously deemed as unresectable became eligible for surgical treatment aiming for a radical asportation. In the 1970s, the midfacial degloving approach affirmed itself as an alternative to the traditional transfacial incisions avoiding external scarring [13]. Endoscopic sinus surgery then affirmed itself progressively as the technique of choice for the treatment of lateral nasal wall tumors and as an extremely effective tool in combination with transfacial approaches for the control of the margins of resection due to the superior visualization [14].

11.4 Patient's Preparation

Maxillectomy is generally performed under general anesthesia. Orotracheal intubation is normally preferred, with the tube being secured to the opposite side of the lesion on the lower lip. In case orotracheal intubation is not deemed possible or in patients with particularly difficult airways, nasal fiber-optic intubation or even a tracheostomy may be taken into consideration. Broad-spectrum antibiotic prophylaxis is given at least 60 min before surgery. Clindamycin or ampicillin/sulbactam cover skin and oral cavity bacteria and are therefore good options. In case a skull base resection is performed, a third-generation cephalosporin is used because of its capability to penetrate the blood-brain barrier [15]. Massive hemorrhage is uncommon; however, appropriate measures should be taken into account in case excessive blood loss occurs so as to maintain adequate blood volume. The pivotal point for hemorrhage in the maxilla region is the

course of the internal maxillary artery in the infratemporal or pterygopalatine fossae.

11.5 Equipment

Regular otolaryngology and maxillofacial surgery instrumentation is normally proper to perform a resection of the maxilla. Standard endoscopic sinus surgery instruments are required in case an endoscopic maxillectomy is performed. Osteotomies may be done by means of reciprocating saws, oscillating saws, or piezoelectric devices. Bone chisels or rongeurs might be required as well.

11.6 Positioning

The patient is in supine position on the operating room table, with the head slightly rotated towards the side of the lesion. In case the eye is spared, a protective tarsorrhaphy or a corneal shield is used.

11.7 Preoperative Evaluation

Before surgery, it is mandatory to investigate the intranasal anatomy with nasal endoscopy. Physical examination of the oral cavity, the orbit, and the cranial nerves is also paramount. As far as radiological examinations are concerned, patients should undergo a CT scan, MRI, or even both. CT scans with contrast provide excellent information on the bony anatomy and the vascular architecture of the lesion. On the other hand, MRI provides better details on soft tissues, especially in those cases in which the lesion is in contiguity with the retained secretions [16]. Histological assessment is also mandatory prior to surgical procedure; sampling may be performed transnasally, transorally, or more seldom through an anterior antrostomy.

11.8 Infrastructure Maxillectomy

In an infrastructure maxillectomy, the hard palate and inferior part of the maxilla are removed, along with some of the teeth, but the orbital floor is preserved. As previously reported, the procedure is performed under general anesthesia with orotracheal or nasotracheal intubation, with the tube being secured contralateral to the lesion. The oral cavity is exposed with appropriate cheek retractors. The mucosa in the fornix is incised with either scalpel or electrocautery along with that on the hard palate granting safe margins around the lesion. If the patient is dentate, a tooth may be extracted in order to make the osteotomy pass through the post-extractive socket, so as to preserve the integrity of the remaining dentition. The mucosal incision is then deepened to the bony wall of the maxilla on the external aspect and to the bony palate on the internal aspect. All soft-tissue attachments to the aforementioned structures should be separated before osteotomies. Either an oscillating saw, a reciprocating saw, or a piezoelectric device is then used to perform the cuts onto the bony walls following the previously defined mucosal incisions. A chisel might be utilized to refine the osteotomies and most of all to detach the specimen from the pterygoid plates on the posterior aspect of the resection. Particular attention must be given to control hemorrhage from the descending palatine artery so as to prevent postoperative bleeding. After the resection, the maxillary antrum may be exposed. If the sinonasal mucosa is healthy, it can be left in place; on the other hand, in case of sinonasal disease, it is advisable to remove it by means of a curette. The procedure usually continues with the steps in accordance with the reconstructive technique of choice.

11.9 Subtotal Maxillectomy

In a subtotal maxillectomy, the entire maxilla, including the infrastructure and the suprastructure, is removed, sparing only the floor of the orbit. The patient is usually administered, as previously mentioned, general anesthesia by orotracheal intubation, with the tube being secured on the opposite side of the lesion. The most common surgical approach in a subtotal maxillectomy is the Weber-Ferguson approach. First of all, the incision line is drawn through

the vermilion border, along the labial philtrum, proceeding around the base of the nose and along the sulcus between the nose and the cheek. In case a subciliary extension is required, the incision continues in a lateral direction 3–4 mm below the cilium to the lateral canthus; however, it can be prolongated further laterally for a wider exposure. The skin incision is performed by means of a scalpel with the subsequent use of electrocautery to control the hemostasis. The upper lip is cut throughout its entire thickness on the median line, up to the superior fornix. At this stage, the superior labial artery is transected and therefore requires ligation or in any case careful hemostasis control. After that, in order to gain adequate elevation of the cheek flap, the incision continues on the mucosa of the fornix. The mucosa is incised in full thickness remaining just above the periosteal layer and continuing until the posterolateral aspect of the maxilla. The subciliary incision is made through the skin and the orbicularis oculi muscle; the dissection is then carried out on a preseptal plane down to the arcus marginalis above the inferior orbital rim. The cheek flap is progressively elevated until the infraorbital nerve is exposed in correspondence of the foramen and the entry of the nerve into the overlying soft tissues. In case the upper margin of the resection is below the foramen, the nerve might be spared so as to preserve the sensitive innervation of the cheek; however, in most cases, the transection of the nerve is necessary for reasons of oncological radicality or anyway to gain a satisfactory exposure of the specimen. The entry into the nasal cavity is obtained through the alar tissues down to the mucosa on the lateral aspect of the pyriform aperture. The oral cavity, the hard palate, and the maxilla are subsequently widely exposed. The first osteotomy is performed on the anterior aspect of the maxilla with the instrument of choice; the superior and the mesial margins of resection are thus identified. The superior osteotomy runs anteriorly through the maxillo-nasal buttress and posteriorly till the malar bone and the posterolateral aspect of the maxilla. Concerning the anterior osteotomy, if the patient is dentate and a tooth is passed through by the mesial margin of resection, it is advisable to extract the element so that the osteotomy is performed in the post-extractive socket and the remaining dentition is preserved.

After that, the mucosal incision on the hard palate is demarcated and performed by means of a needle-tip electrocautery, obviously keeping adequate distance from the lesion. The incision on the hard palate connects the anterior margin of resection to the previously made mucosal incision on the fornix around the maxillary tuberosity and is deepened till the bony layer on its whole length. The hard palate is then divided through this incision with the instrument of choice. Chisels are then helpful to connect the performed osteotomies on the posterior aspect and in particular to detach the specimen from the pterygoid plates. Once the bone cuts have been made, the remaining soft-tissue attachments, most of all the pterygoid muscles, can be transected so that the specimen may be removed. Following the resection, bleeding might be encountered coming from the sphenopalatine artery and by branches of the internal maxillary artery. While the sphenopalatine artery is usually dominated by electrocoagulation, the internal maxillary artery is better controlled by means of vessel ligation. Alike the infrastructure maxillectomy, the remaining sinusal mucosa may be left in place if presenting with a healthy aspect. Following the hemostasis, sharp bony edges get smoothened, and the procedure continues with the chosen reconstructive technique. In the postoperative care, adequate oral hygiene with chlorhexidine or baking soda solution must be ensured, with accurate detersion of debris, crusts, and clots so as to prevent wound infection and dehiscence. Moderate swelling of the cheek and the eyelids is usually encountered as a consequence of the interruption of lymphatic drainage. Following the fourth day after surgery, warm compresses help in reducing the edema. Nose feeding tubes are usually adopted until the surgical wound is healed and the patient is able to get back to a satisfactory oral intake.

An alternative approach avoiding extraoral incisions in subtotal maxillectomy is the midfacial degloving. This approach uses a bilateral circumvestibular incision together with a bilateral

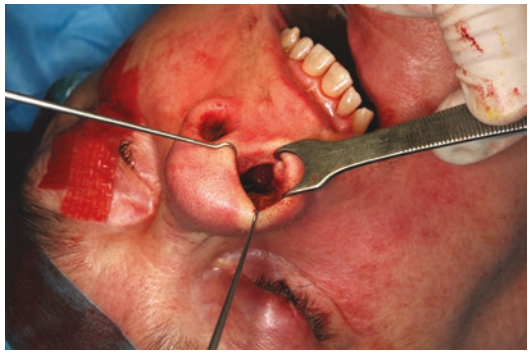


Fig. 11.1 First step of midfacial degloving. A circumvestibular incision has been made to allow the lower lateral cartilages to be reflected with the nasal skin. The latter is then elevated similarly to a closed rhinoplasty

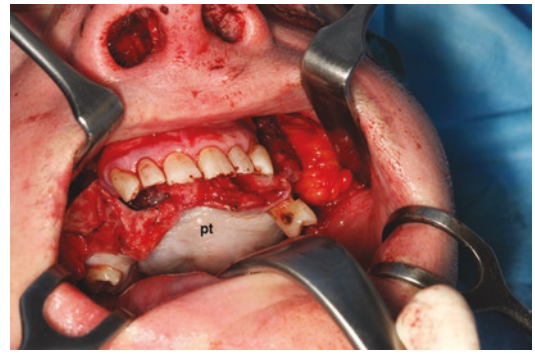


Fig. 11.3 In this image, dissection of the palate has been performed in order to remove the hard palate together with a palate tumor (pt)

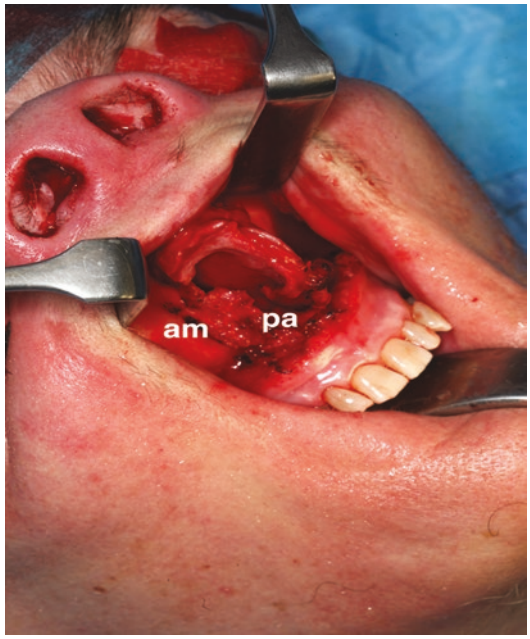


Fig. 11.2 The cheek and nasal skin is elevated in order to expose pyriform aperture (pa) and the anterior maxilla (am). Dissection aims to preserve the inferior orbital nerves

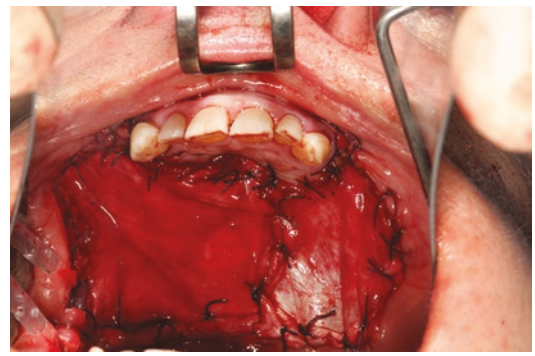


Fig. 11.4 Reconstruction of the palate has been performed with autologous temporoparietal fascia flap, which is adapted and sutured to the resection margins. The skin flap is then replaced and fixed with reabsorbable gum suture under the pyriform aperture

intercartilaginous incision and a transfixion incision, thus enhancing the exposure of the middle third through the exposition of the external nasal skeleton. This approach has the obvious advantage to avoid external scarring but needs wider intraoral incisions to gain adequate exposure (Figs. 11.1, 11.2, 11.3, and 11.4).

11.10 Total Maxillectomy

In a total maxillectomy, the palate, the floor of the orbit, and the whole maxilla are removed. Depending on the extent of tumor invasion and size, this procedure may be associated with an orbital exenteration. The resection of the entire maxilla is indicated when a tumor originating from the sinusal walls ends up filling the entire cavity. This procedure is also indicated in cases of maxillary sarcomas for reasons of oncological radicality. The approach adopted for total maxillectomy does not differ much from that used in subtotal maxillectomy; however, in total

maxillectomy, a larger exposure of the midface is needed. For this reason, the most common access method used in this procedure is the Weber-Ferguson approach with subciliary extension. As previously mentioned, the incision is first demarcated and runs in the midline of the upper lip to the columella. It then proceeds around the ala into the sulcus between the nasal subunit and the cheek up to the medial canthus and, after that, continues with the subciliary extension below the tarsal plate for the entire length of the lower eyelid or further laterally, if needed. The first cut is made into the upper lip, splitting it into two up to the root of the columella and securing the hemostasis of the superior labial artery. The subsequent skin incision around the nose is carried out in depth through the soft-tissue layers of the midface. On the other hand, the first mucosal incision is made along the superior fornix posteriorly till the maxillary tuberosity down to the bone level. The subciliary incision finally elevates a flap on a preseptal plane with a blunt dissection until the arcus marginalis above the inferior orbital rim is reached. Once all the aforementioned incisions have been performed, the resulting cheek flap is lifted till roughly 1 cm laterally of the orbital lateral canthus so as to provide adequate exposure of the region (Figs. 11.5 and 11.6).

Approximately 5.0 mm below the inferior orbital rim, along the midpupillary line, the infraorbitary nerve is encountered and transected. After that, the arcus marginalis is incised either with a scalpel, a Freer periosteal elevator, or electrocautery in order to proceed with a subperiosteal dissection of the orbital floor posteriorly till the orbital process of the palatine bone, which represents the posterosuperior margin of the resection (Fig. 11.7). At this point, a titanium mesh which will be later used for the reconstruction is modeled and bent in order to match the shape of the existing bone and to limit the risk of postoperative enophthalmos (Fig. 11.8).

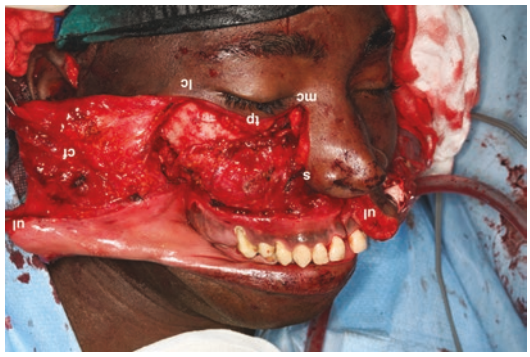


Fig. 11.5 Elevation of the cheek flap. The cheek flap is retracted laterally

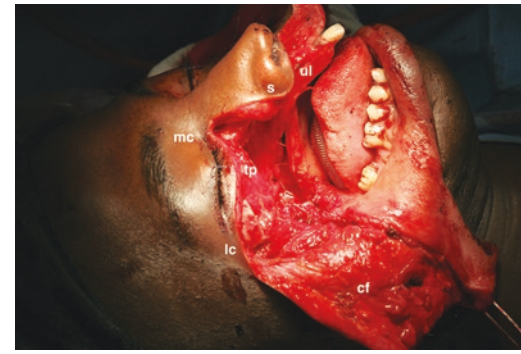


Fig. 11.6 Elevation of the cheek flap. The incision runs in the upper lip until reaching the columella. Then, it goes around the ala up to the medial canthus and follows the lower eyelid. The flap is lifted laterally to the lateral canthus and allows exposure of the entire external surface of the maxilla. *Abbreviations*: ul = upper lip; s = paralateral nasal sulcus; mc = medial canthus; tp = tarsal plate; lc = lateral canthus; cf = cheek flap

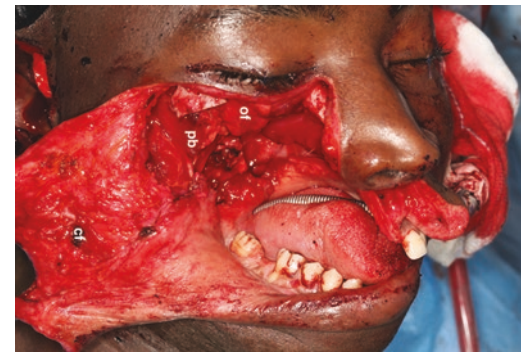


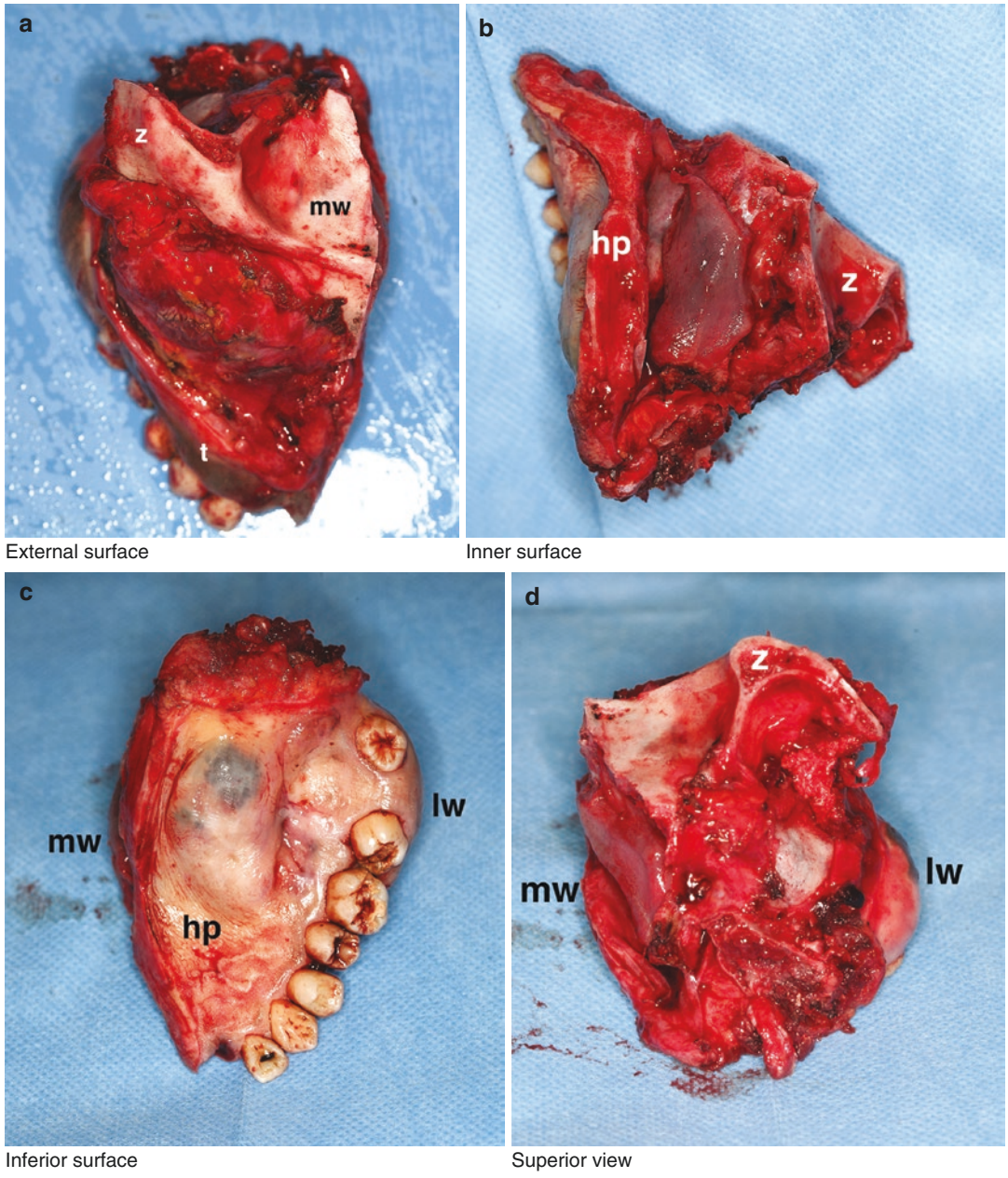
Fig. 11.7 Extension of the maxillectomy as far as the orbital process of the palatine bone (pb). The orbital floor (of) is now uncovered, and the entire maxillary sinus is opened

Fig. 11.8 Positioning of a titanium mesh. The material (white star) is modeled and adapted to the surface of the floor of the orbit. Its purpose will be for reconstruction

Next, the insertion of the masseter muscle to the most anterior and inferior pole of the malar bone is incised and elevated. The following steps take place in the oral cavity, where the demarcation of the resection on the palate and the preparation for the osteotomies occur in a similar fashion to the steps described for the infrastructure maxillectomy and the subtotal maxillectomy. Once all the soft-tissue attachments so far described have been freed, the bone cuts are outlined by means of electrocautery. In the most superior and medial aspect, the maxillo-nasal buttress is cut at the level of the orbital rim, taking care not to damage the lacrimal sac and the medial canthal ligament. Superolaterally, the maxillary bone is divided from the zygoma.

A malleable retractor is then used to retract the orbital content, and the planned osteotomies are continued onto the orbital floor using the landmarks of the inferior orbital fissure and the maxilla-ethmoidal suture. For osteotomies in the orbital floor, the use of a piezoelectric device is highly advisable. Inferiorly, at the level of teeth and hard palate, osteotomies are carried out as previously described. Brisk bleeding is expected to occur from each of the bone cuts. Once the previous steps are completed, osteotomies are connected by means of chisels, leaving the detachment of the pterygoid plates for last given the bleeding associated with branches of the internal maxillary artery and the pterygoid venous plexus. The remaining soft-tissue attachments on the posterior aspect of the resection are freed by means of electrocautery or Mayo scissors. The specimen is then removed, and careful control of the hemostasis takes place, especially focusing on the internal maxillary artery and the related branches (Fig. 11.9a–d).

After that, the procedure can go on with the preferred method for reconstruction. Postoperative indications in a total maxillectomy do not differ much from those observed in a subtotal maxillectomy. Accurate oral hygiene is mandatory, and frequent oral exercise is recommended in order to prevent post-operative trismus. Also in this procedure, a nose feeding tube might facilitate uneventful healing of the intraoral surgical wound. Correct lacrimal drainage should also be monitored, given the risk of epiphora due to cicatricial stenosis of the nasolacrimal duct, with the consequent indication for dacryocystorhinostomy (Figs. 11.10, 11.11, 11.12, 11.13, 11.14, 11.15, 11.16, and 11.17).



External surface

Inner surface

Inferior surface

Superior view

Fig. 11.9 The specimen has been removed after careful hemostasis. Images show the external surface (**a**), the inner aspect (**b**), the inferior aspect (**c**), and a view from above (**d**). *Abbreviations*: z = zygoma; mw = medial wall; t = teeth of the superior arch; hp = hard palate; lw = lateral wall

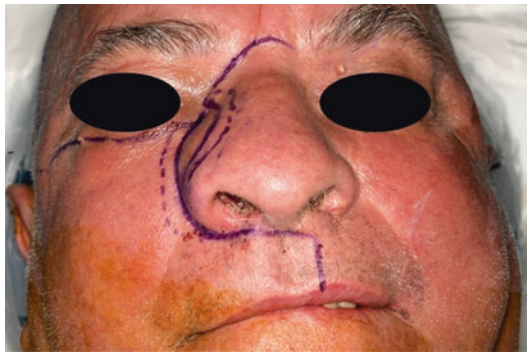


Fig. 11.10 Preoperatively, the patient's head must be slightly rotated towards the side of the lesion to be removed

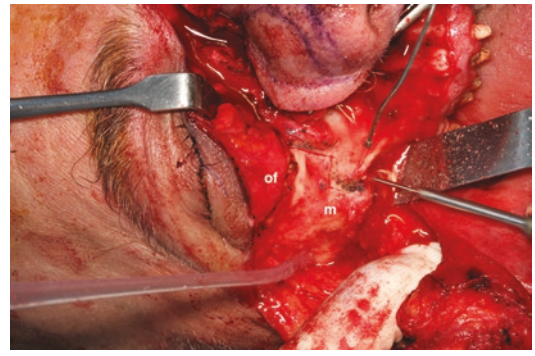


Fig. 11.13 The maxillary bone (m) is drilled in order to be opened and detached, together with the tumor, from the surrounding healthy tissue. In a total maxillectomy, the floor of the orbit (of) is removed

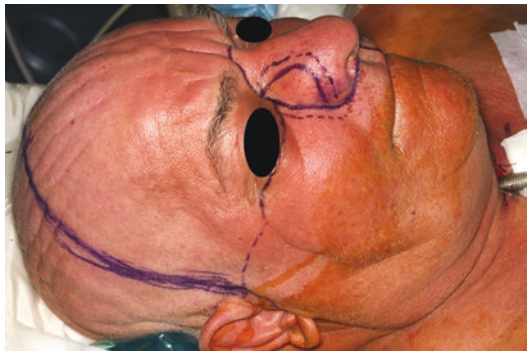


Fig. 11.11 The incision goes through the median line of the superior lip (sl) and proceeds along the sulcus (s) between the nose and the cheek, as far as the medial canthus (mc). Then, it extends laterally to the lateral canthus (lc). The flap is elevated in order to uncover the maxilla (m)

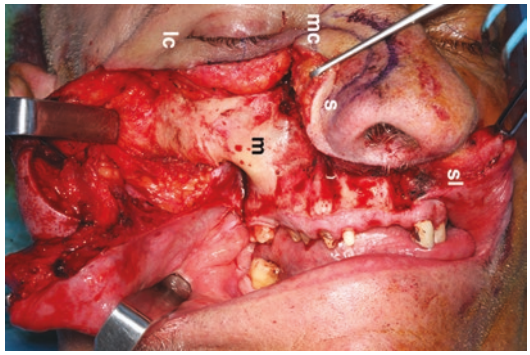


Fig. 11.12 The incision goes through the median line of the superior lip (sl) and proceeds along the sulcus (s) between the nose and the cheek, as far as the medial canthus (mc). Then, it extends laterally to the lateral canthus (lc). The flap is elevated in order to uncover the maxilla (m)

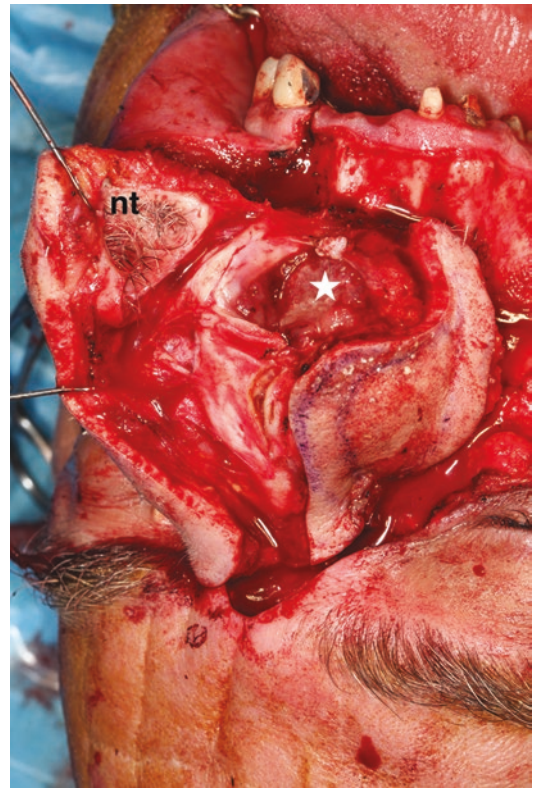


Fig. 11.14 Image showing the intranasal tumor (white star), which requires the maxillectomy. The tip of the nose (nt) is elevated to uncover the nasal cavity

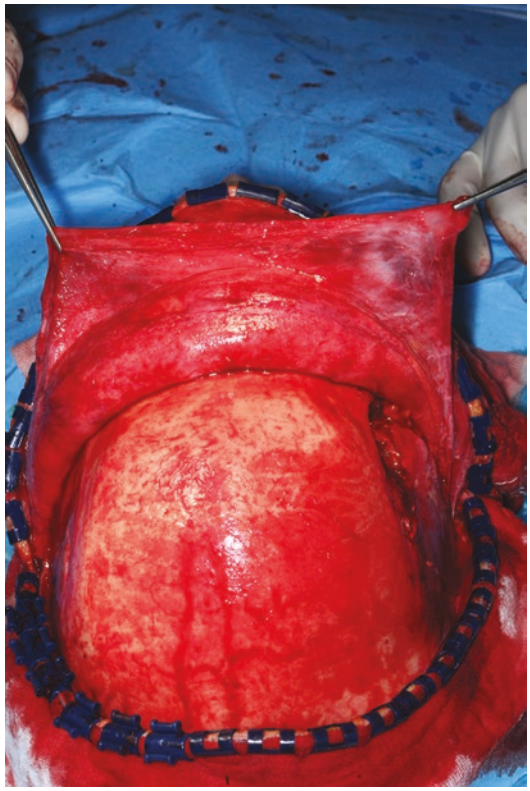


Fig. 11.15 After the radical steps, reconstruction should be performed with proper flaps, according to their extension. In this image, the cranial bones are uncovered with the purpose to collect a galeal flap

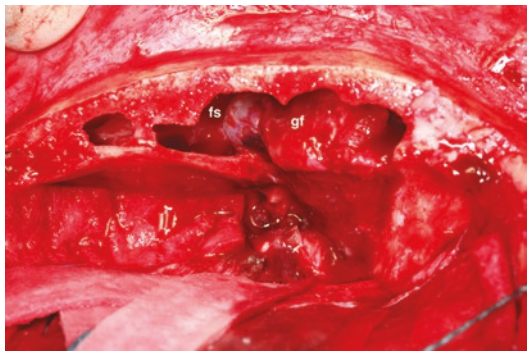


Fig. 11.16 The flap (gf) is made to enter the frontal sinus (fs) to finally reach the maxilla

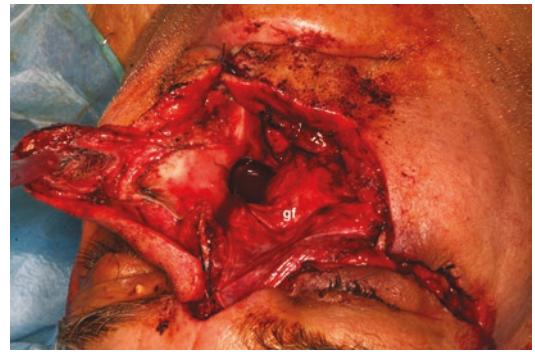


Fig. 11.17 Final steps consist of adapting the flap (gf) to resection margins. Reabsorbable suture is used to fix the galeal flap into the maxillary area. At last, the cutaneous flap is replaced and sutured

11.11 Transnasal Endoscopic Median Maxillectomies

The increasing interest in reducing surgical morbidity has led to extending of the indication of transnasal surgery to several locally aggressive and malignant tumors of the maxillary sinus [17–22]. At the beginning of the twentieth century, endonasal medial maxillectomies, with lateral nasal wall resection, were first described by Sturmann, Canfield, and Denker [23–25]. Nowadays, partial maxillectomies are routinely performed with video-endoscopy assistance. As a result, endoscopic versions of the traditional interventions have been proposed (endoscopic Sturmann–Canfield or endoscopic endonasal Denker operation) [22].

During the last years, understanding of endoscopic anatomy and familiarity with extended endonasal approaches have improved, leading to a more precise definition of different endoscopic maxillectomy types. Although there is not a universal nomenclature system for endoscopic maxillectomies, modular classifications, based on the anatomic structure progressively removed, have been recently proposed, to allow more precise comparisons between different series and defini-

tion of advantages, limitations, and indications of each maxillectomy type [26–28].

According to Schreiber et al. [27], who proposed a novel modular classification, four types of endoscopic median maxillectomies can be identified. Each of them might be performed via either ipsilateral or contralateral transseptal approach.

The surgical steps, characterizing each endoscopic median maxillectomy type, are the following:

- **Type A**: inferior uncinectomy and removal of the medial maxillary wall to the inferior turbinate insertion (inferiorly), orbital floor (superiorly), palatine canal (posteriorly), and nasolacrimal canal (anteriorly). First of all, a middle meatal antrostomy with removal of the inferior portion of the uncinate process is performed. The natural ostium of the maxillary sinus is identified and posteriorly enlarged by removing the upper portion of the medial maxillary wall, as far as the vertical process of the palatine bone. The exposure obtained with such an approach includes the posterior and superior portions of the maxillary sinus. Via such approach, after drilling out the superior and/or posterior maxillary wall (generally as far as the sagittal plane passing through the infraorbital nerve), a corridor to address adjacent anatomic areas, including the intraorbital compartment, the pterygopalatine fossa, the lateral recess of the sphenoid, or the Meckel's cave, may be obtained.
- **Type B**: After type A maxillectomy, the resection is extended inferiorly by removing the medial maxillary wall together with the inferior turbinate (partially or completely) and connecting the nasal floor with the floor of the maxillary sinus. The anterior limit of the resection is represented by the nasolacrimal duct, which should be identified and preserved. The lacrimal bone and the medial maxillary wall anterior to the nasolacrimal duct are preserved. The anterior part of the inferior turbinate may also be spared [26]. After removing the posterior maxillary wall in a medial-to-lateral direction, deeper regions, such as the pterygopalatine fossa or the pterygoid plates, may be approached. Care should be taken not to injure posteriorly the descending palatine arteries and nerves.
- **Type C**: Type B plus resection of the nasolacrimal duct and removal of the residual anterior portion of the medial maxillary wall: The endoscopic maxillectomy is extended anteriorly by removing the lacrimal bone and transecting the nasolacrimal duct a few millimeters distal to the lacrimal sac. This way, surgical maneuverability inside the maxillary sinus is improved, especially on the lateral and inferior walls, and opportunities for inspection are greater. This procedure is particularly helpful in controlling the retrolacrimal recess, which is crucial in obtaining a radical resection of benign and malignant tumors [26]. This approach may be extended anterolaterally, removing the pyriform aperture transnasally by partially or completely drilling out the ascending branch of the maxillary bone. This offers better control of the anterior half of the maxillary sinus (anterior, lateral, and inferior walls), especially the alveolar recess inferiorly and the zygomatic recess of the sinus laterally. This procedure enables complete control of all maxillary sinus walls and recesses. It is also used extensively to lateralize the surgical fulcrum as far as possible during expanded transnasal-transmaxillary-transpterygoid approaches directed towards the infratemporal fossa, nasopharynx, and upper parapharyngeal space [26].
- **Type D**: Type C plus removal of the anterior wall of the maxillary sinus medial to the infraorbital foramen or more laterally. The nasal vestibule is incised in a vertical, slightly curved fashion. The pyriform crest is identified, and the periosteum and soft tissues enveloping the anterior wall of the maxillary sinus are dissected with an elevator until the infraorbital foramen is reached. The anterior wall of the maxillary sinus can be removed as far as the infraorbital nerve or even more laterally, reaching the zygomatic arch and drilling out the lateral wall of the maxillary sinus as well. Usually, the superior limit of the dissection is

represented by a horizontal plane passing through the infraorbital foramen, in order to preserve the infraorbital nerve and not violate the orbital content. However, in selected cases, this approach may be expanded superiorly by removing the superior wall of the maxillary sinus (orbital floor), preserving the periorbital layer. Whenever feasible, attention should be given to the preservation of the anterior superior alveolar nerve, which branches from the infraorbital nerve at a variable distance from the infraorbital foramen and runs within the bone of the maxilla in an antero-inferomedial direction. This procedure enables the management of pathologies involving the anterior wall of the maxillary sinus. It is also used as a corridor for the transnasal approach to deep lateral tumors of the infratemporal fossa, nasopharynx, and upper parapharyngeal space [26].

The type D maxillectomies may be furtherly divided into five subtypes, according to the extension of the anterior dissection [27, 28]:

- Type D1, extended to two imaginary vertical and horizontal lines tangential to the infraorbital foramen (respectively, lateral and cranial boundary), to the pyriform aperture medially and to a diagonal line from the infraorbital foramen to the point on the pyriform aperture dividing the middle and inferior third of the distance between IOF and nasal floor.
- Type D2, same as D1, but caudally extended to a diagonal line from the infraorbital foramen to the inferolateral corner of the pyriform aperture.
- Type D3, same as D1 and D2, but caudally extended to a horizontal line tangential to the nasal floor.
- Type D4, same as D3, with further inferior extension to reach the caudal portion of the anterior alveolar recess of the maxillary sinus.
- Type D5, same as D3, further extended laterally beyond the infraorbital foramen.

In the transseptal approach to each of the type A to D maxillectomies, a vertical incision of septal mucosa and perichondrium is performed preserving the underlying cartilage just posterior to the anterior margin of the septal cartilage and for 1.5–2.0 cm vertically from the nasal floor. Subperichondral dissection of septal mucosa should be extended backward for approximately 5.0 mm, where a vertical incision of septal cartilage is subsequently performed preserving the contralateral septal mucosa and perichondrium. Subperichondral dissection of the contralateral mucosa is extended backward for approximately 5.0 mm. The muco-cartilaginous flap is harvested with a superior and inferior incision starting from its anterior edge and extending backward to the posterior limit of the septal cartilage at the bony-cartilaginous junction. The posteriorly pedicled muco-cartilaginous flap is then laterally dislocated. The septal window is completed with a vertical incision of the contralateral septal mucosa approximately 5 mm posterior to the cartilage incision and extended from the nasal floor upward for 1.5–2.0 cm [27, 28]. In a surgical setting, this technique allows to harvest a septal window, which can be used to pass through the septum only in one direction.

A possible modification to the type C maxillectomy is the prelacrimal approach [29], in which the inferior turbinate is temporarily displaced medially and then replaced in the original position and fixed with a suture. The nasolacrimal duct is skeletonized and mobilized but preserved.

This kind of modification offers a wide surgical window, similarly to what would be obtained with a type C maxillectomy, while preserving the medial maxillary wall and the nasolacrimal duct. However, in the presence of pathologies eroding or infiltrating the medial wall of the maxillary sinus (e.g., inverted papilloma or malignant tumors), the prelacrimal approach is contraindicated, and the type C maxillectomy endoscopic maxillectomy is generally considered safer and more effective [26].

A modified extended prelacrimal approach [18] may provide a higher oncological radicalness. In this technique, a vertical incision is made in the lateral wall of the nasal cavity along the anterior margin of the inferior turbinate to the nasal floor. The nasal mucosal flap and the medial maxillary wall

bone are removed, as well as the nasolacrimal duct and the bone around it. After osteotomy of the medial maxillary wall, the periosteum and mucosa in the maxillary sinus are completely resected. Resection of the anterior wall of maxillary sinus and the tumor inside maxillary sinus is then performed, after subperiosteal dissection of the anterior wall of the maxilla out to the lateral wall. After medial wall and anterior wall of the maxillary sinus have been resected, the posterior wall, orbital floor, lateral wall, part of the zygoma, and ethmoid sinus are also, respectively, removed. Lastly, the floor of maxillary sinus and horizontal plate of palatine bone are resected.

A possible alternative approach to type D maxillectomy type is the endoscopic endonasal anterior maxillotomy after palpating the edge of the pyriform aperture, just anterior to the head of the inferior turbinate, and the mucosa and periosteum are incised vertically. A subperiosteal dissection of the pyriform aperture and anterior maxilla exposes the infraorbital foramen and neurovascular bundle. The course of the anterosuperior alveolar nerve is then identified, and a window is created in the anterior wall of the maxilla using a high-speed drill, staying inferior to the infraorbital foramen and preserving the anterosuperior alveolar nerve trunk and any major branches. The size of the window may range between 0.5 and 1.0 cm. Such techniques allow to control the entire maxillary sinus, up to its anteroinferior corner and the junction of its anterior and lateral wall [30].

11.12 Transoral-Transnasal Endoscopic Maxillectomy

When a more extensive surgical control of the maxilla, and infratemporal and pterygopalatine fossae, is required, a combined transoral-transnasal approach can allow to achieve clear margins and accurate hemostasis, without external cutaneous scars [31]. After an endoscopic medial maxillectomy has been performed, an incision is placed at the level of the ipsilateral gingivobuccal sulcus, from the contralateral central incisor to the ipsilateral third molar. Blunt subperiosteal dissection of the soft tissues is performed with a Freer dissector along the anterior wall of the maxillary sinus, until reaching the infraorbital nerve superiorly and the zygomaticomaxillary fissure laterally. Vertically oriented osteotomies along the intermaxillary fissure, zygomaticomaxillary fissure, and ascending process of the maxilla, and transversally along the superior or inferior margin of the infraorbital neurovascular bundle, are performed with powered instrumentation to detach the anterior aspect of the maxilla.

An incision is made sagittally along the mucosa of the hard palate, which is raised and reflected with a soft-tissue elevator. A nasal floor/palate osteotomy is performed from posterior to anterior, as close as possible to the medial maxillary wall, in order to preserve more palatal bone to facilitate reconstruction, if oncologically possible. The sphenopalatine artery and foramen are identified at the level of the ethmoidal crest. The sphenopalatine artery is clipped and cauterized, and the foramen is opened. The adjacent posterior wall of the maxillary sinus is also removed in a lateral fashion, thus exposing the pterygopalatine and the infratemporal fossae. The internal maxillary artery is identified and clipped, and the posterior osteotomy is continued as laterally and anteriorly as possible, connecting it to the osteotomy previously performed along the zygomaticomaxillary fissure [31].

11.13 Endoscopic-Assisted Transfacial Maxillectomy

Malignant tumors growing posterolaterally in the maxillary sinus are associated with high recurrence risk and worse survival outcomes compared to tumors with predominant anterior or medial extension [32]. Local recurrence is also most frequently located at the posterior margin of resection and is rarely suitable for salvage surgery [33]. Transnasal endoscopic approach to

maxillectomy could provide some advantages, compared to the traditional open approach, including better visualization of the medial/superomedial component of tumors extended towards the midline, more precise and easy delineation of the posterior resection margin in view of the improved magnification, and possibility to carefully dissect neurovascular and muscular structures with optimal bleeding control [34].

Traditional transfacial maxillectomies are classified as inferior maxillectomy, when the segment of maxilla below the axial plane passing through the infraorbital foramen is removed; subtotal maxillectomy, when the superior osteotomy is made along a plane passing between the infraorbital foramen and orbital floor; total maxillectomy, when resection also includes the orbital floor (also extendable to the periorbital/extraconal fat); or extended maxillectomy, when the orbital content has also been removed [35]. Before proceeding with the transnasal osteotomies, posterior resection is carried on transnasally with endoscopic guidance.

The resection of the posterior peri-maxillary tissues can be modulated according to three types of extension [34]:

- Type 1 posterior resection implies removal of the pterygopalatine fossa content. After debulking the nasal and maxillary portion of the tumor, a type B endoscopic medial maxillectomy is performed. The posterior maxillary wall is partially removed, and the pterygopalatine fossa content is left covered by its periosteum and laterally dissected from the pterygoid plates up to a sagittal plane passing through the infraorbital canal. The pterygoid plates are selectively drilled at the level of the pterygomaxillary junction to detach the maxillary bone from the pterygoid process. For tumors invading the junction between the posterior maxillary wall and orbital floor, the inferior orbital fissure may be included in the dissection.
- Type 2 consists of a type 1 posterior resection, with further partial removal of pterygoid process and muscles. After completing the steps of a type 1 resection, the pterygoid process is sectioned below the vidian canal. For tumors invading the upper portion of the pterygopalatine fossa or inferior orbital fissure, the base of the pterygoid process is entirely resected.
- Type 3 posterior resection implies removal of the cartilaginous Eustachian tube and adjacent UPS tissues. After completing a type 2 resection, a mucosal incision surrounding the nasopharyngeal ostium of the Eustachian tube as in type 3 nasopharyngectomy is performed. The cartilaginous portion of the Eustachian tube, mandibular nerve, and adjacent soft tissues are included in the specimen. For tumors abutting the skull base, the medial portion of the greater sphenoidal wing and fibrocartilage basalis can also be removed.

Type 1 posterior resection is indicated when the tumor is inserted on the posterior wall of maxillary sinus and/or determines resorption of the same bony wall and/or for tumors of the hard palate/superior alveolar ridge/superior retromolar trigone extending behind the tuber maxillae, while type 2 should be performed when tumors extend to the PPF or medial portion of the infratemporal fossa fat. Type 3 is indicated in case of lesions involving the pterygoid plates, pterygoid muscles, or anterior portion of the tube.

11.14 Conclusion

Tumors of the maxillary sinus, due to their different patterns of growth and infiltration with reference to the critical surrounding structures, require an extremely flexible surgical approach to tailor the most appropriate oncological resection as per each patient's need. For this reason, it is crucial that surgeons dealing with maxillary sinus diseases master both endoscopic and transfacial open techniques. An accurate knowledge of the anatomy of the pterygopalatine and infratemporal fossae and of the orbit is also required to be confident during resections of the surrounding tissues, often needed to obtain clear margins.

References

1. Thompson LDR, Franchi A. New tumor entities in the 4th edition of the World Health Organization classification of head and neck tumors: nasal cavity, paranasal sinuses and skull base. Virchows Arch. 2018;472(3):315–30.
2. Bernier J. Head and neck cancer, multimodality management. Basel: Springer; 2016.
3. Cantù G, Bimbi G, Miceli R, Mariani L, Colombo S, Riccio S, Squadrelli M, Battisti A, Pompilio M, Rossi M. Lymph node metastases in malignant tumors of the paranasal sinuses: prognostic value and treatment. Arch Otolaryngol Head Neck Surg. 2008;134(2):170–7.
4. Amin MB. AJCC staging manual. 8th ed. Basel: Springer; 2017.
5. Jiang GL, Morrison WH, Garden AS, Geara F, Callender D, Goepfert H, Ang KK. Ethmoid sinus carcinomas: natural history and treatment results. Radiother Oncol. 1998;49(1):21–7.
6. Janfaza P, Nadol JB, Galla R, Fabian RL, Montgomery WW. Surgical anatomy of the head and neck. Philadelphia: Lippincott Williams & Wilkins; 2000.
7. Anniko M, Bernal-Sprekelsen M, Bonkowsky V, Bradley PJ, Iurato S. Otorhinolaryngology, head and neck surgery. Basel: Springer; 2010.
8. Li L, London NR Jr, Prevedello DM, Carrau RL. Anatomy based corridors to the infratemporal fossa: implications for endoscopic approaches. Head Neck. 2020;42(5):846–53.
9. McGuirt WF. Maxillectomy. Otolaryngol Clin N Am. 1995;28(6):1175–89.
10. Weber O. Presentation of a diseased resection of the lower jaw hindering the naturist. Med Assoc Heidelberg. 1845;4:80–2.
11. Ferguson W. In operation of the upper jaw. A system of practical surgery. Edinburgh: John Churchill; 1842. p. 484.
12. Barbosa JF. Surgery of extensive cancer of paranasal sinuses. Presentation of a new technique. Arch Otolaryngol. 1961;73:129–38. https://doi.org/10.1001/archotol.1961.00740020135001.
13. Maniglia AJ. Indications and techniques of midfacial degloving. A 15-year experience. Arch Otolaryngol Head Neck Surg. 1986;112(7):750–2.
14. Waitz G, Wigand ME. Results of endoscopic sinus surgery for the treatment of inverted papillomas. Laryngoscope. 1992;102(8):917–22. https://doi.org/10.1288/00005537-199208000-00012.
15. Youssef AS, Sloan AE. Extended transoral approaches: surgical technique and analysis. Neurosurgery. 2010;66(3 Suppl):126–34. https://doi.org/10.1227/01.NEU.0000366117.04095.EC.
16. Mosier KM. Lesions of the jaw. Semin Ultrasound CT MR. 2015;36(5):444–50. https://doi.org/10.1053/j.sult.2015.08.003. Epub 2015 Aug 28.
17. Karp J, Xiong W, Derikvand S, Javer A. Maxillary sinus ameloblastoma: transnasal endoscopic management. Ear Nose Throat J. 2020;2:145561320930555.
18. He S, Bakst RL, Guo T, Sun J. A combination of modified transnasal endoscopic maxillectomy via transnasal prelacrimal recess approach with or without radiotherapy for selected sinonasal malignancies. Eur Arch Otorhinolaryngol. 2015;272(10):2933–8.
19. Nakayama T, Tsunemi Y, Kuboki A, Asaka D, Okushi T, Tsukidate T, Otori N, Kojima H, Haruna SI. Prelacrimal approach vs conventional surgery for inverted papilloma in the maxillary sinus. Head Neck. 2020;42(11):3218–25.
20. Suzuki M, Nakamura Y, Yokota M, Ozaki S, Murakami S. Modified transnasal endoscopic medial maxillectomy through prelacrimal duct approach. Laryngoscope. 2017;127(10):2205–9.
21. Tepedino MS, Ferrão ACM, Higa HCM, Balsalobre Filho LL, Iturriaga E, Pereira MC, Pinheiro Neto CD. Reversible endoscopic medial Maxillectomy: Endonasal approach to diseases of the maxillary sinus. Int Arch Otorhinolaryngol. 2020;24(2):e247–52.
22. Tomenzoli D, Castelnuovo P, Pagella F, Berlucchi M, Pianta L, Delù G, Maroldi R, Nicolai P. Different endoscopic surgical strategies in the management of inverted papilloma of the sinonasal tract: experience with 47 patients. Laryngoscope. 2004;114(2):193–200.
23. Sturmann D. [The intranasal opening of the maxillary sinus]. Wien Klin Wochenschr. 1908;27:1273–4.
24. Canfield R. The submucous resection of the lateral nasal wall in chronic empyema of the antrum, ethmoid and sphenoid. JAMA. 1908;51:1136–41.
25. Denker A. A new way for the surgery of malignant nasal tumors. Munch Med Wochenschr. 1906;53:953–6.
26. Turri-Zanoni M, Battaglia P, Karligkiotis A, Lepera D, Zocchi J, Dallan I, Bignami M, Castelnuovo P. Transnasal endoscopic partial maxillectomy: operative nuances and proposal for a comprehensive classification system based on 1378 cases. Head Neck. 2017;39(4):754–66. https://doi.org/10.1002/hed.24676.
27. Schreiber A, Ferrari M, Rampinelli V, et al. Modular endoscopic medial maxillectomies: quantitative analysis of surgical exposure in a preclinical setting. World Neurosurg. 2017;100:44–55.
28. Schreiber A, Mattavelli D, Ferrari M, Rampinelli V, Lancini D, Ravanelli M, Bertazzoni G, Rodella LF, Buffoli B, Doglietto F, Nicolai P. Anterior superior alveolar nerve injury after extended endoscopic medial maxillectomy: a preclinical study to predict neurological morbidity. Int Forum Allergy Rhinol. 2017;7(10):1014–21.
29. Zhou B, Han DM, Cui SJ, Huang Q, Wang CS. Intranasal endoscopic prelacrimal recess approach to maxillary sinus. Chin Med J. 2013;126:1276–80.

30. Upadhyay S, Dolci RL, Buohliqah L, Prevedello DM, Otto BA, Carrau RL. Endoscopic endonasal anterior maxillotomy. Laryngoscope. 2015;125:2668–71.
31. Rivera-Serrano CM, Terre-Falcon R, Duvvuri U. Combined approach for extensive maxillectomy: technique and cadaveric dissection. Am J Otolaryngol. 2011;32(5):417–21.
32. Yoshimura R, Shibuya H, Ogura I, et al. Trimodal combination therapy for maxillary sinus carcinoma. Int J Radiat Oncol Biol Phys. 2002;53:656–63.
33. McMahon JD, Wong LS, Crowther J, et al. Patterns of local recurrence after primary resection of cancers that arise in the sinonasal region and the maxillary alveolus. Br J Oral Maxillofac Surg. 2013;51:389–93.
34. Deganello A, Ferrari M, Paderno A, Turri-Zanoni M, Schreiber A, Mattavelli D, Vural A, Rampinelli V, Arosio AD, Ioppi A, Cherubino M, Castelnuovo P, Nicolai P, Battaglia P. Endoscopic-assisted maxillectomy: operative technique and control of surgical margins. Oral Oncol. 2019;93:29–38.

Laryngeal Disease and Tumours and Its Related Surgery

12

Carmelo Saraniti and Barbara Verro

12.1 Introduction

The larynx plays a role in breathing and phonation and is involved in swallowing through its sphincter function in order to protect the lower airways. Therefore, laryngeal pathology, whether benign or malignant, often manifests itself with dysphonia, dyspnoea and/or dysphagia, as well as with other less specific symptoms such as cough, ear pain, pharyngeal globe and sore throat. Furthermore, in most cases, laryngeal pathologies require surgical treatment as anti-inflammatory and/or antibiotic medical therapy alone is seldom sufficient [1, 2]. In any case, for a correct diagnostic and therapeutic classification of the pathology, it is advisable, first of all, to begin with the study of the larynx from an embryological, anatomical and physiological point of view and then to move on to the characteristics of the various laryngeal pathologies and, therefore, how these impair the structure and function of the organ.

12.2 Anatomy of the Larynx

The larynx consists of a cartilaginous and membranous skeleton internally coated by mucosa. Based on the structures that compose it, this organ can be divided into three regions: supraglottic, glottic and subglottic. In particular, the *supraglottic region*, in turn, consists of the following structures:

- The epiglottis, which, with its free edge anteriorly, delimits the aditus laryngis (or epilarynx) and, with its infrahyoid portion, defines the anterior limit of the laryngeal vestibule
- The ary-epiglottic folds, which constitute the lateral limit of the epilarynx
- The false vocal folds, which laterally delimit the laryngeal vestibule
- Morgagni's ventricle, which represents a virtual space bordered below by the true vocal cord, above by the false vocal fold and laterally by the thyroid ala
- The corniculate cartilages of Santorini, above the arytenoids

As regards, instead, the *glottic plane* consists of the following anatomical structures:

- The arytenoids, which are articulated with the cricoid cartilage.
- The anterior commissure, which, at the top, is ventrally delimited by the intermediate lamina

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N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_12

of thyroid cartilage at the superior thyroid notch ventrally and by the insertion of the true vocal cords, of the Broyles' ligament and of the conoid ligament dorsally, below from the lower edge of the thyroid cartilage and laterally from a sagittal plane passing through the anterior third of the true vocal cords [3, 4].
– The true vocal cords, which, from the most superficial to the deepest plane, consist of five histological layers: the stratified squamous epithelium, the intermediate lamina with its three layers—superficial (or Reinke's space), intermediate and deep (or vocal ligament)—and finally the thyroarytenoid muscle.

Finally, the *subglottis* is defined as the portion of the larynx between the glottis and the lower edge of the cricoid cartilage. Superiorly, its ventral and dorsal limits do not match: the former is 1 cm higher than the posterior one. Furthermore, for a correct surgical treatment of laryngeal pathology, especially malignant, it is also advisable to know the so-called pre-epiglottic and upper and lower para-glottic spaces. In particular, the *pre-epiglottic space* is superiorly delimited by the hyo-epiglottic ligament and the glosso-epiglottic valleculae, anteriorly by the thyro-hyoid membrane and the upper border of the thyroid cartilage and inferiorly by the thyro-epiglottic ligament [5].

Laterally, the pre-epiglottic space extends beyond the lateral margin of the epiglottis and, at the level of the small cornu of the hyoid bone, it continues as an *upper para-glottic space*. The latter is medially delimited by the Morgagni's ventricle and by the quadrangular membrane at the top and by the conus elasticus at the bottom, antero-laterally by the thyroid cartilage and posterolaterally by the mucosa of the piriform sinus; postero-inferiorly it extends to the crico-arytenoid joint [6]. As regards, instead, the lateral limit of the *lower para-glottic space* is represented by the thyroid cartilage and the crico-thyroid membrane, its medial limit by the conus elasticus and the posterior one by the arytenoids. Furthermore, according to a first definition, the thyroid-arytenoid muscle is considered part of this space [7]; according to others, however, it represents only its medial limit [8] (Fig. 12.1).

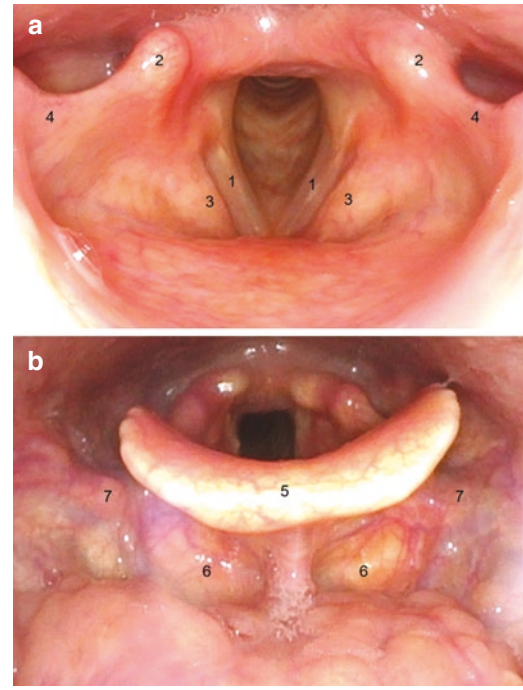


Fig. 12.1 Anatomy of larynx: (**a**) true vocal cords (1), arytenoids (2), false vocal folds (3), ary-epiglottic folds (4) and (**b**) free edge of epiglottis (5), glosso-epiglottic valleculae (6), glosso-epiglottic folds (7)

12.3 Laryngeal Diseases

The diseases that can affect the larynx are numerous and different: benign and malignant lesions, neurological disorders, systemic pathologies, traumatic and infectious diseases, as well as structural anomalies are found. The most frequent benign pathologies are polyps, nodules, cysts [9], granulomas and Reinke's oedema [10]. The laryngeal malignancies occupy the second place in frequency among the head and neck cancers [11, 12]. Laryngeal squamous cell carcinoma (LSCC) is the most frequent laryngeal tumour (approximately 95% of cases) [13, 14]; rarer (remaining about 5% of cases) are other histotypes such as chondrosarcoma, leiomyosarcoma and melanoma [15, 16].

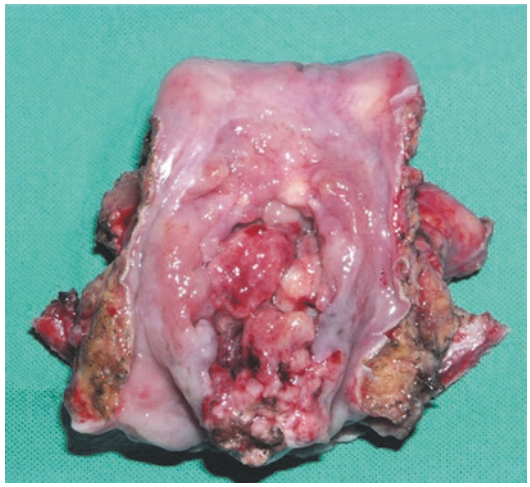


Fig. 12.2 Supraglottic carcinoma

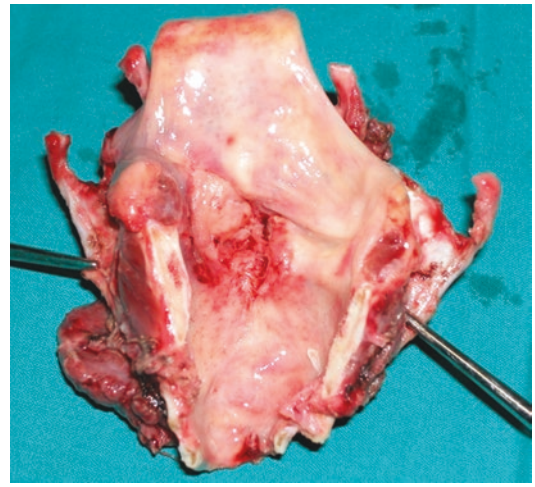


Fig. 12.3 Glottic-supraglottic carcinoma

12.4 Supraglottic Carcinoma

Supraglottic carcinoma accounts for about one-third of laryngeal tumours and, in most cases, they are squamous cell carcinomas [17]. In consideration of its anatomical structure, the onset of symptoms is rather late and this, together with an early lymph node involvement, explains the worse prognosis of cancers that arise in this region compared to glottic carcinomas [18]. Therefore, since the anatomical structures of the supraglottic plane are mainly involved in swallowing, in the case of supraglottic carcinoma, the symptoms will be characterized by dysphagia, pharyngeal globe, sore throat, haemoptysis and otalgia. Vestibular carcinoma is an exception, since it originates from the false vocal fold and, therefore, manifests itself early with dysphonia (Fig. 12.2).

12.5 Glottic Carcinoma

The glottic plane represents the most frequent site of laryngeal carcinoma [19]. Furthermore, unlike the supraglottis, the glottic plane has a poor lymphatic vascularization. So, the early onset of dysphonia and the late lymph node involvement often allow an early diagnosis of glottic carcinoma and, consequently, a less invasive therapeutic approach with a good prognosis [20]. The most frequent symptom is hoarseness, with changes in the tone of voice. The dysphonia, in this case, is persistent and does not tend to regress or improve with medical therapy, contrary to what happens in the case of inflammatory disease. Other symptoms of suspicion, less specific but more frequent in case of advanced-stage glottic carcinoma, are dyspnoea, odynophagia, otalgia, haemoptysis and foreign-body sensation (Fig. 12.3).

12.6 Subglottic Carcinoma

Subglottic carcinoma accounts for about 5% of laryngeal cancers [21]. It correlates with a late onset of symptoms, characterized above all by stridor and dyspnoea, and this feature, together with the low incidence of subglottic carcinoma, is responsible for a poor prognosis. The involvement of the mediastinal and paratracheal lymph nodes in 20% of cases as well as the tendency to relapse at the level of tracheal stoma are two other relevant details (Fig. 12.4).

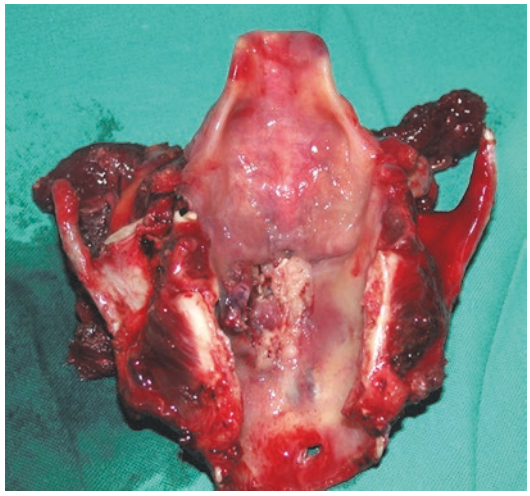


Fig. 12.4 Glottic-subglottic carcinoma

12.7 Diagnosis: Investigation Tools

Regardless of the nature of the laryngeal disease, the diagnostic protocol provides for a multistep evaluation with progressively more advanced and invasive tests and technologies. The first step is represented by *fibre-optic laryngoscopy* [22], which allows to study the morphology and functionality (motility) of the pharyngeal and laryngeal structures during phonation and respiration. Furthermore, for a more in-depth study of vocal cord motility, *videostroboscopic examination* can be performed since it allows to observe the vocal cord movement in slow motion during phonation [23]. For a more accurate and precise study of the epithelial and submucosal laryngeal vascularization, *narrowband imaging (NBI)* can be used, since it allows to formulate a first diagnostic hypothesis of the laryngeal lesion according to the pattern of vascularization based on intraepithelial papillary capillary loops (IPCL) [24, 25]. The next diagnostic step is the *neck computed tomography (CT)* with and without contrast medium, which allows to evaluate the locoregional extension of the neoplasm. For this reason, CT represents a fundamental examination for the staging of the carcinoma and for the correct therapeutic classification. Finally, where CT does not provide sufficient information, *magnetic resonance imaging* can provide additional data, especially in cases of extension to the pre-epiglottic and/or para-glottic spaces [26].

12.8 Surgical Treatment

Laryngeal surgery could be divided into functional and lesional. The former corresponds to laryngoplasty with a mainly reparative purpose; the second surgery, on the other hand, corresponds to laryngectomies with excisional purposes. Therefore, the latter allows the radical excision of malignant lesion with the consequent temporary or permanent impairment of some laryngeal functions (respiratory, phonatory, sphincter) based on the location and extent of the tumour and, consequently, on the type of surgery. Anyway, this surgery can be considered as valid and effective only when it is able to guarantee the oncological radicality and, at the same time, the restoration of the sphincter and respiratory function of the larynx.

In particular, laryngectomy can be partial and total, depending on the pathology, its location, and extent and degree of infiltration. Until the 1950s, total laryngectomy was performed in case of tumours with involvement or extension beyond the glottic plane [27, 28]. Over the years, however, efforts have been made progressively to develop new conservative surgical techniques in order to ensure organ preservation, where possible [27, 28]. Indeed, the applicability of conservative and reconstructive techniques depends on several factors: histotype and pattern of tumour growth, tumour location, TNM stage and general status of the patient [29]. At the beginning of conservative surgery, two main types of partial laryngectomy were defined: the vertical partial laryngectomy, including the frontal-lateral introduced by Leroux-Robert between the 1950s and the 1970s [30], now no longer in use, and partial horizontal laryngectomy, which includes, first of all, the supraglottic laryngectomy designed by Alonso in 1947. In 2014, the European Laryngological Society (ELS) proposed a new classification of open partial horizontal laryngectomies (OPHL), based on the lower resection

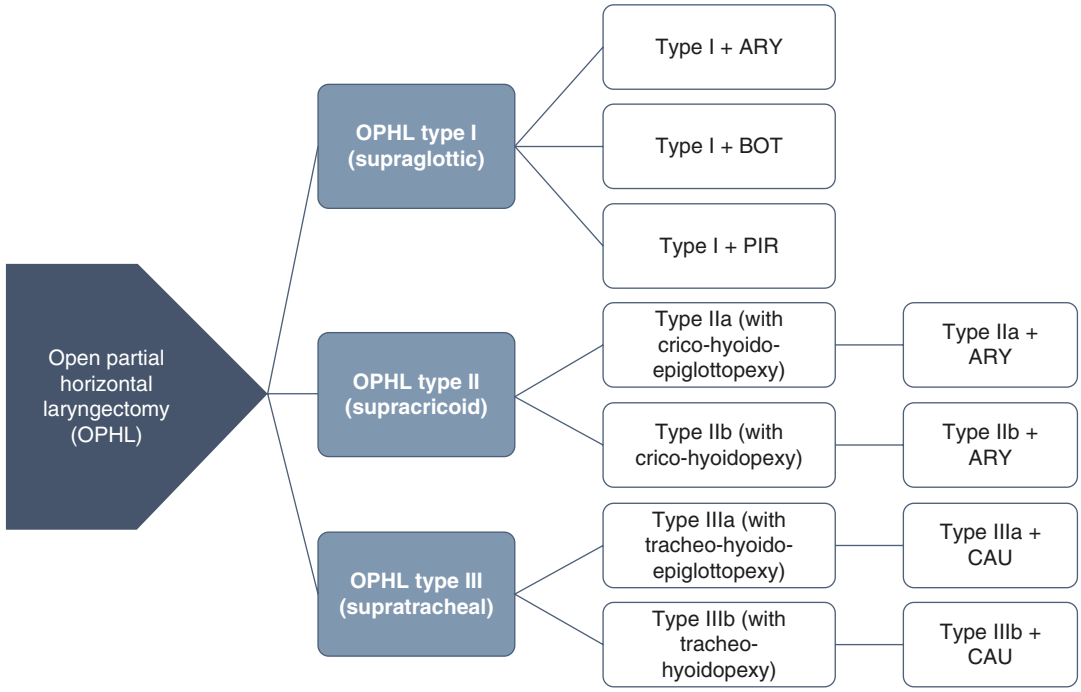


Fig. 12.5 Classification of open partial horizontal laryngectomy according to ELS. ARY: arytenoid, BOT: base tongue, PIR: piriform sinus, CAU: crico-arytenoid unit

limit of the specific surgery [31]. Thus, supraglottic (OPHL type I), supracricoid (OPHL type II) and supratracheal (OPHL type III) partial horizontal laryngectomies are distinguished. Furthermore, every single type of intervention can be extended to other nearby structures, laryngeal and/or pharyngeal, such as the arytenoid (ARY), the base tongue (BOT), the piriform sinus (PIR) or the crico-arytenoid unit (CAU) (Fig. 12.5).

12.9 Surgical Steps Common to All Types of Laryngectomies

12.9.1 Skin Incision

Cervical skin incisions with cephalad pedicle are the most frequently used; as often laryngeal surgery is associated with mono- or bilateral neck dissection, a Paul Andrè-type incision or a modified L-shaped incision is made. The most used incision starts from the mastoid tip and descends vertically to encompass the inferior insertion of sternomastoid muscle, describing a curve with internal concavity; at this point, the incision continues horizontally passing about 2–3 cm from the sternal manubrium to the contralateral mastoid (bi-mastoid incision). This type of skin incision is preferred because it has several advantages. It allows to respect the vascularization of the skin flap while preserving the main pedicles: supero-medial and infero-lateral. In addition, it guarantees an excellent visualization of the surgical site, from the submandibular region to the jugulum and supraclavicular fossae, allowing the identification and isolation of the vasculo-nervous and muscular structures of the neck, as well as of the pharynx, larynx and thyroid. Finally, another advantage of this technique is represented by the good aesthetic result of the scar with low risk of complications such as fistulas or skin necrosis (Fig. 12.6).

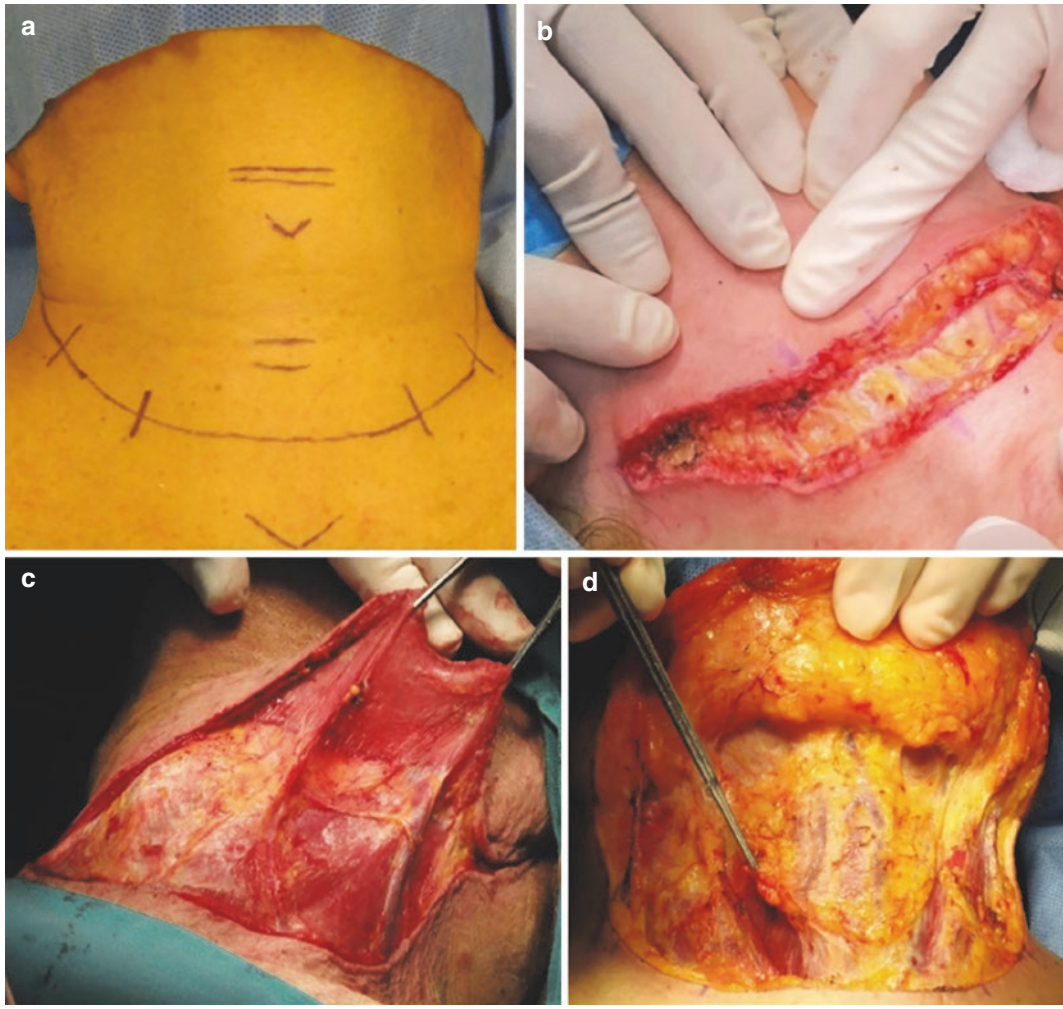


Fig. 12.6 (**a**) Skin incision marking, (**b**) skin incision, (**c**) detachment of the myo-cutaneous flap, (**d**) incision of the deep cervical fascia

12.9.2 Detachment of the Myo-cutaneous Flap

The incision includes skin, subcutis and platysma muscle. So, a myo-cutaneous flap is created which should be detached until it exceeds the body of hyoid bone by 1–2 cm. The superficial layer of the deep cervical fascia is now exposed. Dissection should be performed superficially to the external jugular vein, the greater auricular nerve and the superficial anterior branches of the cervical plexus (transverse cervical nerve and superficial cervical nerve) (Fig. 12.6).

12.9.3 Incision of the Deep Cervical Fascia Along the Anterior Border of the Sternocleidomastoid Muscle

In this surgical time, the section of the nerve branches originating from the point of Erb is performed. The superior portion of external jugular vein, anterolateral to the sternocleidomastoid muscle, can be preserved in the case of total laryngectomy with or without neck dissection. This is followed by the ligation and section of the anterior jugular veins, inferiorly at the sternal level and superiorly at the hyoid level (Fig. 12.6).

12.9.4 Exposure of the Larynx

Once the myo-cutaneous flap has been elevated, the plane of the extrinsic laryngeal muscles is exposed. The prelaryngeal muscles can be preserved and repositioned at the end of the surgery to protect and cover the residual larynx only when the demolition surgery does not include a contextual mono- or bilateral neck dissection. If, on the other hand, a mono- or bilateral neck dissection must be performed, the prelaryngeal muscles would most likely be devascularized and denervated; therefore, their preservation could be a disadvantage, as they will be exposed to necrosis and/or fibrosis. If their preservation is planned, the prelaryngeal muscles can be dissected at their hyoid insertion, turned downwards, or they can be dissected in their hyoid insertion and at the jugulum, with a lateral hinge on the omohyoid which is not dissected. As regards the musculature deep layer, the sternothyroid muscle can be preserved or dissected, depending on the type of surgery: spared in supraglottic laryngectomy, and dissected in supracricoid laryngectomy. The thyro-hyoid muscle is dissected at the hyoid insertion and completely resected (Fig. 12.7).

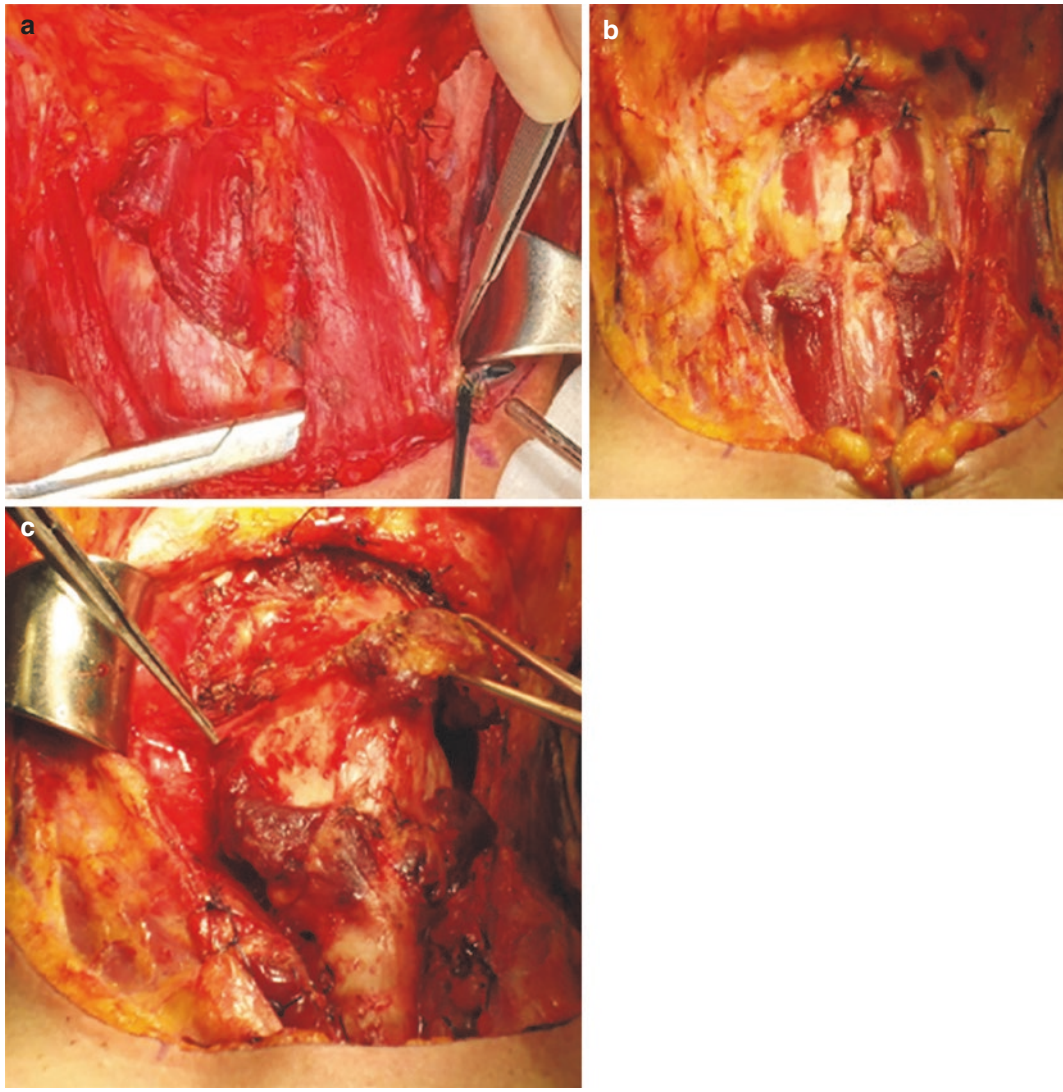


Fig. 12.7 (**a**) Dissection of superficial layer of strap muscles, (**b**) dissection of deep layer of strap muscles, (**c**) exposition of larynx

12.9.5 Larynx Skeletonization

- *Section of the inferior constrictor pharyngeal muscles* inserted into the thyroid cartilage, making an incision along the lateral thyroid border, while the larynx is rotated contralaterally.
- *Detachment of both piriform sinuses* from lateral to medial wall: this step can be limited on the upper third in case of supraglottic laryngectomy or complete in case of total or supracricoid laryngectomy.

12.9.6 Management of the Laryngeal Neurovascular Pedicle

As a rule, the ligation of the vascular pedicle is performed when the thyro-hyoid membrane is exposed. Artery and vein are on a superficial plane to the internal branch of the superior laryngeal nerve, which must be respected. Pedicle ligation can be avoided when the surgeon chooses to perform a narrow "V" thyrotomy (Fig. 12.8).

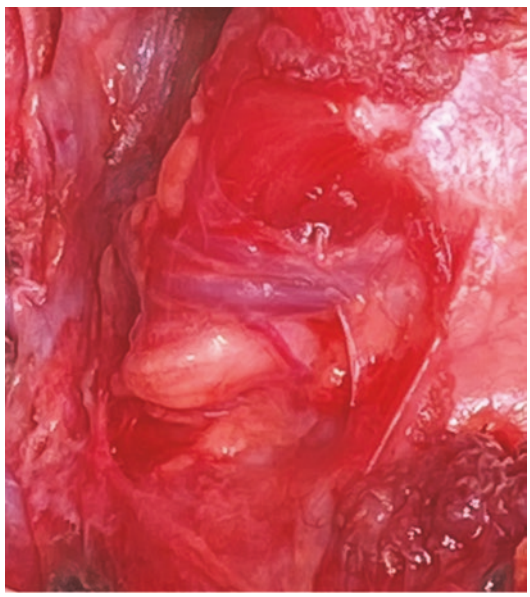


Fig. 12.8 Laryngeal neurovascular pedicle

12.10 Open Partial Horizontal Laryngectomy (OPHL)

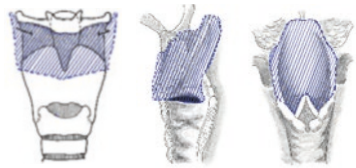
Unlike total laryngectomy, conservative surgery allows to preserve organ function without the need for permanent tracheostomy [32]. Furthermore, OPHL is also indicated in case of recurrence of laryngeal carcinoma after transoral laser microsurgery (TLM) [33] or radiotherapy [34], with excellent results in terms of oncological radicality and functional preservation.

As regards the swallowing function, in the immediate post-operative period, high rate of aspiration and dysphagia is reported in the literature [35], which drastically reduces over time within the first year after surgery, in about 90% of cases. Especially in the case of OPHL type II and III, this surgery causes an alteration of the voice that appears deep, hoarse, breathy and tiring because it demands excessive effort to close the neoglottis and allows the emission of phonemes [36]. In particular, the sphincter function of the neoglottis, in the case of OPHL type IIa and IIIa, is obtained by the anterior movement of arytenoid(s) towards the tongue base which, together with the residual epiglottis, allows the vibration of the mucosa and therefore the phonation [37]. Thus, overall, OPHL is a valid therapeutic alternative to radiotherapy and TLM with values between 70% and 90% in terms of local disease control (LC), disease-free survival (DFS) and overall survival (OS) [38–40].

12.10.1 Horizontal Supraglottic Laryngectomy: OPHL Type I

Horizontal supraglottic laryngectomy (Table 12.1) is performed in case of vestibular, marginal and laryngeal tumours of the three folds (pharyngo-epiglottic, glosso-epiglottic, ary-epiglottic). Superiorly, the resection involves the removal of the thyroid-hyo-epiglottic lodge, which represents a structure that anteriorly acts as a barrier to neoplastic progression. Inferiorly, the section must reach the ventricular floor, up to

Table 12.1 Horizontal supraglottic laryngectomy

OPHL type I	
OPHL type I + ARY	
OPHL type I + BOT	
OPHL type I + PIR	

ARY: arytenoid, BOT: base tongue, PIR: piriform sinus
Images drawn by Vincenzo Verro

the superior arcuate line, that is, the so-called *biological wall* between the supraglottic and glottic regions.

From the prognostic point of view, this type of surgery allows to obtain results that are mostly comparable to TLM; therefore, it is indicated where there is difficult transoral laryngeal exposure, in the case of bulky tumour [12, 36] or where there is an invasion of the lower portion of the pre-epiglottic space. Furthermore, comparing this type of surgery with TLM, Chiesa Estomba et al. found no statistically significant differences in terms of overall (OS) and specific survival (SS), as well as in terms of risk of aspiration pneumonia and dysphagia. Actually, in the literature, it has been reported that the recovery of swallowing function is faster in case of surgery performed by TLM but it should be noted that the same parameter, evaluated in the long term, does not show significant differences between the two surgical techniques [12].

12.10.1.1 Surgical Technique

In laryngeal horizontal surgery, the residual larynx is raised up to reach the hyoid bone and the tongue base, so the fixed point is represented by the set of hyoid bone, tongue and suprahyoid musculature.

1. Skin incision
2. Detachment of the myo-cutaneous flap
3. Incision of the deep cervical fascia along the anterior border of the sternocleidomastoid muscle
4. Exposure of the larynx
5. Larynx skeletonization
   - Section of the inferior constrictor pharyngeal muscles
   - Detachment of both piriform sinuses
6. Management of the laryngeal neurovascular pedicle
7. Subisthmic tracheostomy

   A subisthmic tracheostomy is usually performed to prevent compromising the vascularity of the cricoid cartilage and of the trachea. During the procedure, the Lalouette pyramid and the prelaryngeal lymph node are removed to expose the space between the cricoid and the lower edge of the thyroid cartilage. After this, the thyroid-pericardial lamina is incised and the thyroid ima veins are ligated. Once the anterior wall of trachea is exposed, we can choose the level of tracheostomy: between third and fourth or between fourth and fifth tracheal rings. Then, horizontal incision is made between the two tracheal rings and bilateral section of the anterior part of the ring is performed in order to create a lower hinged flap (Bjork's flap). This flap is then sutured to the skin with single stitches (Fig. 12.9).
8. Exeresis of the pre-epiglottic space

   Once the larynx has been exposed and the vascular pedicle has been ligated, and the amount of thyroid cartilage to be resected has been decided, the pre-epiglottic space will be excised by incising the thyro-hyoid membrane at its attachment to the lower edge of the hyoid bone. The detachment will continue on the inner face of the hyoid bone until the hyo-epiglottic ligament is dissected (Fig. 12.10).

   Once the hyoid bone, the thyro-hyoid membrane and the thyroid shield have been exposed, the external perichondrium must be detached by incising it on the upper edge of the thyroid ala for all its extension, which varies according to the thyrotomy decided by the surgeon: narrow V, wide V or horizontal. The different angulation of the thyrotomy affects the next step, which is the detachment of the piriform sinus in its upper third, and therefore also the section of the constrictor at the lateral edge of the thyroid ala, with extension of the detachment depending on the height of the thyrotomy itself.

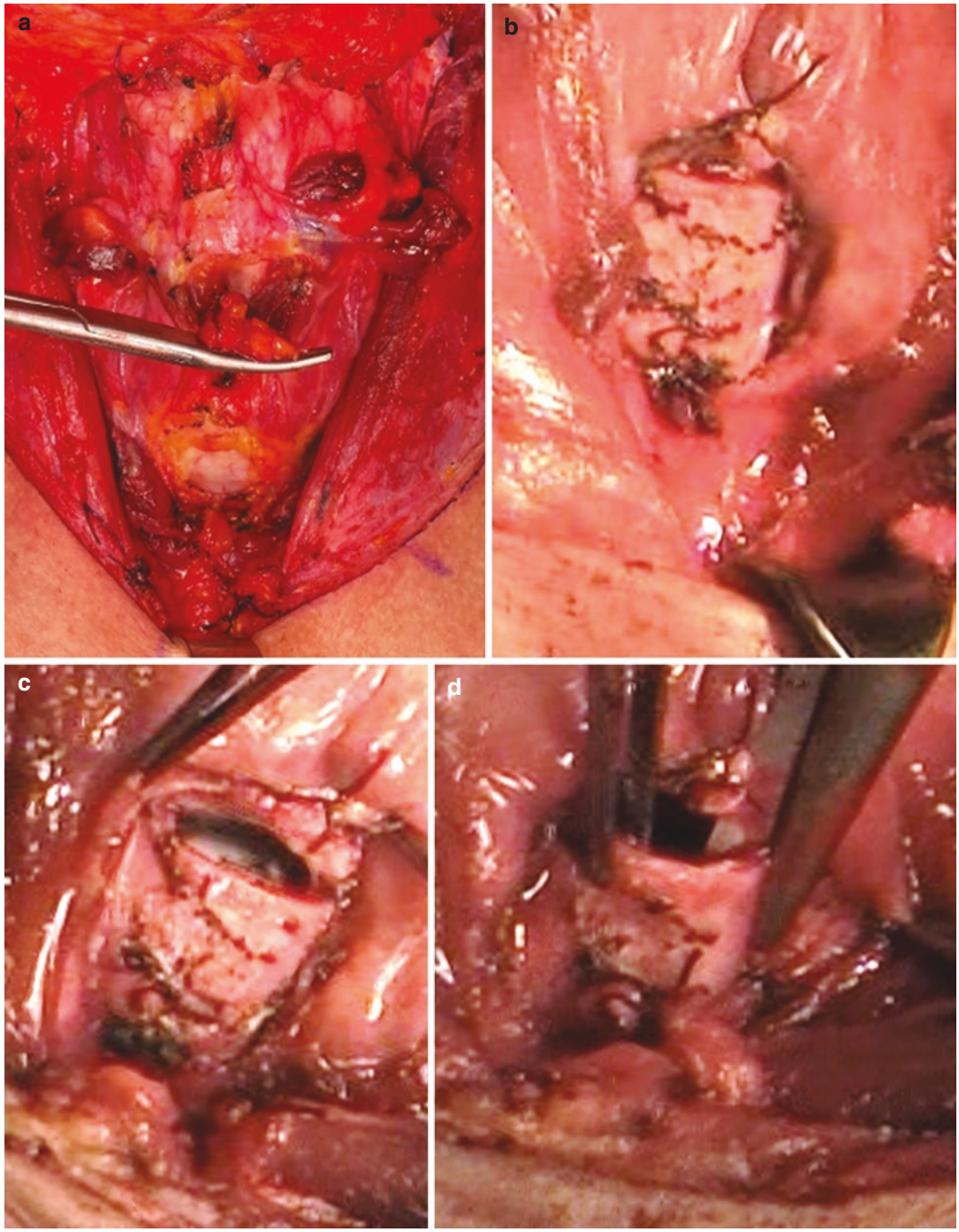


Fig. 12.9 Subisthmic tracheostomy: (**a**) incision of thyroid-pericardial lamina, (**b**) ligation of ima veins, (**c**) horizontal incision between two tracheal rings, (**d**) creation of Bjork's flap

9. Pharyngotomy

   Access to the hypopharynx will be performed by horizontal pharyngotomy, superiorly and medially to the pedicle, allowing to dissect the mucosa of the glosso-epiglottic vallecula. This pharyngotomy will allow the epiglottis to be overturned outwards by tractioning with a transfixed stitch or grasping forceps (Fig. 12.11).

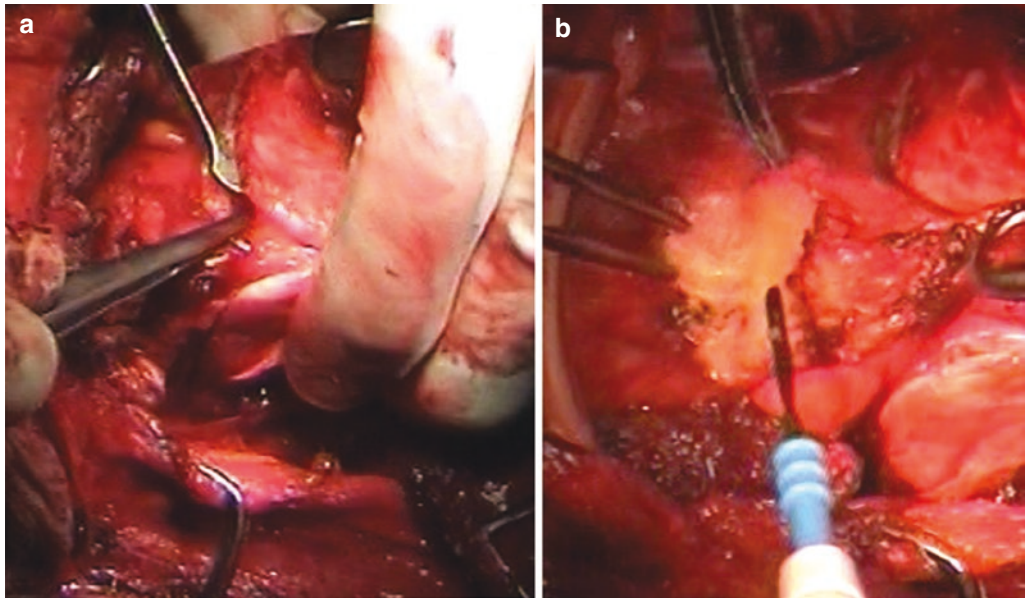


Fig. 12.10 Exeresis of the pre-epiglottic space: (**a**) detachment of external perichondrium of thyroid cartilage, (**b**) section of thyro-hyoid membrane

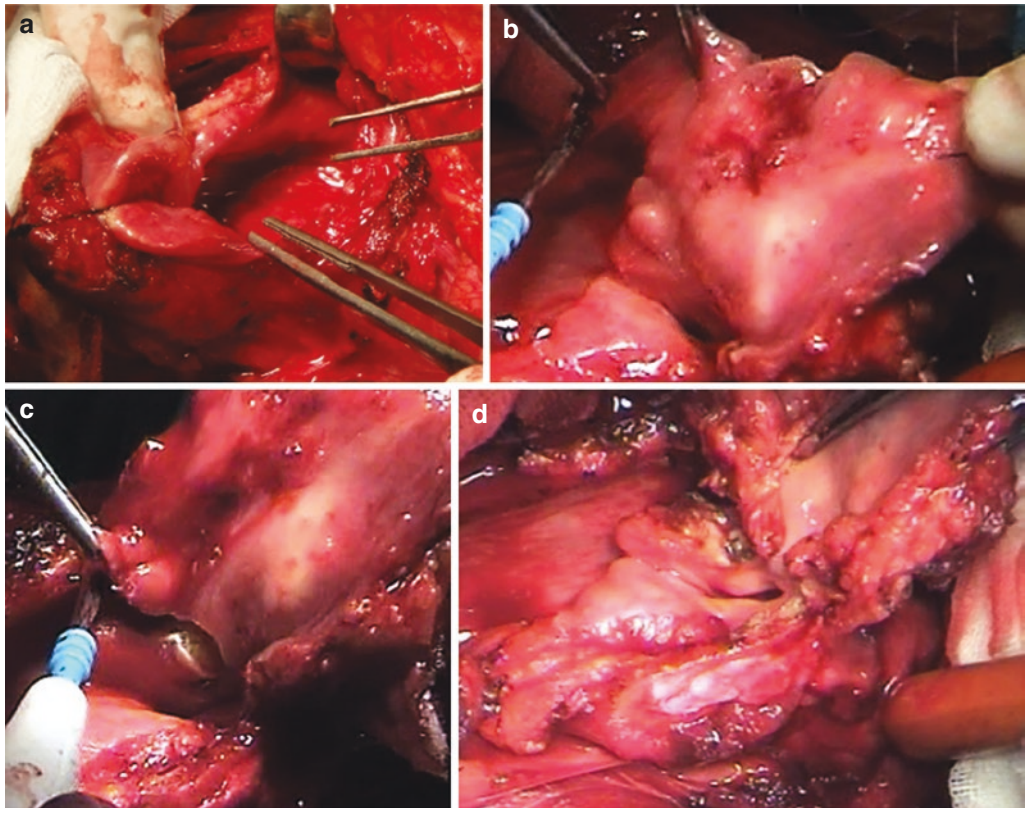


Fig. 12.11 (**a**) Epiglottis' traction by a transfixed stitch, (**b**) vertical section of pharyngo-laryngeal wall, (**c**) horizontal section through the ventricular floor, (**d**) detachment of the supraglottis from the glottis

10. Section of ary-epiglottic fold, false vocal fold and medial wall of the piriform sinus up to the ventricular floor (pharyngolaryngeal wall)
11. Vertical section of the pharyngoepiglottic fold (Fig. 12.11)
12. Horizontal section through the ventricular floor (Fig. 12.11)
13. Detachment of the supraglottis from the glottis (Fig. 12.11)

    The section line passes from the floor of the ventricle, along the previously performed thyrotomy line, to the anterior commissure. The same will be performed contralaterally.
14. Laryngeal closure and suspension

    The perichondrium, previously spared, can be sutured to the ventricle floor in order to cover the exposed para-glottic space. The pexy can start laterally by suturing the mucosa of the lateral wall of the piriform sinus with the mucosa of the lateral pharynx wall (Fig. 12.12).
15. Pexy

    Pexy is usually performed with three single stitches (Fig. 12.12):
    - A median passing from the lower border of the thyroid cartilage to include the tongue base and the hyoid bone.
    - Two laterals that pass the lower edge of the thyroid cartilage and internally follow the medial wall of the thyroid ala, lateral to the vocal cord: Superiorly, the needle passes above the intermediate digastric tendon avoiding the lingual artery. The

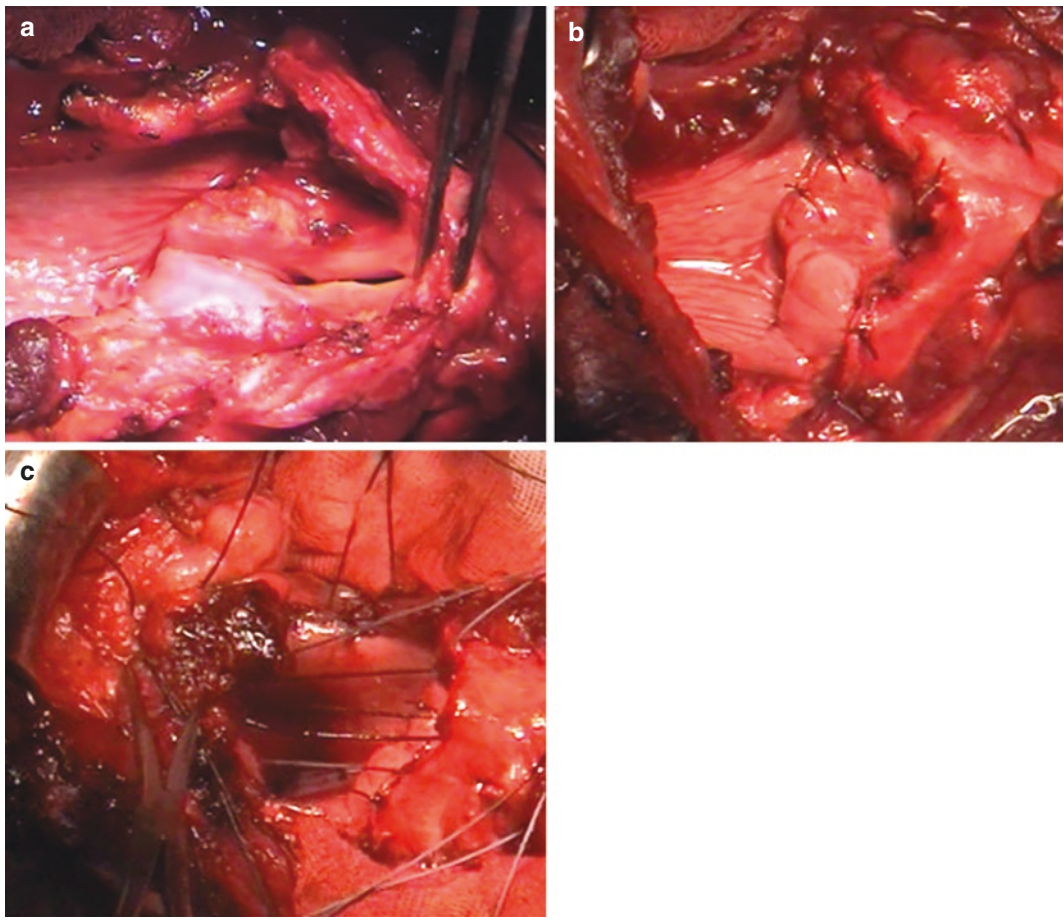


Fig. 12.12 (**a**) Glottic plane with arytenoids, (**b**) perichondrium sutured to ventricle floor in order to cover the paraglottic space, (**c**) pexy with three single stitches

suture used is absorbable, 0 or 1, with a curved atraumatic needle, with a diameter of 48 mm.

12.10.2 Horizontal Supracricoid Laryngectomy: OPHL Type II

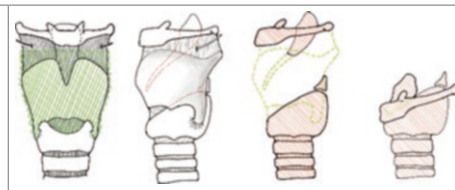
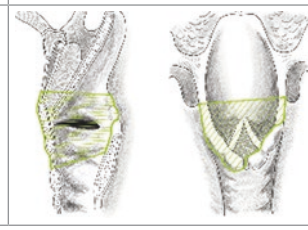
Succo et al. defined OPHL type II as the gold standard procedure in case of supraglottic T3 and glottic T3 carcinoma with true vocal cord fixity [29]. It consists of the removal of the epiglottis, the entire thyroid cartilage, Morgagni's ventricle, both true and false vocal cords and the pre-epiglottic and para-glottic spaces. Therefore, the only preserved structures are the cricoid cartilage, at least one mobile arytenoid cartilage and the hyoid bone [41]. Therefore, this surgery allows radical oncology and preservation of organ function with a better quality of life than that of patients who have undergone total laryngectomy with voice prosthesis placement [42], with a 5-year OS rate greater than 82.10%, a 5-year SS rate greater than 89.19% and a 5-year LC rate greater than 82.46% [41, 43, 44].

Furthermore, as regards the main indications for OPHL type II, the surgical procedure must be distinguished in the two subtypes. OPHL type IIa or CHEP (crico-hyoido-epiglottopexy) (Table 12.2) is indicated in these stages: (1) glottic T2 tumours with fixity of the vocal cord without involvement of the corresponding arytenoid and (2) glottic T2 tumours with extension to the ventricle, at the false vocal fold, to the infrahyoid epiglottis and/or with impaired vocal cord motility. OPHL type IIb with CHP (crico-hyoidopexy) (Table 12.3) is indicated in (1) glottic T2 tumours with bilateral invasion, (2) glottic T3 tumours originating from the anterior commissure and involving the pre-epiglottic space, (3) supraglottic or transglottic T2 tumours with invasion of the pre-epiglottic space and/or vocal cord fixity with normal motility of the corresponding arytenoid and (4) supraglottic or transglottic T4 tumours with partial involvement of the thyroid ala without exceeding the external perichondrium [41, 45].

However, OPHL type II is contraindicated in the following situations: (1) fixity of both arytenoid cartilages, (2) invasion of the crico-thyroid membrane, (3) invasion of the cricoid cartilage, (4) extension of the tumour to the glosso-epiglottic vallecula and/or invasion of the thyro-hyoid membrane, (5) invasion of the hyoid bone and (6) extension of the tumour beyond the external perichondrium of the thyroid cartilage [45].

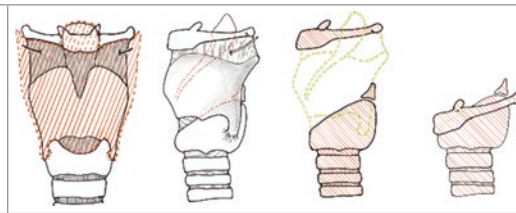
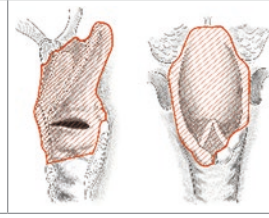
Finally, the main problem related to this surgery is represented by the impairment of

Table 12.2 Horizontal supracricoid laryngectomy with crico-hyoido-epiglottopexy

OPHL type IIa	
OPHL type IIa + ARY	

ARY: arytenoid
Image drawn by Vincenzo Verro

Table 12.3 Horizontal supracricoid laryngectomy with crico-hyoidopexy

OPHL type IIb (with crico-hyoidopexy)	
OPHL type IIb + ARY	

ARY: arytenoid
Image drawn by Vincenzo Verro

swallowing function with consequent risk of aspiration and aspiration pneumonia [46]. Anyway, over time, the patient will implement a compensation mechanism represented by the antero-medial rotation of the residual arytenoid with closure of the airways during swallowing [43].

12.10.2.1 Surgical Technique

1. Skin incision
2. Detachment of the myo-cutaneous flap
3. Incision of the deep cervical fascia along the anterior border of the sternocleidomastoid muscle
4. Exposure of the larynx
5. Larynx skeletonization (Fig. 12.13)
   - Section of the inferior constrictor pharyngeal muscles
   - Detachment of both piriform sinuses
   - Section of the small cornu of the thyroid cartilage, which is always performed in order to avoid recurrent nerve injuries during the disarticulation manoeuvre
6. Management of the laryngeal neurovascular pedicle
7. Subisthmic tracheostomy
8. Inferior endolaryngeal access (Fig. 12.14)

   Transection of the crico-thyroid muscles and of the crico-thyroid membrane, at the upper edge of the cricoid ring: The mucous membrane of the cricoid ring can be detached and removed in order to have an additional margin of healthy tissue. This surgical step is common to OPHL type IIa and IIb.
9. Superior endolaryngeal access (Figs. 12.14 and 12.15)
   - *OPHL type IIa:* Horizontal section of the thyro-hyoid membrane, of the tissues of the pre-epiglottic space and of the epiglottis, along the plane corresponding to the upper edge of the thyroid cartilage and within two vertical lines passing through the small thyroid cornu. Preservation of the suprahyoid portion of the epiglottis will ensure good tension of the ary-epiglottic folds
   - *OPHL type IIb*: Access is the same as that of OPHL type I
10. Endolaryngeal resection

    After the two accesses are performed and thus entering the larynx inferiorly and superiorly, the endolaryngeal inspection is reached by a full-thickness cut from the less involved side, taking care to spare the lateral crico-arytenoid muscle and the crico-arytenoid unit. This section encompasses the false cord, the posterior ventricular cornu

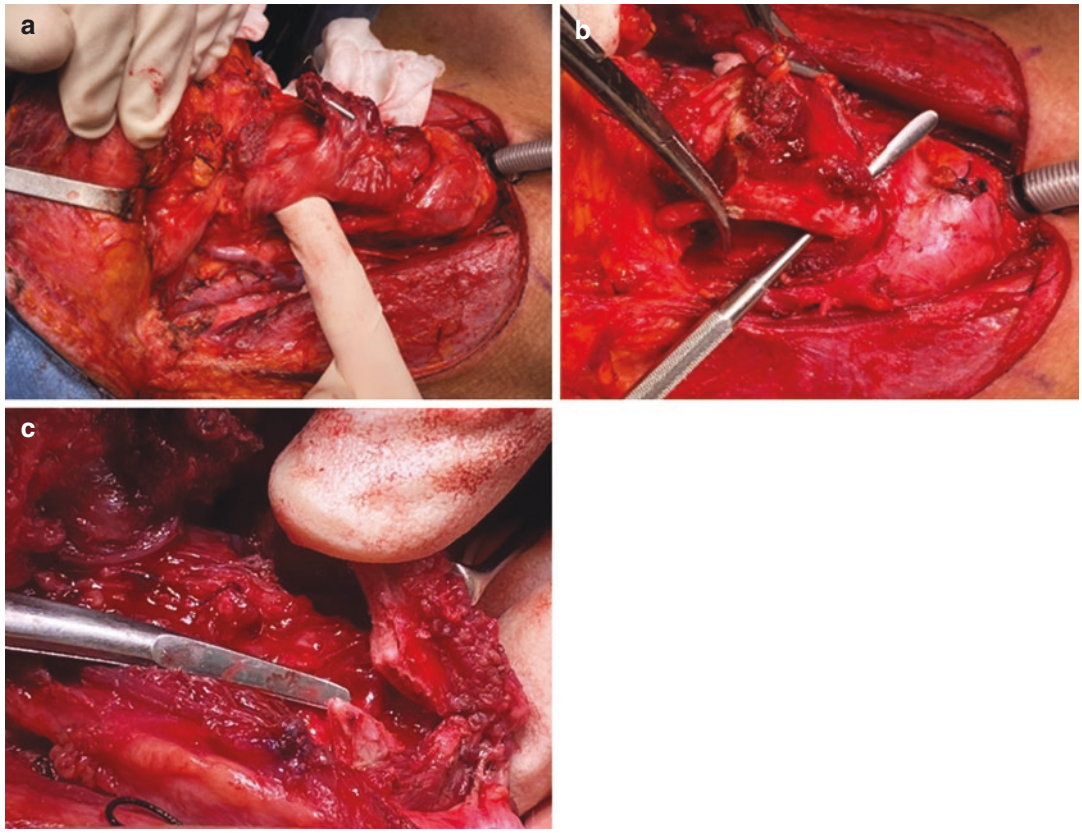


Fig. 12.13 (**a**) Detachment of piriform sinus, (**b**, **c**) section of the small cornu of the thyroid cartilage

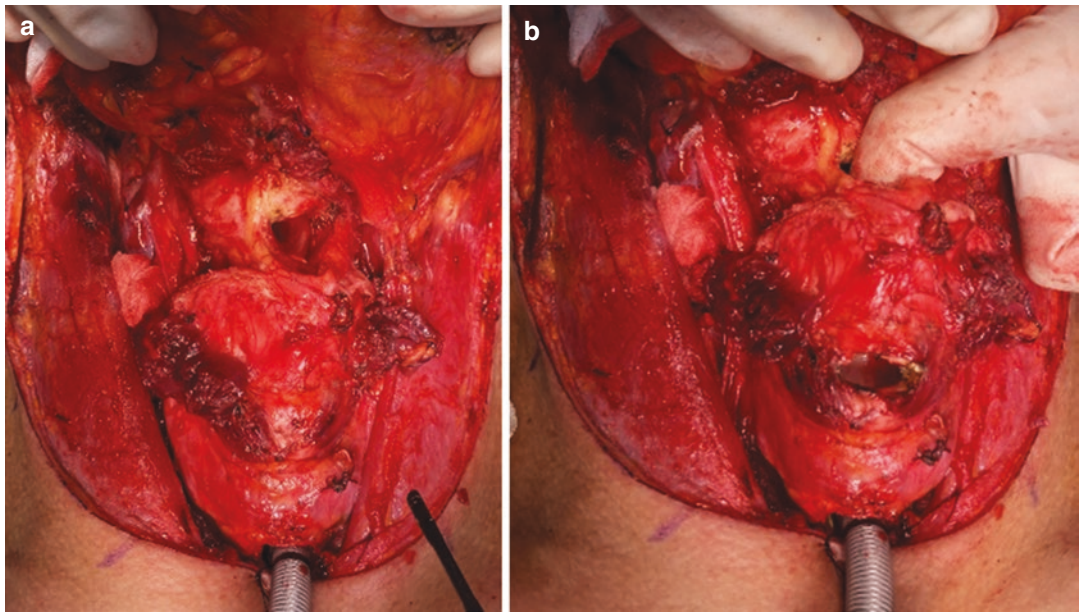


Fig. 12.14 OPHL type II: (**a**) superior endolaryngeal access, (**b**) superior and inferior endolaryngeal accesses

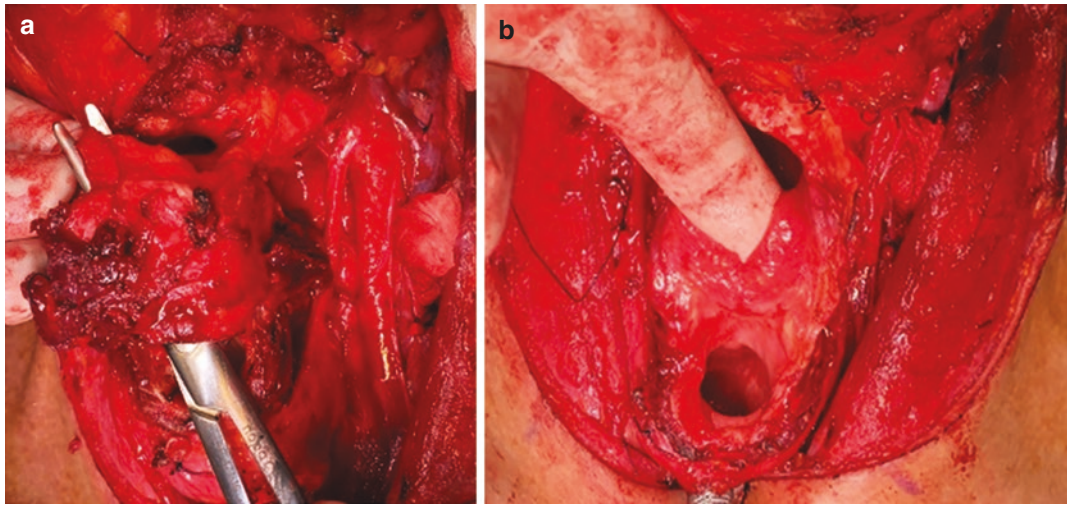


Fig. 12.15 OPHL type IIa: (**a**) horizontal section along the upper edge of the thyroid cartilage, (**b**) after endolarynx section and exeresis

and the true vocal cord at the vocal apophysis. The integrity of the piriform sinus is guaranteed. This section is also performed contralaterally in case of sparing of both arytenoids.

– *OPHL type II + ARY:* The sectioned muco-cartilage flap is reversed contralaterally after manual fracture of the thyroid shield in order to assess the real extension of the tumour and to continue with the next section under visual control. Endolaryngeal incisions should be made no less than 2 mm away from the lesion. This surgical time includes:

  • A hypoglottic horizontal section up to the midline, below the crico-arytenoid joint
  • A section of the mucosa along the edge of the arytenoid
  • A section along the ary-epiglottic fold bordering the medial wall of the piriform sinus

  • In this case, the excision of one arytenoid includes the detachment of the lateral crico-arytenoid muscle from the cricoid in order to ensure complete exeresis of the lower para-glottic space.

If the maintenance of both arytenoids is expected, the external detachment must be performed laterally to the lateral crico-arytenoid muscles in order to safeguard their integrity.

Once the exeresis is complete, on the side where the arytenoid is removed, it is advisable to reposition the medial wall of the piriform sinus to the cricoid in order to ensure a wider piriform sinus. Actually, on the side where the arytenoid is present, the tension of the piriform sinus' inlet will be guaranteed by the pexy.

11. Pexy

It is carried out by three single points, one median and two laterals, passing through the lower edge of the cricoid with 0 and 1–0 thread, 38 mm diameter, atraumatic needle (Fig. 12.16).

– *OPHL type IIa:* The median suture point will include, as the first step, the residual epiglottis and a portion of the tongue base, as close as possible to the lingual V; as the second step, the body of the hyoid bone is included. This suture can include

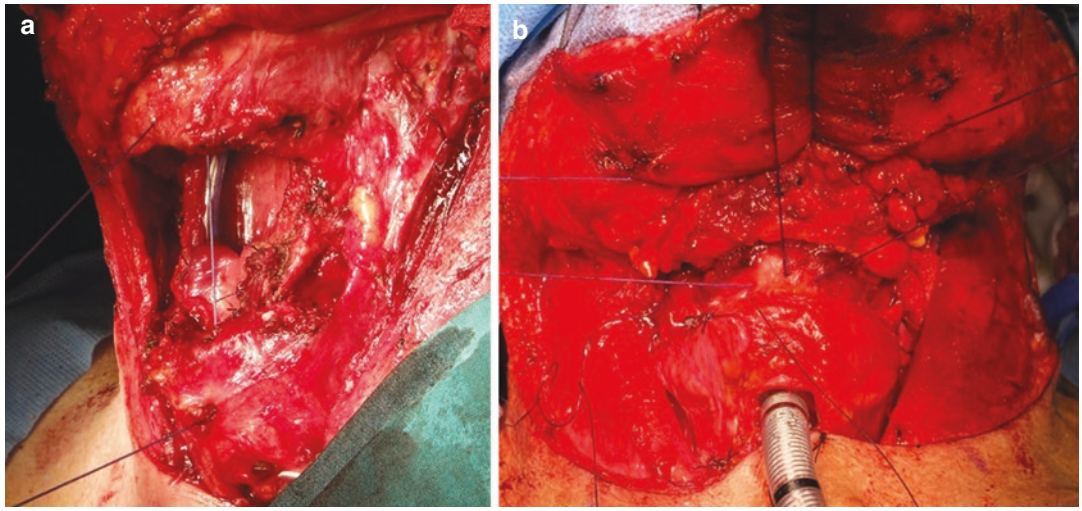


Fig. 12.16 (**a**) Crico-hyoido-epiglottopexy, (**b**) crico-hyoidopexy

the epiglottis, tongue base and hyoid bone in one step. The two lateral stitches will pass laterally to the median point, at the limit between the plate and the ring. These will also include the residual epiglottis and the tongue base and will pass centrally to the small cornu of the hyoid bone to avoid the lingual artery

– *OPHL type IIb*: The superior passage to the tongue base occurs as per the supraglottic laryngectomy (OPHL type I)

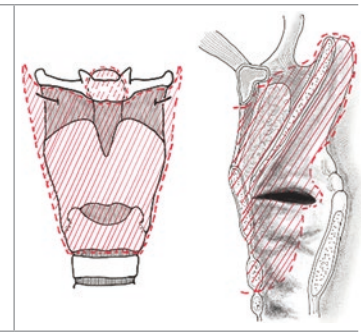
12. Pexy protection (optional)

The thyroid gland can be used to protect and reinforce the crico-hyoid-pexy. Being free on the lower side from the thyro-pericardial membrane, its raising will be facilitated. Then, the thyroid body is sutured to the suprahyoid muscles with stitches passing through the upper edge of the gland, avoiding the medial branch of superior thyroid artery.

12.10.3 Horizontal Supratracheal Laryngectomy: OPHL Type III

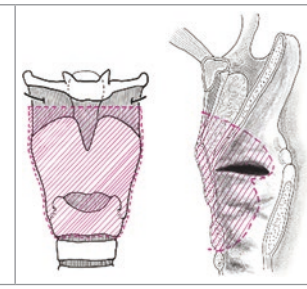
The horizontal supratracheal laryngectomy (Tables 12.4 and 12.5) was introduced in 2006 to

Table 12.5 Horizontal supratracheal laryngectomy with tracheo-hyoidopexy

OPHL type IIIb (with tracheo-hyoidopexy)	
OPHL type IIIb + ARY	

ARY: arytenoid
Image drawn by Vincenzo Verro

Table 12.4 Horizontal supratracheal laryngectomy with tracheo-hyoido-epiglottopexy

OPHL type IIIa (with tracheo-hyoido-epiglottopexy)	
OPHL type IIIa + ARY	

ARY: arytenoid
Image drawn by Vincenzo Verro

respond to the need of a surgery that would guarantee the preservation of the laryngeal function with an excellent long-term locoregional control in those cases which cannot be solved by a less extensive demolition, i.e. OPHL type II [29].

Therefore, this type of OPHL is indicated in the case of (1) glottic T2 tumours with anterior or lateral extension at the subglottic level and invasion of the elastic cone up to the cricoid ring; (2) T3 transglottic tumours with involvement of the upper para-glottic space and subglottic extension; (3) T3 glottic-subglottic tumours with involvement of the para-glottic space, elastic cone and external perichondrium of the thyroid cartilage; and (4) T4a tumours with limited extralaryngeal, anterior or lateral extension [29, 47]. Conversely, it is contraindicated in case of (1) T4a supraglottic carcinoma with involvement of the tongue base or invasion of the hyoid bone, (2) N3, (3) T4a tumours with involvement of the first tracheal ring and (4) T3 glottic-subglottic tumours involving the posterior crico-arytenoid muscle and the submucosa of the sinus piriform [29, 47].

This surgical technique includes the resection of the glottic and subglottic plane, thyroid cartilage and amount of the cricoid cartilage depending on the tumour extension but always with preservation of at least one crico-arytenoid unit [48]. Assuming that a more extensive exeresis is correlated with a more compromised laryngeal function, Schindler et al. compared various parameters (swallowing, voice and speech and quality of life) between OPHL type IIa and IIIa and demonstrated the absence of statistically significant differences between the two long-term surgical techniques [37]. The most frequently reported complication is known as post-operative laryngeal obstruction (POLO), which can be treated with CO2 laser surgery [19, 29].

In conclusion, OPHL type III can be considered an effective therapeutic strategy in the case of glottic or transglottic tumours with subglottic extension as an alternative to the chemoradiotherapy protocol, with oncological radicality and, at the same time, partial preservation of the larynx [48].

12.10.3.1 Surgical Technique

1. Skin incision
2. Detachment of the myo-cutaneous flap
3. Incision of the deep cervical fascia along the anterior border of the sternocleidomastoid muscle
4. Exposure of the larynx
5. Larynx skeletonization
   - Section of the inferior constrictor pharyngeal muscles
   - Detachment of both piriform sinuses
6. Management of the laryngeal neurovascular pedicle
7. Subisthmic tracheostomy
8. Inferior access

   The horizontal section passes through the lower edge of the cricoid cartilage.
9. Superior access
   - OPHL type IIIa: the superior approach is comparable to an OPHL type IIa
   - OPHL type IIIb: the superior approach is the same as OPHL type I and IIb
10. Cricoid resection

    There are two types of cricoid resection
    - Cricoid arches
    - Cricoid arches + half cricoid plate + CAU
11. Piriform sinuses

    If the resection does not involve half cricoid plate, the piriform sinuses will be fixed with sutures to the lateral part of the plate and possibly also to the first tracheal ring.

    In the case of resection of a half cricoid plate, the ipsilateral retro-cricoid mucosa will be fixed with sutures to the residual plate, the section line on the plate and the pars membranacea of trachea.
12. Pexy

    In this case, the pexy is performed between the first tracheal ring at the bottom and follows the same steps as OPHL type I and type II above.

12.11 Total Laryngectomy

Total laryngectomy was performed for the first time in 1873 by Billroth [49] and, until a few decades ago, has represented the therapeutic gold

standard for advanced laryngeal cancers. To date, the conservative surgery has reduced total laryngectomy only in limited cases, i.e. in case of T3 and T4a laryngeal carcinoma, where conservative laryngectomy or non-surgical therapy failed (the so-called "salvage surgery") [50, 51]. Several studies have demonstrated the advantage of total laryngectomy over chemoradiotherapy in terms of survival and quality of life [52, 53], even in case of T4a where the surgical approach represents the best therapeutic option [54]. Obviously, the surgical indication and its effectiveness in terms of OS, LC and quality of life depend on the patient, his/her age and comorbidities.

Total laryngectomy involves impairment in breathing, speech and swallowing; therefore, the rehabilitation phase is also fundamental as well as the demolition phase. Thus, breathing is ensured by the tracheostomy which, differently from OPHL interventions, in this case will be permanent. With regard to phonation, instead, various strategies for voice rehabilitation have been developed over the years: the tracheoesophageal prosthesis (TEP), the oesophageal speech or the electronic larynx [55]. According to many studies, TEP would represent the best solution for voice restoration because it is more similar to normal phonation in terms of sound and functioning [56, 57]. Despite this, it would not be correct to define TEP as an absolute gold standard, since the best voice restoration strategy depends on the patient with his/her comorbidities and preferences [58]. Swallowing can be affected by total laryngectomy; about 40% of laryngectomized patients can develop dysphagia even years after surgery and especially after adjuvant chemoradiotherapy [59, 60]. Actually, laryngectomy inevitably causes an alteration of the physiology of swallowing with an increased pharyngeal transit time of the bolus and pharyngeal residue and a reduced peristaltic contraction of the oesophagus [61].

Moreover, other complications may affect the post-operative course of total laryngectomy: pharyngocutaneous fistula (about 28% of cases) or tracheo-oesophageal fistula (5% of cases), pharyngeal stenosis (about 14% of cases) or tracheostomy stenosis (about 20% of cases) [62]. Nevertheless, total laryngectomy remains the most preferable choice in case of stage IV laryngeal cancer compared to chemoradiotherapy [63].

12.11.1 Surgical Technique

1. Skin incision
2. Detachment of the myo-cutaneous flap
3. Incision of the deep cervical fascia along the anterior border of the sternocleidomastoid muscle
4. Dissection of the fascia in the latero-medial direction
5. Section of omohyoid and sternohyoid muscles

   Section of the omohyoid muscle along the anterior edge of the sternocleidomastoid muscle and lower section of the sternohyoid muscle are performed. Superiorly, these muscles are dissected at the hyoid attachment.
6. Lower section of the sternothyroid muscle
7. Section of the thyro-hyoid muscle at insertion on the hyoid

   NB: Management of strap muscles: the strap muscles can be removed before laryngectomy or left and removed in en bloc modality with larynx, especially in case of T4a with infiltration of strap muscles, platysma and skin.
8. Thyroid time

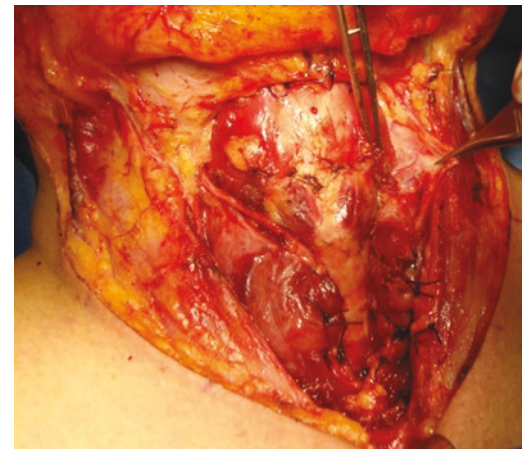


Fig. 12.17 Detachment of thyroid lobes from the laryngeal-tracheal axis

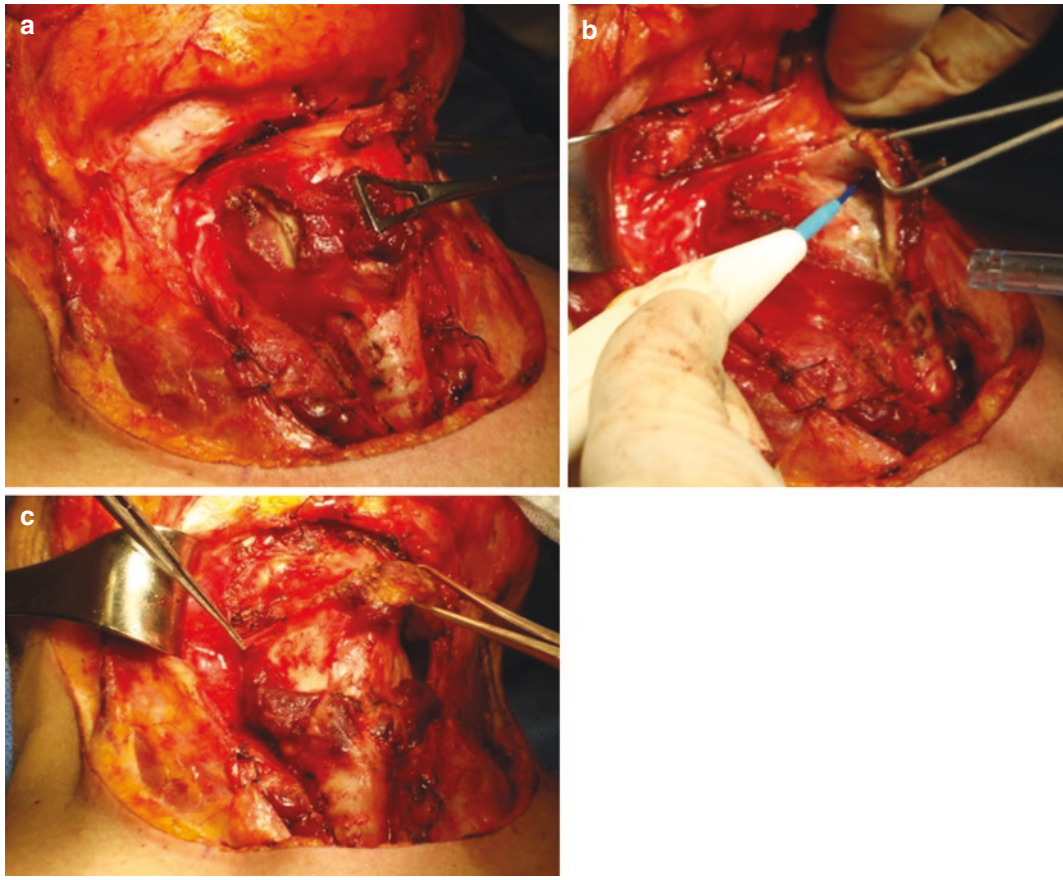


Fig. 12.18 (**a**) Contralateral rotation of the larynx, (**b**) dissection of the piriform sinus, (**c**) section of the suprahyoid muscles' insertion to the hyoid bone

Detachment of thyroid lobes from the laryngeal-tracheal axis is performed. Separate the two thyroid lobes by performing an isthmotomy or isthmectomy, according to need (Fig. 12.17).

9. Ligature of the laryngeal pedicle
10. Contralateral rotation of the larynx with positioning of the finger behind the thyroid ala (Fig. 12.18)
11. Section of the constrictor muscles along the lateral edge of the thyroid ala up to the upper cornu and, inferiorly, to detach the crico-pharyngeal muscle
12. Blunt dissection of the piriform sinus via the internal sub-perichondrium (Fig. 12.18)
13. Section of the suprahyoid muscles' insertion to the hyoid bone (Fig. 12.18)
14. Incision along the upper edge of the hyoid bone from the body up to the large cornu which are separated from the lateral walls of the hypopharynx
15. Section of the hyo-glossus ligament
16. Tracheostomy

    It is usually performed by including two tracheal rings, between the second and the third rings. If the tracheostomy was per-

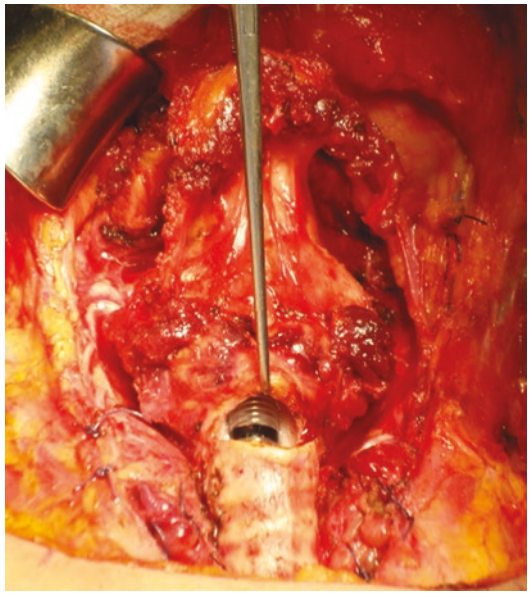


Fig. 12.19 Tracheotomy

formed previously, the tracheal section should be performed inferiorly to the previous tracheostomy, including only one tracheal ring (Fig. 12.19).

17. Detachment of larynx and trachea from hypopharynx and oesophagus

    Once the posterior membranous wall of the trachea is dissected, the laryngo-tracheal axis is detached by blunt dissection, from the bottom upwards. Section of recurrent nerves follows. Detachment can reach up to the upper edge of the cricoid plate (Fig. 12.20).

18. Pharyngotomy

    This can be performed at the top along the glosso-epiglottic fossae or, below, at the height of the upper edge of the cricoid in the interarytenoid region. At this point, once the approach to the hypopharynx has been chosen, the section must follow the ary-epiglottic fold, curving medially along the glosso-epiglottic fossae until it surrounds the contralateral ary-epiglottic fold. Access, upper or lower, is performed on the side less affected by the tumour (Fig. 12.20).

19. Examination of the endolaryngeal tumour

    Examination of endolaryngeal tumour's extension to evaluate the need of wider resections on its margins should be carried out.

20. Crico-pharyngeal myotomy

    This step is critical in view of voice prosthesis placement. Before closing the pharynx, the finger is put at the level of the pharyngotomy opening in order to stretch the muscle that is dissected along the lateral wall of the hypopharynx. This manoeuvre should be performed carefully in order to dissect only the muscle fibres in order to spare the underlying mucosa (Fig. 12.20).

21. Tracheo-oesophageal fistula

    Tracheo-oesophageal fistula and insertion of voice prostheses can be performed (Fig. 12.21).

22. Closure of the pharynx

    The suture is performed in a T shape: the horizontal branch along the upper edge of the piriform sinuses and the vertical branch along the retro-cricoid region (Fig. 12.22). Usually, the suture is performed in interrupted sutures and involves three layers:

    (a) Inverting suture: mucosa-mucosa
    (b) Submucosal-serous
    (c) Constrictor muscle layer

    This suture can also be performed in two layers:

    (a) Serous-serous
    (b) Constrictor muscle layer

23. Packaging of the tracheostomy

    Once the tracheal section is performed, the anterior edge of the trachea is fixed with interrupted suture to the skin of the jugulum. Laterally, the sternal head of the sternocleidomastoid muscle should be used to fix the tracheostomy in order to avoid possible

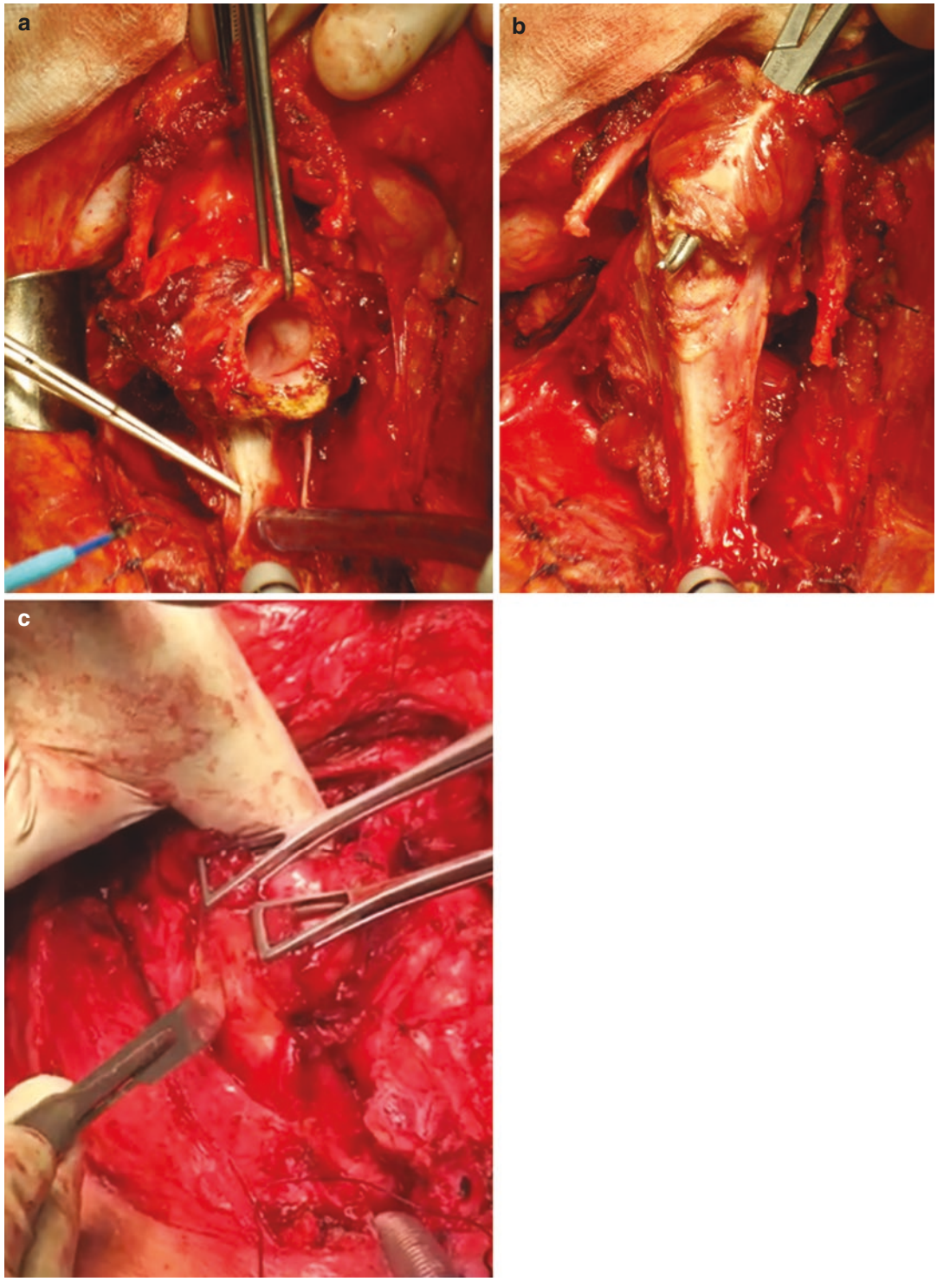


Fig. 12.20 (**a**) Detachment of larynx from hypopharynx and oesophagus, (**b**) pharyngotomy, (**c**) crico-pharyngeal myotomy

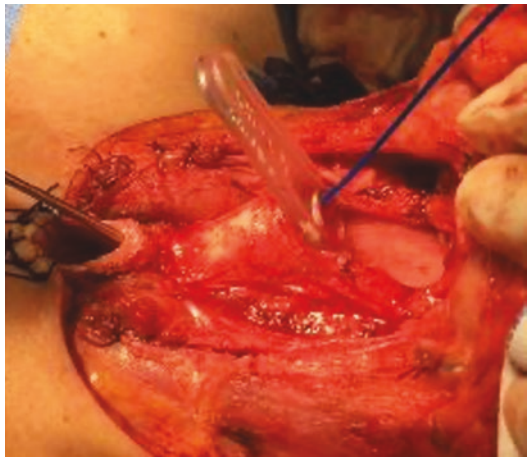


Fig. 12.21 Trache-oesophageal fistula

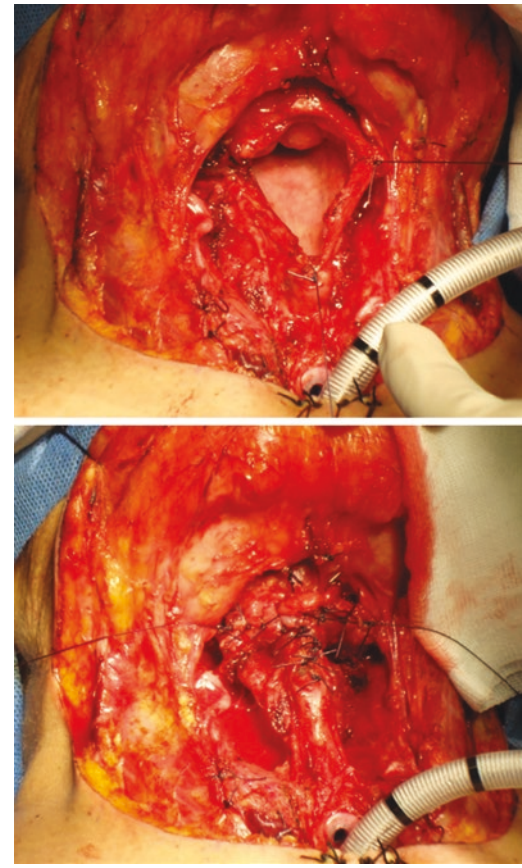


Fig. 12.22 Closure of the pharynx

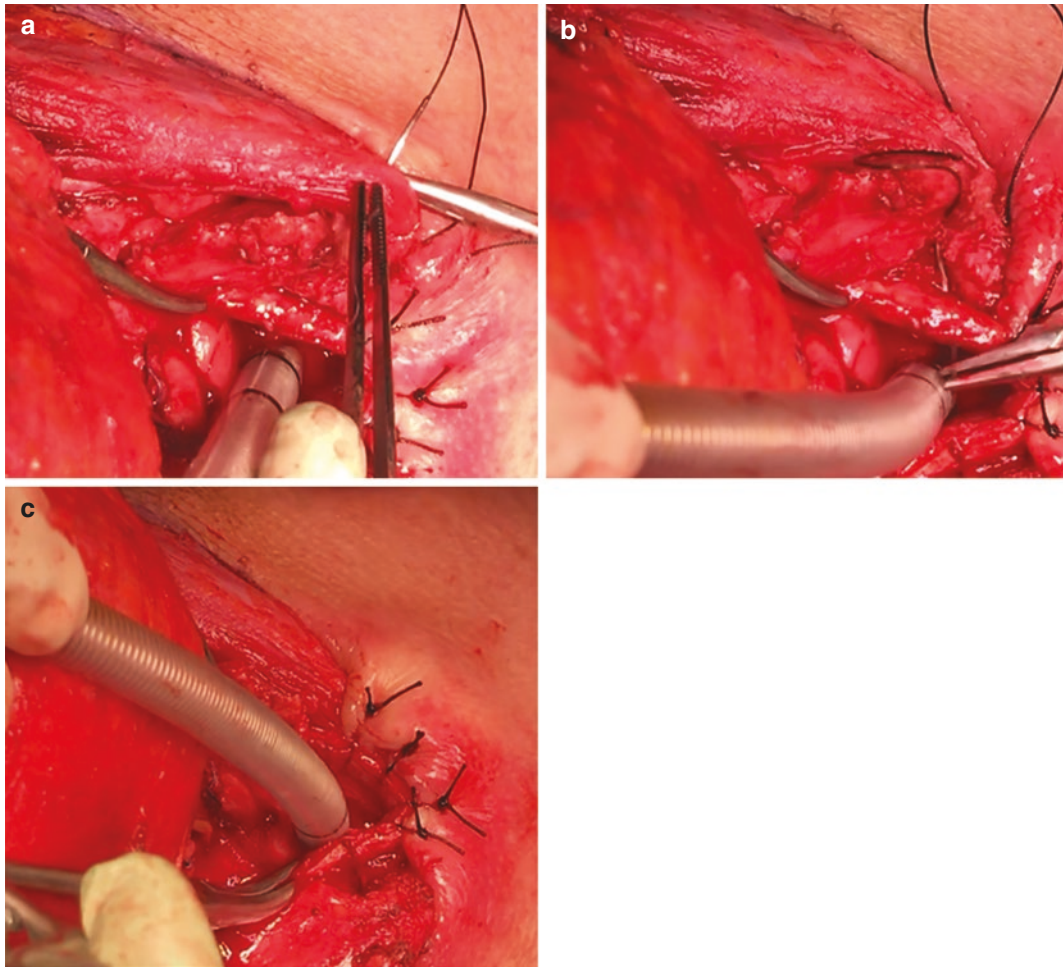


Fig. 12.23 Packaging of the tracheostomy including in a single suture point: (**a**) skin, (**b**) sternomastoid muscle, (**c**) lateral part of the tracheal ring

circular stenosis of the tracheostoma or its sliding behind the sternal manubrium and to ensure stable flattening of the tracheostoma: this procedure is performed including the lateral part of the tracheal ring, the sternomastoid muscle and the skin in a single suture point (Fig. 12.23).

12.12 Future Challenges

As previously written, in the case of total laryngectomy, there is a significant impairment of patient's quality of life due to dependence on the tracheostomy for breathing, for unnatural speech strategies and for swallowing difficulties. This is the reason why, in the last 50 years, new strategies have been theorized in order to recreate the organ with its functions. In particular, implanting an artificial laryngeal prosthesis has been hypothesized: this experiment to date has only been performed on animals with various serious complications such as infections, erosion and migration of the prosthesis with a serious danger to life [64]. In 2001, Strome et al. performed a laryngeal transplant on a male patient [65]. Forty months after transplant, the patient presented voice and swallowing ability near to normal condition; but it was not possible to close the tracheal stoma and restore the normal and physiological airway.

If to date the surgical techniques, in the case of both OPHL and total laryngectomy, are well defined and globally accepted, the strategies for recreating the larynx post-total laryngectomy have not yet been studied and the proposed hypotheses are still in the initial stages of experimentation. Therefore, the future challenge is to identify the best strategy to recover all laryngeal functions near to normal.

12.13 Conclusion

The larynx performs important and difficult functions with an elegant simplicity [51]. Oncological laryngeal surgery must be carried out with care both in the demolition phase and in the reconstructive phase. So, two main objectives have to be reached: radicality of resection and function preservation guaranteeing the best quality of life for the patient.

According to this, over the years, different surgical techniques have been proposed in order to couple a less demolitive surgery with oncological radicality in order to limit total laryngectomy as much as possible. For the same reason, the strategies for phonatory and respiratory rehabilitation are equally important and fruitful. Unfortunately, due to its fundamental role in three essential functions for humans (breathing, speaking, eating), recreating the larynx remains the most difficult challenge but also the most important in order to give back to the patient "simply" his/her normality.

References

1. McCarrel TM, Woodie JB. Update on laryngeal disorders and treatment. Vet Clin North Am Equine Pract. 2015;31(1):13–26. https://doi.org/10.1016/j.cveq.2014.11.009.
2. Alonso JM. Conservative surgery of cancer of the larynx. Trans Am Acad Ophthalmol Otolaryngol. 1947;51:633–42.
3. Rucci L. Testo Atlante di embriologia clinica della Laringe. La chirurgia conservativa compartimentale della regione glottica. Florence: Firenze University Press; 2006.
4. Prades JM, Peoc'h M, Petcu C, Karkas A, Dumollard JM, Gavid M. The anterior commissure of the human larynx revisited. Surg Radiol Anat. 2017;39(8):871–6. https://doi.org/10.1007/s00276-017-1814-2.
5. Mor N, Blitzer A. Functional anatomy and oncologic barriers of the larynx. Otolaryngol Clin N Am. 2015;48(4):533–45. https://doi.org/10.1016/j.otc.2015.04.002.
6. Joo YH, Park JO, Cho KJ, Kim MS. Relationship between paraglottic space invasion and cervical lymph node metastasis in patients undergoing supracricoid partial laryngectomy. Head Neck. 2012;34(8):1119–22. https://doi.org/10.1002/hed.21892.
7. Tucker G Jr. Some clinical inferences from the study of serial laryngeal sections. Laryngoscope. 1963;73:728–748. https://doi.org/10.1288/00005537-196306000-00010.
8. Sato K, Kurita S, Hirano M. Location of the preepiglottic space and its relationship to the paraglottic space. Ann Otol Rhinol Laryngol. 1993;102(12):930–4. https://doi.org/10.1177/000348949310201204.
9. Naunheim MR, Carroll TL. Benign vocal fold lesions: update on nomenclature, cause, diagnosis, and treatment. Curr Opin Otolaryngol Head Neck Surg. 2017;25(6):453–8. https://doi.org/10.1097/MOO.0000000000000408.
10. Stinnett S, Chmielewska M, Akst LM. Update on management of hoarseness. Med Clin North Am. 2018;102(6):1027–40. https://doi.org/10.1016/j.mcna.2018.06.005.
11. Tulli M, Re M, Bondi S, et al. The prognostic value of anterior commissure involvement in T1 glottic cancer: a systematic review and meta-analysis. Laryngoscope. 2019; https://doi.org/10.1002/lary.28395.
12. Chiesa Estomba CM, Betances Reinoso FA, Lorenzo Lorenzo AI, Fariña Conde JL, Araujo Nores J, Santidrian HC. Functional outcomes of supraglottic squamous cell carcinoma treated by transoral laser microsurgery compared with horizontal supraglottic laryngectomy in patients younger and older than 65 years. Acta Otorhinolaryngol Ital. 2016;36(6):450–8. https://doi.org/10.14639/0392-100X-864.
13. Gao P, Gong L, Wang X. Induction chemotherapy in patients with resectable laryngeal cancer: a meta-analysis. Mol Clin Oncol. 2018;9(2):155–62. https://doi.org/10.3892/mco.2018.1645.
14. Ferlay J, Soerjomataram I, Dikshit R, et al. Cancer incidence and mortality worldwide: sources, methods and major patterns in GLOBOCAN 2012. Int J Cancer. 2015;136(5):E359–86. https://doi.org/10.1002/ijc.29210.
15. Ciolofan MS, Vlăescu AN, Mogoantă CA, et al. Clinical, histological and Immunohistochemical evaluation of larynx cancer. Curr Health Sci J. 2017;43(4):367–75. https://doi.org/10.12865/CHSJ.43.04.14.
16. Horakova Z, Bretislav G, Karel V, Pazourkova M, Urbanková P, Petr S. Non-squamous cell carcinomas of the larynx madridge. J Otorhinolaryngol. 2018;3(1):41–6. https://doi.org/10.18689/mjol-1000108.

17. Yılmaz T, Süslü N, Atay G, Günaydın RÖ, Bajin MD, Özer S. The effect of midline crossing of lateral supraglottic cancer on contralateral cervical lymph node metastasis. Acta Otolaryngol. 2015;135(5):484–8. https://doi.org/10.3109/00016489.2014.986759.
18. Elegbede AI, Rybicki LA, Adelstein DJ, et al. Oncologic and functional outcomes of surgical and nonsurgical treatment of advanced squamous cell carcinoma of the supraglottic larynx. JAMA Otolaryngol Head Neck Surg. 2015;141(12):1111–7. https://doi.org/10.1001/jamaoto.2015.0663.
19. Succo G, Bussi M, Presutti L, et al. Supratracheal laryngectomy: current indications and contraindications. Acta Otorhinolaryngol Ital. 2015;35(3):146–56.
20. Tachibana T, Orita Y, Marunaka H, et al. Glottic cancer in patients without complaints of hoarseness. Head Neck. 2016;38(Suppl 1):E316–20. https://doi.org/10.1002/hed.23992.
21. MacNeil SD, Patel K, Liu K, et al. Survival of patients with subglottic squamous cell carcinoma. Curr Oncol. 2018;25(6):e569–75. https://doi.org/10.3747/co.25.3864.
22. Paul BC, Rafii B, Achlatis S, Amin MR, Branski RC. Morbidity and patient perception of flexible laryngoscopy. Ann Otol Rhinol Laryngol. 2012;121(11):708–13. https://doi.org/10.1177/000348941212101102.
23. Caffier PP, Nawka T, Ibrahim-Nasr A, et al. Development of three-dimensional laryngostroboscopy for office-based laryngeal diagnostics and phonosurgical therapy. Laryngoscope. 2018;128(12):2823–31. https://doi.org/10.1002/lary.27260.
24. Ni XG, He S, Xu ZG, et al. Endoscopic diagnosis of laryngeal cancer and precancerous lesions by narrow band imaging. J Laryngol Otol. 2011;125(3):288–96. https://doi.org/10.1017/S0022215110002033.
25. Piazza C, Del Bon F, Peretti G, Nicolai P. Narrow band imaging in endoscopic evaluation of the larynx. Curr Opin Otolaryngol Head Neck Surg. 2012;20(6):472–6. https://doi.org/10.1097/MOO.0b013e32835908ac.
26. Banko B, Dukić V, Milovanović J, Kovač JD, Artiko V, Maksimović R. Diagnostic significance of magnetic resonance imaging in preoperative evaluation of patients with laryngeal tumors. Eur Arch Otorhinolaryngol. 2011;268(11):1617–23. https://doi.org/10.1007/s00405-011-1701-0.
27. Bussu F, Paludetti G, Almadori G, et al. Comparison of total laryngectomy with surgical (cricohyoidopexy) and nonsurgical organ-preservation modalities in advanced laryngeal squamous cell carcinomas: a multicenter retrospective analysis. Head Neck. 2013;35(4):554–61. https://doi.org/10.1002/hed.22994.
28. Del Bon F, Piazza C, Lancini D, et al. Open partial horizontal laryngectomies for T3–T4 laryngeal cancer: prognostic impact of anterior vs. posterior laryngeal compartmentalization. Cancers (Basel). 2019;11(3):289. https://doi.org/10.3390/cancers11030289.
29. Succo G, Crosetti E, Bertolin A, et al. Benefits and drawbacks of open partial horizontal laryngectomies, part A: early- to intermediate-stage glottic carcinoma. Head Neck. 2016;38(Suppl 1):E333–40. https://doi.org/10.1002/hed.23997.
30. Gosepath J. Die verschiedenen Methoden der Teilresektionen des Kehlkopfes [The various methods of partial resection of the larynx]. HNO. 1972;20(8):227–40.
31. Succo G, Peretti G, Piazza C, et al. Open partial horizontal laryngectomies: a proposal for classification by the working committee on nomenclature of the European Laryngological Society. Eur Arch Otorhinolaryngol. 2014;271(9):2489–96. https://doi.org/10.1007/s00405-014-3024-4.
32. Tomeh C, Holsinger FC. Laryngeal cancer. Curr Opin Otolaryngol Head Neck Surg. 2014;22(2):147–53. https://doi.org/10.1097/MOO.0000000000000032.
33. Lucioni M, Bertolin A, Lionello M, Giacomelli L, Rizzotto G, Marioni G. Open partial horizontal laryngectomy for salvage after failure of CO_2 laser-assisted surgery for glottic carcinoma. Eur Arch Otorhinolaryngol. 2016;273(1):169–75. https://doi.org/10.1007/s00405-015-3734-2.
34. Marioni G, Marchese-Ragona R, Kleinsasser NH, et al. Partial laryngeal surgery in recurrent carcinoma. Acta Otolaryngol. 2015;135(2):119–24. https://doi.org/10.3109/00016489.2014.969811.
35. Benito J, Holsinger FC, Pérez-Martín A, Garcia D, Weinstein GS, Laccourreye O. Aspiration after supracricoid partial laryngectomy: incidence, risk factors, management, and outcomes. Head Neck. 2011;33(5):679–85. https://doi.org/10.1002/hed.21521.
36. Succo G, Crosetti E. Limitations and opportunities in open laryngeal organ preservation surgery: current role of OPHLs. Front Oncol. 2019;9:408. https://doi.org/10.3389/fonc.2019.00408.
37. Schindler A, Pizzorni N, Fantini M, et al. Long-term functional results after open partial horizontal laryngectomy type IIa and type IIIa: a comparison study. Head Neck. 2016;38(Suppl 1):E1427–35. https://doi.org/10.1002/hed.24254.
38. de Vincentiis M, De Virgilio A, Bussu F, et al. Oncologic results of the surgical salvage of recurrent laryngeal squamous cell carcinoma in a multicentric retrospective series: emerging role of supracricoid partial laryngectomy. Head Neck. 2015;37(1):84–91. https://doi.org/10.1002/hed.23563.
39. Paleri V, Thomas L, Basavaiah N, Drinnan M, Mehanna H, Jones T. Oncologic outcomes of open conservation laryngectomy for radiorecurrent laryngeal carcinoma: a systematic review and meta-analysis of English-language literature. Cancer. 2011;117(12):2668–76. https://doi.org/10.1002/cncr.25831.
40. Succo G, Crosetti E, Bertolin A, et al. Benefits and drawbacks of open partial horizontal laryngectomies, part B: intermediate and selected advanced stage laryngeal carcinoma. Head Neck. 2016;38(Suppl 1):E649–57. https://doi.org/10.1002/hed.24064.
41. Pinar E, Imre A, Calli C, Oncel S, Katilmis H. Supracricoid partial laryngectomy: analyses of oncologic and functional outcomes. Otolaryngol

Head Neck Surg. 2012;147(6):1093–8. https://doi.org/10.1177/0194599812457334.
42. Weinstein GS, El-Sawy MM, Ruiz C, et al. Laryngeal preservation with supracricoid partial laryngectomy results in improved quality of life when compared with total laryngectomy. Laryngoscope. 2001;111(2):191–9. https://doi.org/10.1097/00005537-200102000-00001.
43. Leszczyńska M, Wierzbicka M, Tokarski M, Szyfter W. Attempt to improve functional outcomes in supracricoid laryngectomy in T2b and T3 glottic cancers. Eur Arch Otorhinolaryngol. 2015;272(10):2925–31. https://doi.org/10.1007/s00405-014-3244-7.
44. Pescetto B, Gal J, Chamorey E, et al. Role of supracricoid partial laryngectomy with cricohyoidoepiglottopexy in glottic carcinoma with anterior commissure involvement. Eur Ann Otorhinolaryngol Head Neck Dis. 2018;135(4):249–53. https://doi.org/10.1016/j.anorl.2018.05.004.
45. Brasnu DF. Supracricoid partial laryngectomy with cricohyoidopexy in the management of laryngeal carcinoma. World J Surg. 2003;27(7):817–23. https://doi.org/10.1007/s00268-003-7116-3.
46. Simonelli M, Ruoppolo G, de Vincentiis M, et al. Swallowing ability and chronic aspiration after supracricoid partial laryngectomy. Otolaryngol Head Neck Surg. 2010;142(6):873–8. https://doi.org/10.1016/j.otohns.2010.01.035.
47. Succo G, Fantini M, Rizzotto G. Supratracheal partial laryngectomy: indications, oncologic and functional results. Curr Opin Otolaryngol Head Neck Surg. 2017;25(2):127–32. https://doi.org/10.1097/MOO.0000000000000344.
48. Rizzotto G, Crosetti E, Lucioni M, et al. Oncologic outcomes of supratracheal laryngectomy: critical analysis. Head Neck. 2015;37(10):1417–24. https://doi.org/10.1002/hed.23773.
49. Hall FT, O'Brien CJ, Clifford AR, McNeil EB, Bron L, Jackson MA. Clinical outcome following total laryngectomy for cancer. ANZ J Surg. 2003;73(5):300–5. https://doi.org/10.1046/j.1445-2197.2003.02562.x.
50. Steuer CE, El-Deiry M, Parks JR, Higgins KA, Saba NF. An update on larynx cancer. CA Cancer J Clin. 2017;67(1):31–50. https://doi.org/10.3322/caac.21386.
51. Zenga J, Goldsmith T, Bunting G, Deschler DG. State of the art: rehabilitation of speech and swallowing after total laryngectomy. Oral Oncol. 2018;86:38–47. https://doi.org/10.1016/j.oraloncology.2018.08.023.
52. Dziegielewski PT, O'Connell DA, Klein M, et al. Primary total laryngectomy versus organ preservation for T3/T4a laryngeal cancer: a population-based analysis of survival. J Otolaryngol Head Neck Surg. 2012;41(Suppl 1):S56–64.
53. Forastiere AA, Ismaila N, Lewin JS, et al. Use of larynx-preservation strategies in the treatment of laryngeal cancer: American Society of Clinical Oncology clinical practice guideline update. J Clin Oncol. 2018;36(11):1143–69. https://doi.org/10.1200/JCO.2017.75.7385.
54. Strojan P, Haigentz M Jr, Bradford CR, et al. Chemoradiotherapy vs. total laryngectomy for primary treatment of advanced laryngeal squamous cell carcinoma. Oral Oncol. 2013;49(4):283–6. https://doi.org/10.1016/j.oraloncology.2012.11.002.
55. van Sluis KE, van der Molen L, van Son RJJH, Hilgers FJM, Bhairosing PA, van den Brekel MWM. Objective and subjective voice outcomes after total laryngectomy: a systematic review. Eur Arch Otorhinolaryngol. 2018;275(1):11–26. https://doi.org/10.1007/s00405-017-4790-6.
56. Elmiyeh B, Dwivedi RC, Jallali N, et al. Surgical voice restoration after total laryngectomy: an overview. Indian J Cancer. 2010;47(3):239–47. https://doi.org/10.4103/0019-509X.64707.
57. Moukarbel RV, Doyle PC, Yoo JH, Franklin JH, Day AM, Fung K. Voice-related quality of life (V-RQOL) outcomes in laryngectomees. Head Neck. 2011;33(1):31–6. https://doi.org/10.1002/hed.21409.
58. Kapila M, Deore N, Palav RS, Kazi RA, Shah RP, Jagade MV. A brief review of voice restoration following total laryngectomy. Indian J Cancer. 2011;48(1):99–104. https://doi.org/10.4103/0019-509X.75841.
59. Ward EC, Bishop B, Frisby J, Stevens M. Swallowing outcomes following laryngectomy and pharyngolaryngectomy. Arch Otolaryngol Head Neck Surg. 2002;128(2):181–6. https://doi.org/10.1001/archotol.128.2.181.
60. Robertson SM, Yeo JC, Dunnet C, Young D, Mackenzie K. Voice, swallowing, and quality of life after total laryngectomy: results of the west of Scotland laryngectomy audit. Head Neck. 2012;34(1):59–65. https://doi.org/10.1002/hed.21692.
61. Arenaz Búa B, Pendleton H, Westin U, Rydell R. Voice and swallowing after total laryngectomy. Acta Otolaryngol. 2018;138(2):170–4. https://doi.org/10.1080/00016489.2017.1384056.
62. Hasan Z, Dwivedi RC, Gunaratne DA, Virk SA, Palme CE, Riffat F. Systematic review and meta-analysis of the complications of salvage total laryngectomy. Eur J Surg Oncol. 2017;43(1):42–51. https://doi.org/10.1016/j.ejso.2016.05.017.
63. Grover S, Swisher-McClure S, Mitra N, et al. Total laryngectomy versus larynx preservation for T4a larynx cancer: patterns of care and survival outcomes. Int J Radiat Oncol Biol Phys. 2015;92(3):594–601. https://doi.org/10.1016/j.ijrobp.2015.03.004.
64. Debry C, Vrana NE, Dupret-Bories A. Implantation of an artificial larynx after total laryngectomy. N Engl J Med. 2017;376(1):97–8. https://doi.org/10.1056/NEJMc1611966.
65. Strome M, Stein J, Esclamado R, et al. Laryngeal transplantation and 40-month follow-up. N Engl J Med. 2001;344(22):1676–9. https://doi.org/10.1056/NEJM200105313442204.

Neck Dissections in Head and Neck Malignancy

13

Norhafiza Mat Lazim

13.1 Introduction

Treatment of neck in the setting of head and neck cancer is crucial. Neck metastasis is a common phenomenon in head and neck malignancy, especially in higher stage tumour, poorly differentiated tumours, and mucosal related malignancy. A good control of the neck disease ensures better treatment outcomes. The risk of neck recurrence and distant spread of the tumour will be lessened. It is a challenge to manage neck metastasis, as the area of the neck is wide with multiple critical neurovascular structures located in this region. The neck node's location also varies according to levels I–VI of the neck nodes, which requires an accurate decision on which neck levels require dissection. Multiple factors need to be considered including the detailed characteristics of the primary tumours, the patient factors, and the expertise/clinician factors.

The head and neck malignancy will spread through the primary lymphatic drainage of the echelon nodes, which mostly are to level I–VI neck nodes (Fig. 13.1). The primary area of drainage is critical in determining the neck node involvement. Certain subsites of head and neck malignancy have different predilection of neck node levels. For instance, oral cavity carcinoma metastasizes to level I–III neck nodes. Oropharyngeal and hypopharyngeal carcinomas metastasize to level II–IV neck nodes. In comparison, laryngeal carcinoma spreads to level VI and nasopharyngeal carcinoma metastasizes to level V mostly (Table 13.1).

A meticulous clinical examination is necessary in order to rule out neck metastases. This is especially true in the setting of head and neck cancer patients who had received chemoradiation as primary treatment. The neck tends to get fibrosed and thickened due to granulation tissue; hence, neck

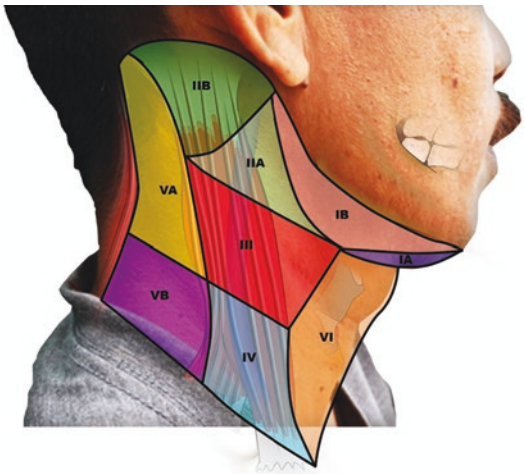


Fig. 13.1 Neck node levels I–VI harbour critical structures of the neck

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N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_13

Table 13.1 Lymphatic drainage of head and neck anatomic subsites

	Anatomic region	Lymphatic drainage area
1.	Oral cavity • Anterior two-third tongue buccal mucosa • Floor of mouth • Hard palate • Gingiva • Retromolar trigone	Generally levels I–III Level Ia Level Ib Level II Level III Level II Level III
2.	Oropharyngeal • Base of tongue • Tonsils • Lateral pharyngeal wall	Level II Level III Level IV
3.	Pharyngeal • Posterior pharyngeal wall • Lateral pharyngeal wall • Pyriform sinus • Post-cricoid area	Level IIa Level IIb Level III Level IV
4.	Salivary glands • Parotid glands • Submandibular glands • Sublingual glands	Level II Level III Level IV Level I
5.	Nasal cavity • Paranasal sinuses • Nasopharynx	Level Ib Level II Level III
6.	• Thyroid glands • Parathyroid glands	Level IV Level V Level VI
7.	Laryngeal • Supraglottic • Glottic • Subglottic	Level II Level III Level IV Level VI
8.	• Temporal bone • EAC • Pinna	Parotid nodes Occipital nodes Level V

palpation is more challenging. In a suspicious neck mass, the supplementary assessment tool like ultrasound and CT scan would offer a great help. Blood parameters such as tumour marker will provide additional value for clinical suspicion of certain types of head and neck malignancy. Thyroglobulin is a tumour marker for papillary thyroid carcinoma, whereas calcitonin is the tumour marker for medullary thyroid carcinoma. Serum calcium level, LDH, and ALP are good markers of bony metastases.

Clinical examination of neck nodes will require the documentation of size, location, multiplicity, consistency, and fixation (to underlying structures and superficial skin). The endoscopic examination of nasal cavity, nasopharynx, oral cavity and oropharynx, and laryngeal anatomic site will complement the findings in order to rule out the primary tumour. A better and accurate delineation of the detailed morphology of the neck nodes can be obtained from the imaging tools. Confirming a lymph node metastasis requires not only quantitative measurements, but also the absence of fatty hilum, blood flow, presence of cystic or coagulation necrosis, and peripheral capsular vascularization in a clinical setting. In addition, it is well known that level I and II lymph nodes are larger than those at the other levels [1]. Typical characteristics of lymph nodes suggestive of malignancy are highlighted in Table 13.2.

The most commonly used imaging modalities for detecting cervical lymph node metastasis in patients with HNC are CT scan and MRI. The minimum axial diameter measurements of suspicious nodes are useful for evaluating the metastases. A minimal axial diameter of 10 mm was considered to be the best size criterion for MRI and 12 mm for CT. Other

criteria to suggest neck metastases include shapes of the neck nodes, presence of central necrosis, size of nodes >1.5 cm at jugulodigastric nodes, and >2.0 cm at level III and IV neck nodes (Table 13.2). In expert hands, ultrasound may also offer the diagnosis of neck node metastases. This depends on several characteristics, which include increased vascularity, heterogeneity, extracapsular infiltration, and so forth.

Selected features of neck node metastases signify prognosis of head and neck cancer patients. For instance, matted nodes, bilateral and multiple nodes, supraclavicular nodes, and ulcerative nodes point out to the aggressive and advanced nature of the primary tumour. Previous investigators have attempted to stratify LNM patients using clinicopathological features such as lymph node density, location of the tumour and/or lymph node, and extracapsular extension, among others [2].

Table 13.2 Characteristics of metastatic lymph nodes

	Lymph node characteristics highly suggestive of metastatic neck nodes
1. Size	More than 1.5 cm at levels I and II More than 2.0 cm at levels III, IV, and V
2. Location	Primary echelon nodes of the involved organs
3. Consistency	Firm and hard in consistency
4. Border	Rounded border
5. Central necrosis	Presence of central necrosis and heterogenous
6. Calcification	Variety of calcification, increased vascularity
7. Extracapsular	Loss of defined cortex, irregular margin
8. Number	Multiple and matted

13.2 Risk Factors of Neck Metastases

There are multiple factors that predispose to neck metastases. The stage of the tumour, histological grading, and type of tumour are significant factors which govern the neck metastases. The higher the stage of tumour, the more the likelihood of neck metastases. T3 and T4 tumours have a high propensity for neck metastases compared to T2 or T1 tumour. Tumours which are classified as poorly differentiated tumours have increased risk of neck metastases than well- or moderately differentiated tumours. Oral cavity cancers have higher tendency for micrometastasis to necks in contrast to salivary gland tumours. The depth of invasion (DOI) of tongue tumour is crucial in predicting the risk of neck metastases (Fig. 13.2).

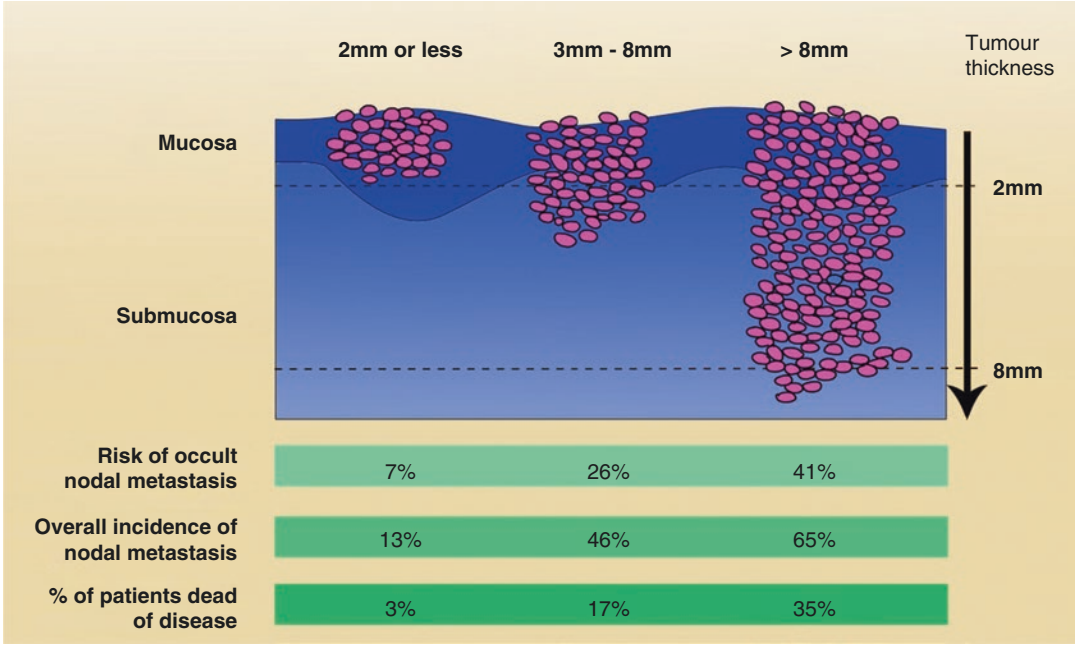


Fig. 13.2 Risk of neck node metastasis increases as the tumour thickness increases

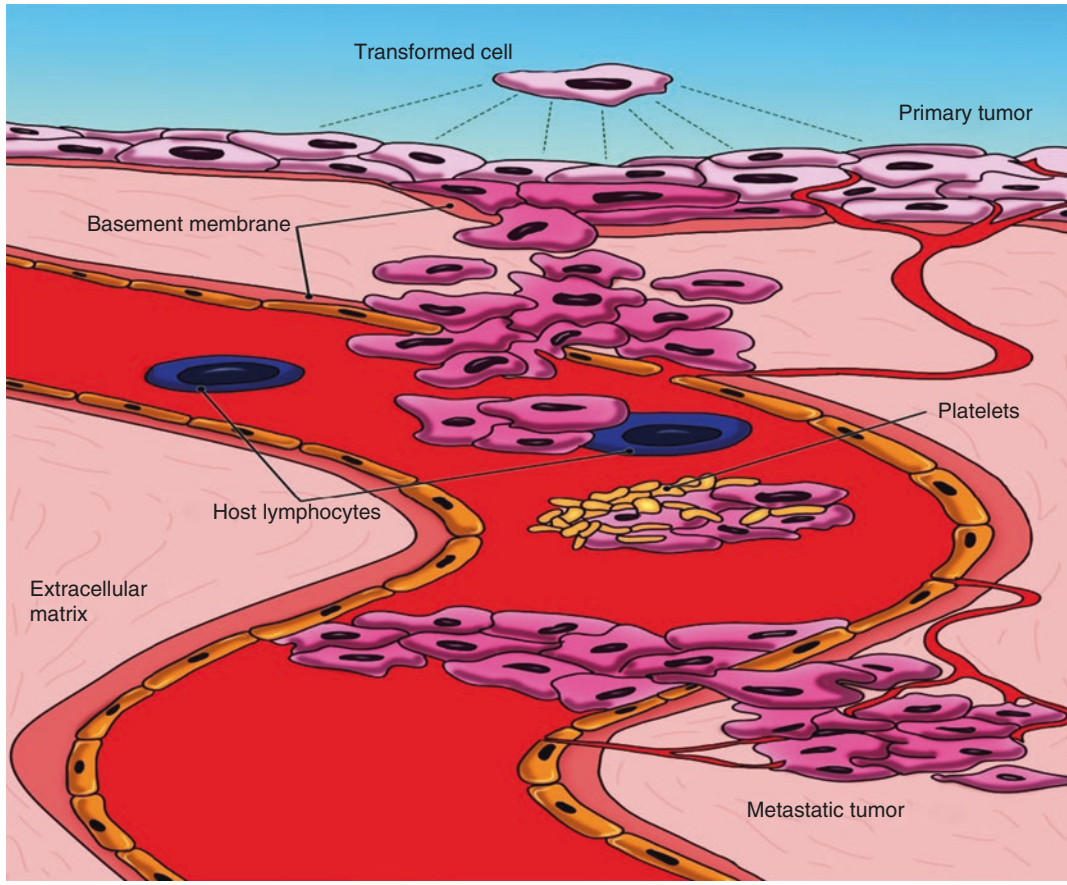


Fig. 13.3 Mechanisms of tumour spread through the systemic circulation

The tumour microenvironment is a prerequisite for a metastatic mechanism. Numerous critical factors present in the tumour microenvironment facilitate the process of metastases. This allows the interaction between tumour cells and platelets, lymphocytes, and other proteins [3] (Fig. 13.3).

13.3 Principle of Neck Dissection

Metastasis of the neck lymph node is one of the most important prognostic factors in squamous cell carcinoma of the head and neck. Majority of head and neck carcinoma patients, especially stage III and IV diseases, present with palpable neck nodes. Thus, it is important to detect neck lymph node disease early to achieve better survival. This in fact infers to the detection of micrometastases in the neck before it becomes a clinically apparent disease. This occult neck node metastasis is a critical factor when considering the optimal management of head and neck malignancy. However, there is great controversy about the best management of the neck due to the broad range of occult lymph node metastasis rates in SCC [4]. The accurate data on the risk of occult neck node metastases is sparse as not many studies are available due to rarity of some of the head and neck malignancies such as salivary gland carcinoma.

There is an orderly progression of lymphatic spread from a primary malignancy. This commonly follows the normal distribution of the lymphatic drainage. For example, in the oral cavity carcinoma, the lymphatic spread is to level I, II, and III neck nodes. The involvement of lower nodes without upper node involvement and skip metastasis is rare. In violated neck, however, the

skip metastasis is common at level IV neck nodes. This is inclusive in patients who had previous radiation or surgery, where the normal drainage pattern of the lymphatic is distorted.

Generally, the neck treatment for oral cavity carcinoma is selective neck dissection in N0 disease and modified radical neck dissection for N+ disease. The supraomohyoid neck dissection is the most common practice for N0 tumour. Recently, in node-positive patients, selective neck dissections are increasingly being performed. This is true especially in the setting of neck node metastases that are limited to one level of neck, that are of small size 1.0–2.0 cm, that are mobile nodes, and wherein primary tumour does not belong to high grade. The other factors that should be considered when deciding SND for N+ tumour is presence of good oncology facility and expertise and patient being able to comply to strict follow-up policy.

Selected cases with N+ disease required anterolateral neck dissection or MRND. The same principle applies where the characteristics of neck node metastases such as the size, the numbers, the neck node level involvement, and the fixation of the neck nodes among others should be considered. It should be borne in mind that the aim of neck dissection is to improve patient's prognosis and survival while maintaining the best quality of life of these patients. In patients who underwent supraomohyoid neck dissection, extended supraomohyoid neck dissection, or modified radical or radical neck dissection due to cN0 to cN(+) disease, 3-year neck recurrence-free survival and disease-specific survival were not significantly different. In this account, probably the least morbid neck dissection should be performed for selected patients with good prognostication factors.

The other types of treatment of choice for neck metastases include wait-and-watch policy, prophylactic radiation, and brachytherapy. Essentially, this depends on the patient factors, tumour factors, and expertise availability. Decision regarding the best of treatment possible should be discussed with patients and family members. It is important not to breach the principle of clinical conduct, i.e. do no harm the patient when choosing the treatment. Overzealous surgeon should consider the patient's quality of life before embarking on unnecessary surgery, i.e. overtreating the patients. In order to choose the appropriate therapeutic modality, the quality of life and shoulder functions are important to consider when consideration of MRND is taken in addressing the neck metastases [5].

The other critical factors that should be considered in the decision-making of choice of neck dissection are the depth of tumour infiltration and the grade of the tumour. In T1 stage tumours with infiltration depth ≤4 mm or low-grade (G1–G2) tumours, the 'watchful waiting' strategy for cervical metastases is appropriate given the low regional recurrence rate of 15% and the overall survival rate of 100%. In the case of T2 lesions with an infiltration depth ≥4 mm or high grade (G3), elective neck dissection is preferred with 13% risk of local recurrence and 100% survival at 6 years.

For oral cavity cancers, there has been a strong debate whether selective neck dissection has comparable outcomes with irradiation alone [6]. Conventionally, selective supraomohyoid neck dissection is advocated for tongue carcinoma. The risk of skip metastases mandates inclusion of level IV, especially in violated neck like post-surgery case or in patients who already received chemoradiation. Patients with lateralized oropharyngeal carcinoma who are treated with upstream curative surgery should undergo ipsilateral neck dissection at levels II–IV. Adequate dissection should involve at least 18 lymph nodes.

Patients receiving upstream END had significantly improved overall survival at 3 years compared to patients with therapeutic-only dissection. Disease-specific survival was even more dramatically improved in patients receiving END at 69.5% compared to 45.9% in patients receiving therapeutic neck dissection. The key difference appeared to be explained by a more advanced nodal stage and a higher incidence of extracapsular spread in patients who did not undergo END at the time of glossectomy [6].

There is controversy with regard to neck management for advanced laryngeal squamous cell carcinoma in TL procedures. The German guidelines recommend level IIA–IV ipsilateral selective neck dissection (SND) for lateralized T3 glottic cancers and extension of therapy to the contralateral neck

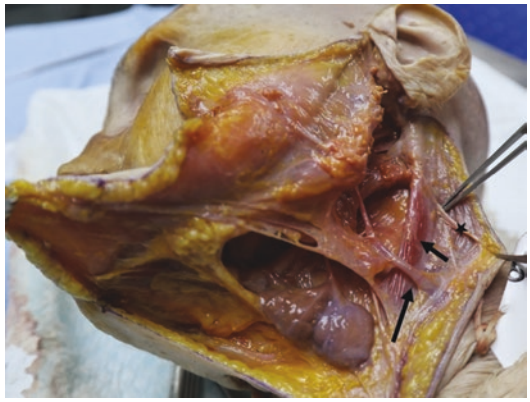


Fig. 13.4 The greater auricular nerve GAN (star) and the external jugular vein EJV (long arrow) cross superficial to SCM (short arrow) in the neck

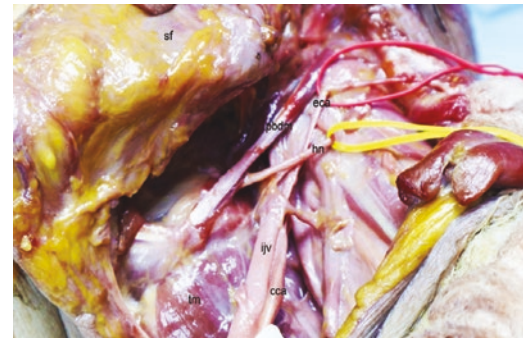


Fig. 13.5 Posterior belly of digastric (pbdm) is the landmark for critical structures like internal jugular vein (IJV), common carotid artery (cca), and hypoglossal nerve (hn), which are located deep to the muscle

in cases of midline crossing tumour growth during elective intervention [7]. Clinicians who treat patients with head and neck cancer are aware that deciding whether or not to perform a neck dissection is a difficult decision. In clinical practice, the task is to balance the potential advantages of a neck dissection for regional monitoring against the potential morbidity in patients that are irradiated for squamous cell carcinoma cervical node metastasis [8]. These morbidities include injury to the structures that are encountered during neck dissection such as the greater auricular nerve and external jugular vein during the skin flap raising or structures like carotid artery, IJV, and hypoglossal nerve during deeper dissection (Figs. 13.4 and 13.5).

13.4 Classification of Neck Dissection

Based on the guidelines of the American Academy of Otolaryngology–Head and Neck Surgery and the American Head and Neck Society, generally the classification of neck dissection is as in Table 13.3. The three major categories are selective neck dissection, modified radical neck dissection, and radical neck dissection.

Selective neck dissection removes all the nodes and fibrofatty tissue at the region of levels I, II, III, IV, or V. Further subcategory of selective neck dissection is provided in Table 13.3. Each of these neck node levels is bounded by selected structures and contains the nodes plus other critical neurovascular structures. For instance, level Ib involves all lymph nodes between the posterior edge of the submandibular gland, the anterior digestive belly, and the stylohyoid muscle and includes pre- and postvascular nodes along the facial artery of the mandible and glandular nodes associated with the musculoskeletal gland.

Table 13.3 Neck dissection and characteristics

	Types of neck dissection	Neck node level that needs to be addressed
1.	Selective neck dissection	
	(a) Supraomohyoid	Levels I, II, and III
	(b) Lateral	Levels II, III, and IV
	(c) Anterolateral	Levels I, II, III, and IV
	(d) Posterolateral	Levels II, III, IV, and V
2.	Modified radical neck dissection	
	(a) MRND type I	Preservation of SAN
	(b) MRND type II	Preservation of SAN and IJV
	(c) MRND type III	Preservation of SAN, IJV, and SCM
3.	Radical neck dissection	Removal of all lymphatic tissues at all neck levels plus SAN, IJV, and SCM
4.	Central compartment neck dissection	Removal of lymphatic and fibrofatty tissue from hyoid bone to sternal notch and from carotid sheath on either side
5.	Sentinel lymph node biopsy	Limited to level I of neck in clinically N0 tumour
6.	Superselective neck dissection	Similar concept with SNLB

13.5 Central Compartment Neck Dissection

The incidence of thyroid cancer is increasing, largely due to over-detection due to prevalent diagnostic and radiological imaging methods. Papillary thyroid cancer (PTC) remains the most common malignancy of thyroid cancer. It has a high tendency for regional metastases to the cervical lymph nodes. Lymph node involvement of the differentiated thyroid cancer is common, and cervical metastasis is observed in up to 80% of papillary thyroid cancers. The central compartment neck dissection is most performed for the PTC (Fig. 13.6). The role of routine central lymph node dissection in the treatment of PTC has been

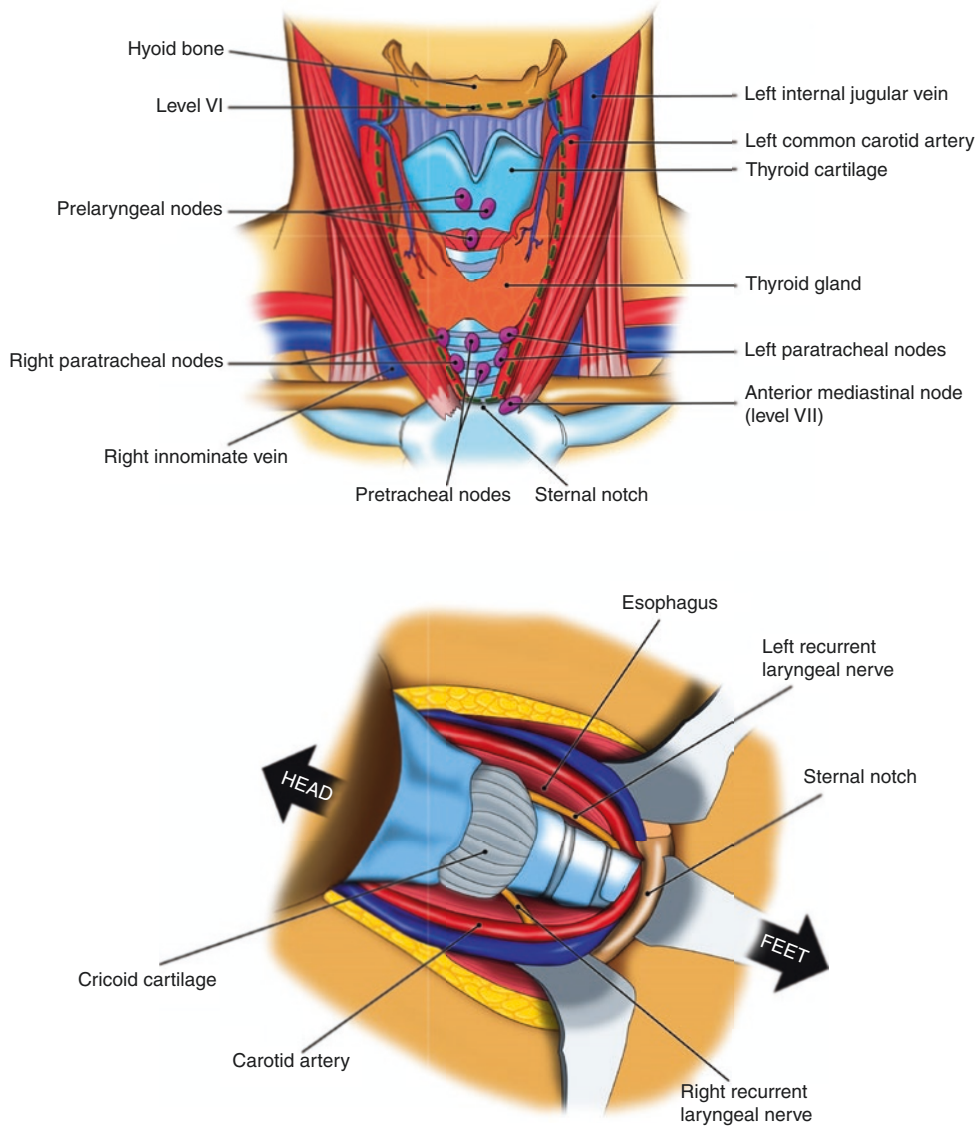


Fig. 13.6 Central compartment neck dissection is commonly performed for papillary thyroid carcinoma. The boundary for CCND is hyoid bone superiorly, carotid sheath laterally, and sternal notch or innominate artery inferiorly. Recurrent laryngeal nerve is at greater risk of injury in contrast to the case where total thyroidectomy is performed alone without neck dissection

the focus of research over the past several decades and is still controversial [9]. Different centres use different criteria in deciding which group of patients should have central compartment neck dissection at the time of total thyroidectomy.

Clinicopathological features and central lymph node metastasis patterns were analysed in patients who underwent total thyroidectomy for PTC with bilateral prophylactic central neck dissection without evidence of central lymph node metastasis on preoperative imaging to predict regional recurrence [10]. Regional recurrence in univariate analysis was associated with tumour size >1 cm, central lymph node metastasis, lymph node ratio, and prelaryngeal lymph node metastasis. A lymph node ratio of 0.26 was a significant risk factor for regional lymph node recurrence.

13.6 Selective Neck Dissection

The utilization of selective neck dissection continues to be debated, especially in the management of tongue cancers and salivary gland cancer. In this tumour, traditionally, selective neck dissection is performed for N0 neck. There are several types of selective neck dissection, and each of these types removes a group of neck nodes (Fig. 13.7). The supraomohyoid type removes level I, II, and III nodes. The lateral types remove node at levels II, III, and IV. The anterolateral types include level I together with II, III, and IV nodes (Fig. 13.8). The posterolateral removes level II, III, IV, and V neck nodes.

These days, with advancement in the imaging modality for follow-up surveillance, N0 neck can be treated with watchful and waiting policies. As the types of surgery are rapidly evolving to reduce the morbidity of neck dissection, some proponents suggest sentinel lymph node biopsy for N0 tongue cancer. This is a similar concept with superselective neck dissection. The results of some studies show that superselective IIb preservation dissections of the neck are technically feasible and appear to be oncologically safe when performed in highly selected groups of patients as elective prophylactic procedures. Prophylactic dissection suggests that a significant number of occult metastases

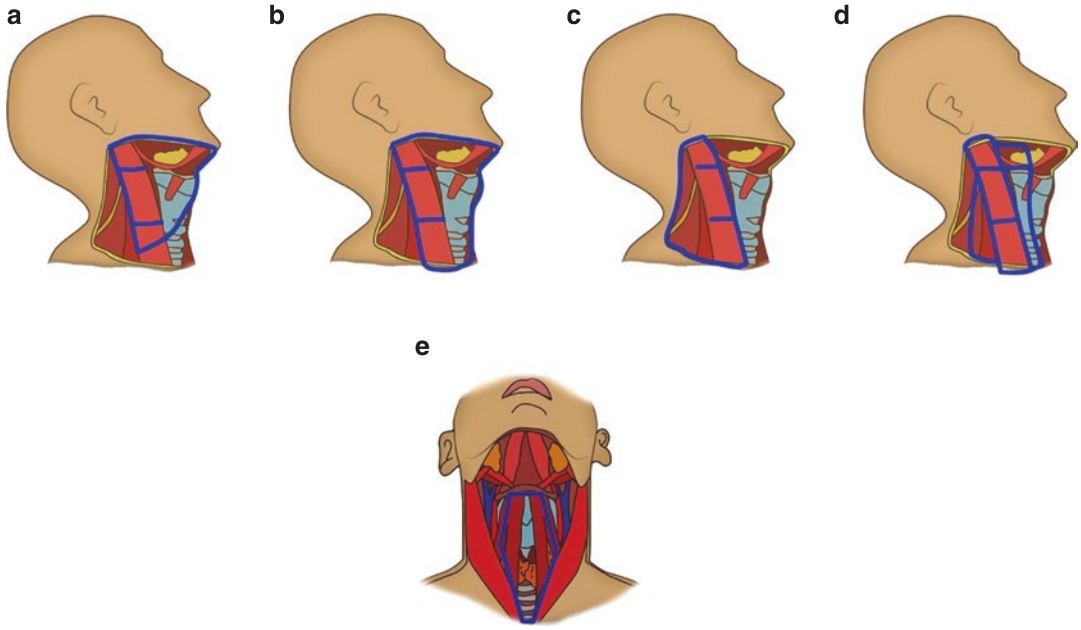


Fig. 13.7 The types of selective neck dissection and the groups of neck nodes that are removed for that particular type of neck dissection: (**a**) levels I–III (supraomohyoid), (**b**) levels II–IV (extended supraomohyoid), (**c**) levels II–IV (lateral), (**d**) levels II–V (posterolateral), and (**e**) levels VI–VIII (anterior/paratracheal)

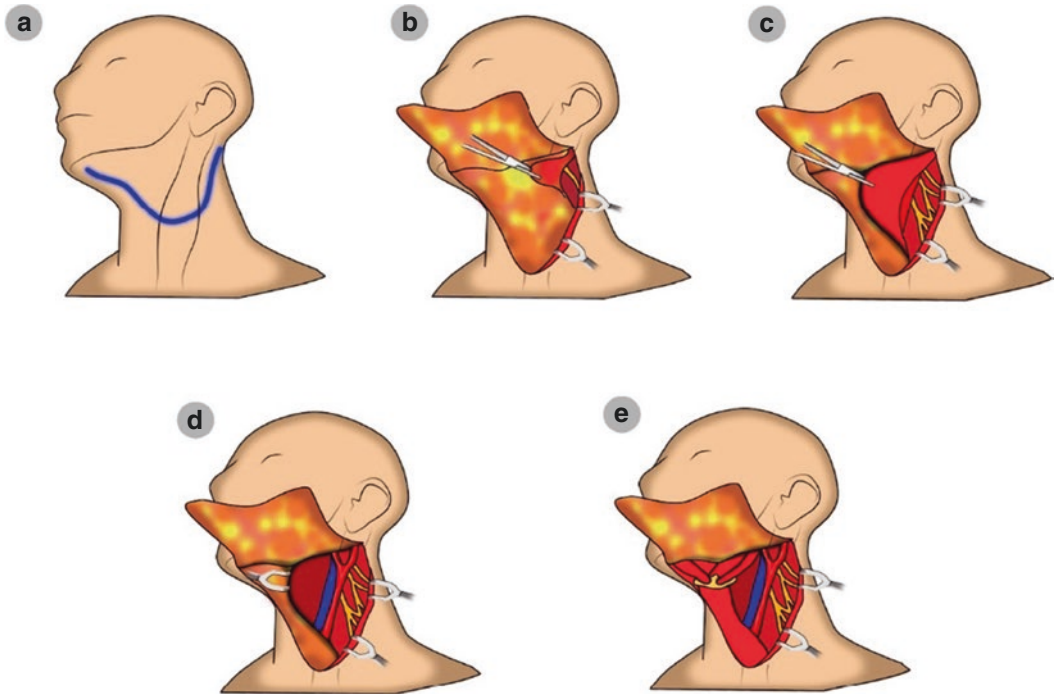


Fig. 13.8 (**a**) Skin incision, (**b**) Skin flap elevation, (**c**) Subcutaneous tissue dissection, (**d**) Level II, III & IV dissection exposes the IJV and common carotid artery, (**e**) Level I dissection in addition to level II-IV dissection

seen in the current study are better than waiting and watching policies. There are multiple complications that can arise from selective neck dissection as many critical structures are located in the region and are at risk of injury.

The shoulder syndrome appears after neck dissection of early-stage oral carcinoma due to traction of the accessory nerve during level IIb removal, which greatly affects the quality of life of the patient. Since occult metastasis is extremely low in early-stage oral carcinoma at level IIb, some surgeons suggest that to improve the quality of life, level IIb may be exempted from dissection. Other surgeons, however, take the opposite view, and there is therefore no consensus on the need for IIb dissection in oral squamous cell carcinoma T1–2N0M0 [11]. Other complications of neck dissection can significantly impair patient's quality of life such as chylous leak, neural paresis, and facial and neck scaring that occurs at higher risk especially with MRND, RND, or extended neck dissection (Fig. 13.9).

13.7 Surgical Techniques with Cases Illustrations

13.7.1 Selective Neck Dissection

Selective neck dissection is indicated primarily in tumours with N0 neck and selected N1 neck disease. In oral cavity cancer, especially tongue cancer, with N0 neck, the SND is necessary as the risk of occult metastases to the neck is 40%. The idea of performing neck dissection is to eradicate the micrometastases so that the locoregional spread and recurrence can be controlled. Occasionally, tumours with N1 which are characterized by a single 1.0 cm node, that is mobile and limited to one level of the neck, can be safely addressed with SND. The MRND for this type of N1 neck metastasis is too morbid for this group of patients, especially in the setting of centres with adequate oncology facility and comprehensive post-treatment follow-up schemes. Important surgical techniques during selective neck dissection is provided in Table 13.4.

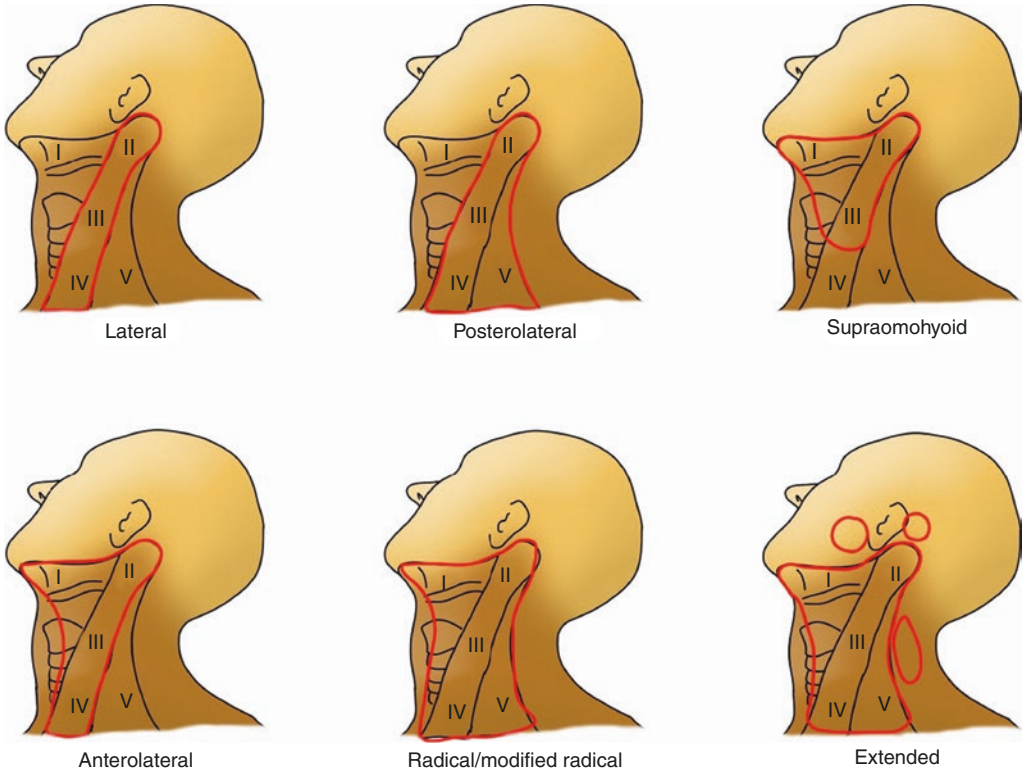


Fig. 13.9 The modified neck dissection, radical neck dissection, and extended neck dissection

Table 13.4 Tips in selective neck dissection

	Pearls and pitfalls in selective neck dissection
1.	A transcervical skin incision starting at SCM muscle, following skin crease at two finger breadths below mandible and ending at the midline of neck at cricoid cartilage
2.	A subplatysmal flap elevation using blade size 11 or monopolar with a Colorado tip
3.	Level Ia dissection with the medial-most border is the contralateral anterior belly of digastric. Fibrofatty tissue held with Allis forceps/Babcock and retracted inferolaterally with dissection
4.	Level Ib dissection with preservation of marginal mandibular nerve. The nerve is fine and run across the submandibular capsule and can be traced as it crosses the facial artery and vein. The facial artery lies anteriorly to the vein and should be identified and ligated, twice anterior to the submandibular gland and posterior to the glands Once the submandibular glands have been released and retracted inferiorly, the mylohyoid retracts superomedially to expose the lingual nerve and submandibular duct. The duct is ligated at most proximally via a ligaclip. The hypoglossal nerve that lies 1-1.5 cm below the lingual nerve and deep to posterior belly digastric tendon should be identified and preserved
5.	Level II dissection entails clearance of fibrofatty tissues over level IIb (posterior to SAN) and level IIa (anterior to SAN). SAN needs to be identified as it crosses the IJV and runs posteroinferolaterally to insert and innervate the SCM muscle. The posterior border of dissection is the exit of cervical plexus that underlies the posterior border of SCM
6.	Level III dissection continues from level II fibrofatty tissue retraction downward, following on the IJV and carotid artery. IJV has multiple fine fibrous layers, which need to be dissected together with the fibrofatty tissue specimen. Some IJVs have multiple fine branches which can be ligaclipped to control bleeding. Ansa cervicalis almost always runs across IJV at this level and can be sacrificed or preserved. The medial-most border of dissection is the superior thyroid artery
7.	Level IV dissection runs from the line of the caudal border of cricoid cartilage to clavicle Dissection will expose a few branches of the IJV, which lies deep to omohyoid muscle. The deep muscle of the neck, scalene muscle forming the floor, and phrenic nerves run on scalene anterior

13.7.2 Case Illustration 1

Case of a 38-year-old Malay lady diagnosed with carcinoma of tongue T2N0M0, well-differentiated squamous cell carcinoma planned for left hemiglossectomy and bilateral selective supraomohyoid neck dissection as the macroscopic tumour is close to the midline of the tongue.

Intraoperatively, the surface anatomy of the neck and critical surgical landmarks are drawn. These include the anterior border of SCM, angle of mandible, and external jugular vein (Fig. 13.10). The identification of these structures allows orientation during dissection to ensure a safe surgery.

The subplatysmal skin flap should be raised superiorly to mandible and inferiorly till clavicle to facilitate a fine dissection of fibrofatty tissues from level I to level IV (Figs. 13.11 and 13.12). The thicker the flap, the better, as more vascularization of the flap will prevent flap necrosis during healing post-operatively.

The identification of platysma is rather easy once the surgeon is familiar with the neck's anatomy details. The best guide is that the platysma runs in opposite direction to the SCM and it is deficient at midline and lateral part of the neck. It originates from the clavicular border and inserts into mandible. It receives blood supply from submental artery on the upper half and from suprascapular artery from lower half. This varied blood supply can be used for designing a platysma-based flap.

The SCM lies deep to platysma and needs to be retracted laterally to allow dissection of fibrofatty tissue overlying the carotid sheath (Fig. 13.13). The fascia overlying the IJV needs to be completely cleared as it contains most of the nodes, in contrast to the fascia over the carotid artery.

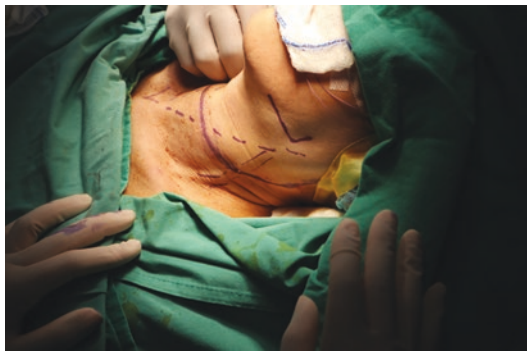


Fig. 13.10 The landmarks are drawn, which include the inferior border of mandible, anterior border of SCM muscle, external jugular vein, and outline of skin incision along the skin crease

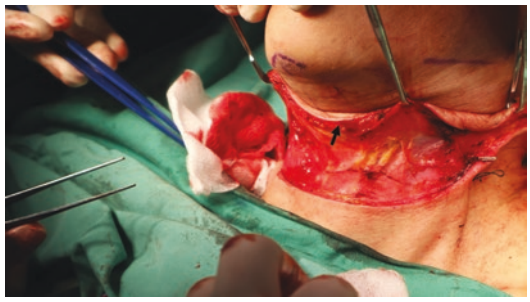


Fig. 13.11 The subplatysmal skin flap (arrow) is raised, and skin flap is retracted with hooks

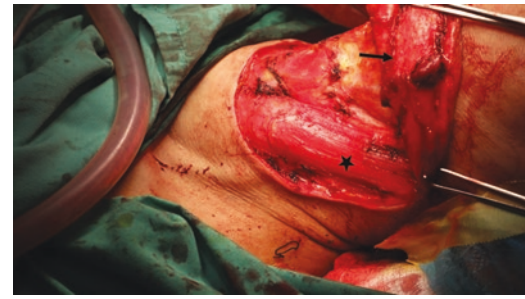


Fig. 13.12 The subplatysmal skin flap is raised and retracted superiorly (arrow). The sternocleidomastoid muscle is visible (star)

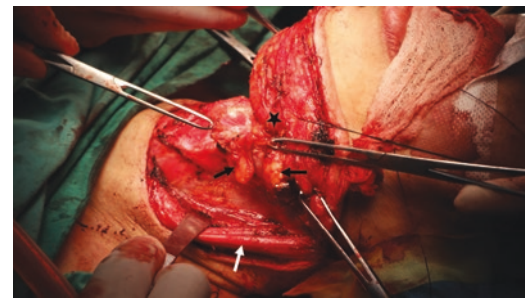


Fig. 13.13 Levels Ia and Ib (star) are dissected first. The dissected tissue is held with forceps (black arrow). This antegrade dissection facilitates easy dissection as traction and countertraction are more efficient. The SCM muscle (white arrow) is retracted laterally for a wider exposure

The fibrofatty tissue is held for Allis forceps and retracted downward to facilitate better dissection. A small cut on the tissue superiorly allows greater dissection of tissue with good traction and countertraction (Fig. 13.14). The dissection starts at level Ia. The medial border for level Ia dissection is the anterior belly of digastric muscle on the other side.

Level Ib dissection is mainly to ensure a safe extirpation of the submandibular glands as many vital structures are intimately related to the submandibular glands (Fig. 13.14). The facial artery and vein need to be identified and ligated to avoid unnecessary bleeding. The marginal mandibular nerve needs to be identified and preserved.

The marginal mandibular nerve is superficial to facial artery and vein. One of the techniques to preserve the nerve is by creating the Martin-Hayes flap. This is done by ligating facial artery and vein and reflecting it superiorly, so as to preserve the nerve which is enveloped by the flap.

Level II dissection is more technically challenging as more structures need to be addressed. The spinal accessory nerve divides this level into IIA and IIB. The dissection in this area needs to be done meticulously in order to avoid injury to the SAN. The IIa dissection can be performed first and reflected underneath the SAN to level IIB. The SAN can be identified by palpating the C2 vertebral body as the SAN runs across this vertebral body. The skeletonized SAN opens up space underneath for the tissue dissection. Then level IIb is dissected inferiorly to levels III and IV (Figs. 13.15 and 13.16).

The IJV has numerous branches, which can be clipped during the dissection. The ansa cervicalis can be visualized crossing the IJV and can be resected together with the fascia and fibrofatty tissue. The vagus nerve is easily identified as it resides between the IJV and carotid artery (Fig. 13.17). Care should be taken during dissection to avoid injury to vagus nerve. The branches of the external carotid should be isolated from the fibrofatty tissue, so that heavy bleeding can be avoided.

The dissection specimen should be removed en bloc to ensure no seeding of tumour tissues if the tumour is cut within the surgical bed (Fig. 13.18). The specimen should be orientated with suture or colour-coded button for correct histopathology assessment.

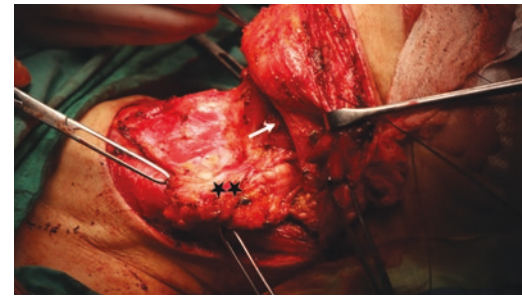


Fig. 13.14 Dissection of fibrofatty tissue continues to levels Ib and II (stars). At level Ib (white arrow), the submandibular gland has been dissected together with the fibrofatty tissue specimen

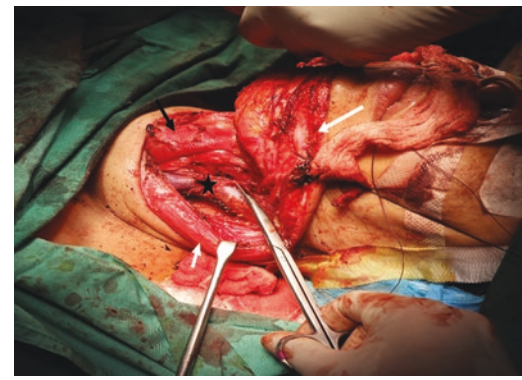


Fig. 13.15 Dissection of levels II, III, and IV with removal of fibrofatty tissue overlying the IJV (star). The SCM (short arrow) is retracted to expose the IJV. The strap muscle is visible anteriorly (black arrow). The skin flap remains retracted (long white arrow)

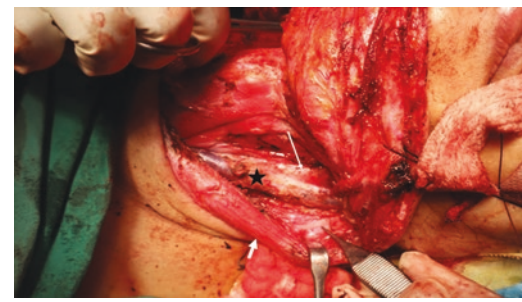


Fig. 13.16 The dissection of levels I, II, III, and IV has been completed. The IJV (star), carotid artery (long arrow), and retracted SCM (short arrow) are visible

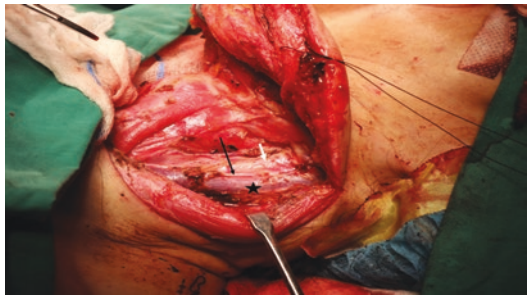


Fig. 13.17 Selective neck dissection is completed. The IJV (star), common carotid artery (white arrow), and vagus nerve (black arrow) are visible

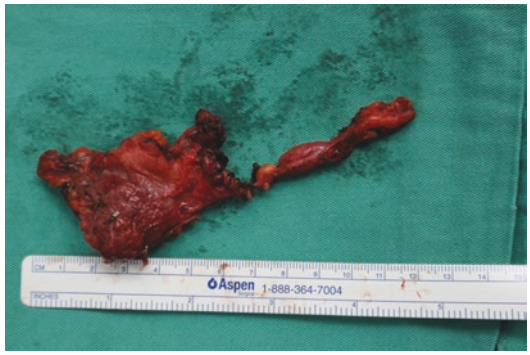


Fig. 13.18 The en bloc dissection specimen measuring 7.0 cm × 4.0 cm

13.7.3 Case Illusration 2

This is a case of maxillary sinus ca T4N1MO planned for extended left maxillectomy and left anterolateral SND. The mass occupies the whole left maxilla area with extension to the infraorbital region. The skin incision is designed as in Figs. 13.19 and 13.20. The modified Weber-Ferguson skin incision is used for total maxillectomy.

The cut on the skin, subcutaneous tissue, and platysma can be made with a blade or a cautery. The small blood vessels can be coagulated instantly with cautery. If big anterior facial vein is present, it can be clipped or ligated. The platysma muscle can be identified as thin fibres extending from mandible to clavicle. It can be cut, and the plane beneath the muscle is used to lift the skin flap superiorly (Figs. 13.21 and 13.22).

The tissue is cut by using a blade size 11 or a fine cautery (with a Colorado tip). This ensures a fine cutting of the tissue layer by layer. The dissection is started at level Ia and continues with level IB where submandibular gland is visualized.

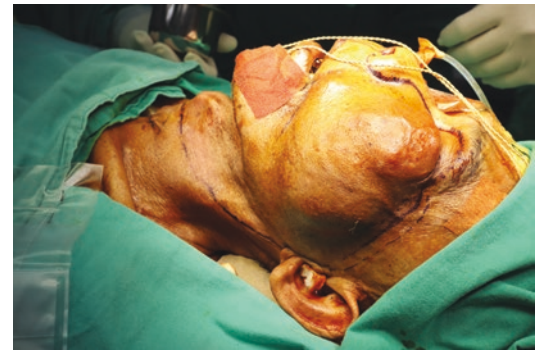


Fig. 13.19 The outline of modified Weber-Ferguson is marked, and ipsilateral neck dissection skin incision follows the primary tumour excision line

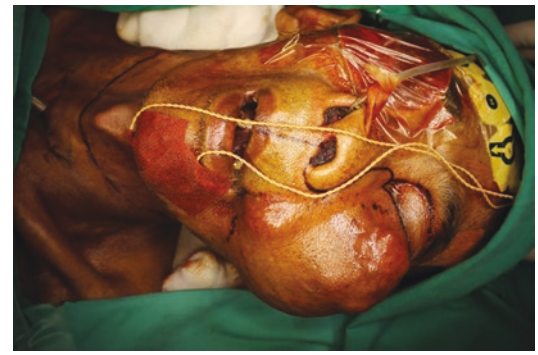


Fig. 13.20 The outline of skin incision for maxillectomy and ipsilateral orbital exenteration

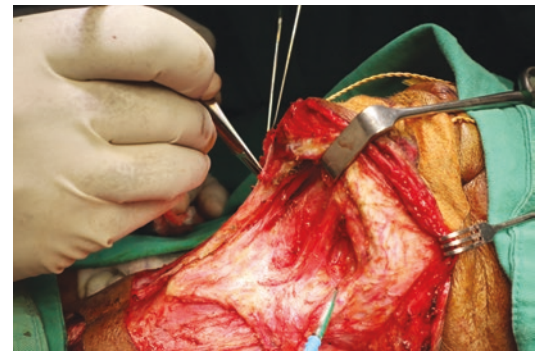


Fig. 13.21 A subplatysmal skin flap is raised superiorly till the level of mandible and inferiorly till clavicular level. This exposes level I, II, III, and IV neck for the fibrofatty tissue removal

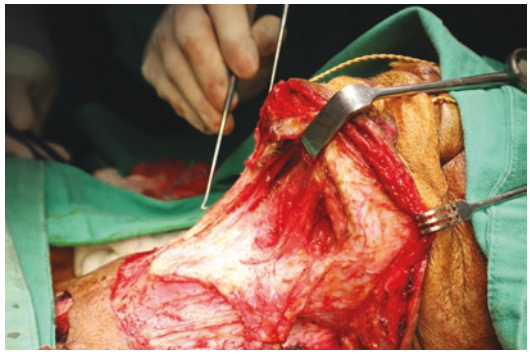


Fig. 13.22 Dissection starts at levels Ia and IB. The tissue at level Ia is held with Allis tissue forceps and retracted inferiorly to ease the dissection

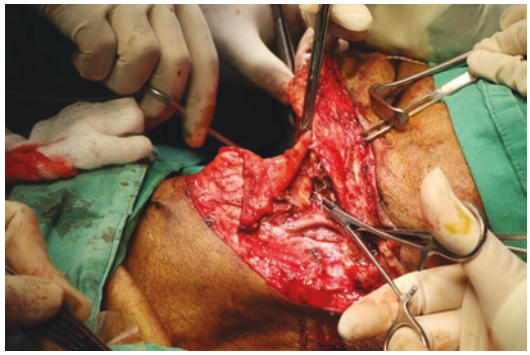


Fig. 13.23 Dissection at level Ib addressing the removal of submandibular gland and its nodes. Branches of facial artery and vein need to be ligated

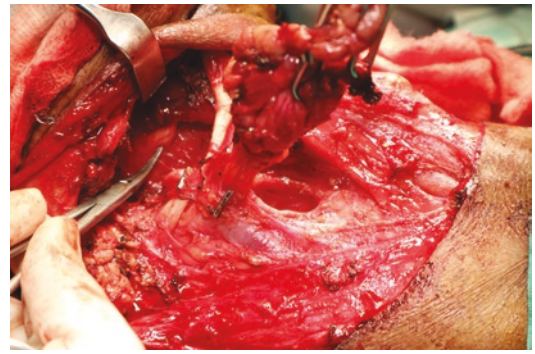


Fig. 13.24 The submandibular gland is removed together with the fibrofatty tissue of neck dissection specimen

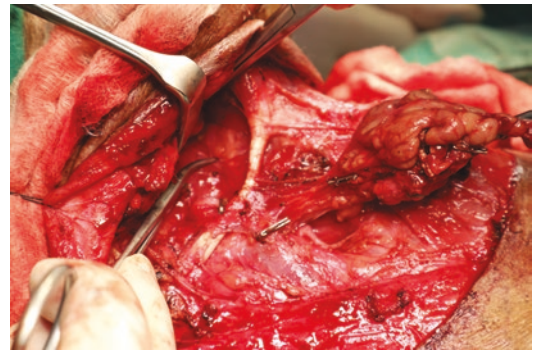


Fig. 13.25 The anterior and posterior belly of digastric muscle is well visualized once the submandibular gland has been retracted inferiorly

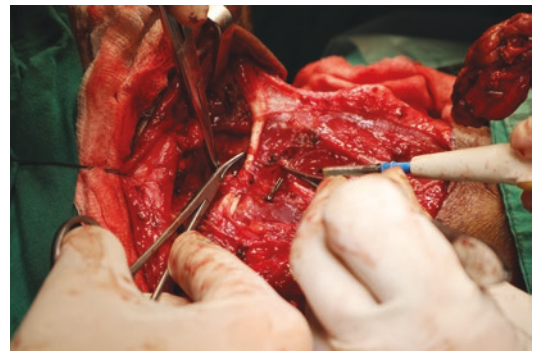


Fig. 13.26 The dissection continues inferiorly at level III and IV neck. This patient has a thin neck and not much of the fibrofatty tissue is visualized apart from the thin fascia

The marginal mandibular nerve can be identified as it runs superficial to the submandibular gland capsule. The use of microsurgical loupes and nerve stimulator facilitates the marginal mandibular nerve identification and preservation. The facial artery and vein need to be ligated twice, anterior and posterior to the glands (Fig. 13.23). Once the submandibular gland is released just underneath the mandible, it can be retracted down as the dissection continues. Retraction of mylohyoid muscle superomedially exposes the lingual nerve, submandibular nerve, and hypoglossal nerve (Figs. 13.24 and 13.25).

The dissection continues at levels III and IV (Fig. 13.26). The fascia overlying the IJV is dissected in continuity with the fascia overlying the carotid artery. This exposes the carotid artery and vagus nerve (Figs. 13.27 and 13.28). The lower end of the IJV can be identified by using omohyoid muscle. The vein lies intimately deep to the muscle (Fig. 13.29). This is used if dissection is

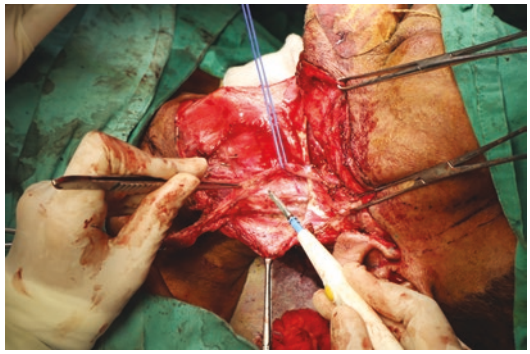


Fig. 13.27 Dissection continues to expose the carotid sheath and its content (IJV, vagus nerve, common carotid artery)

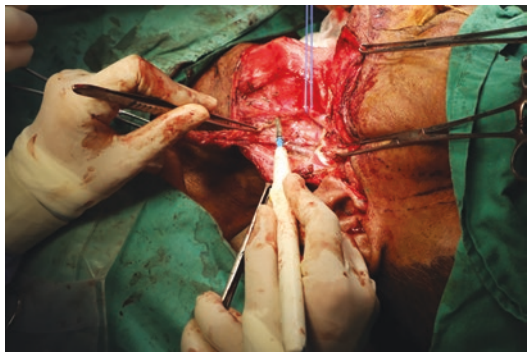


Fig. 13.28 Dissection on the fascia over carotid artery is done, and the tissue is medialized

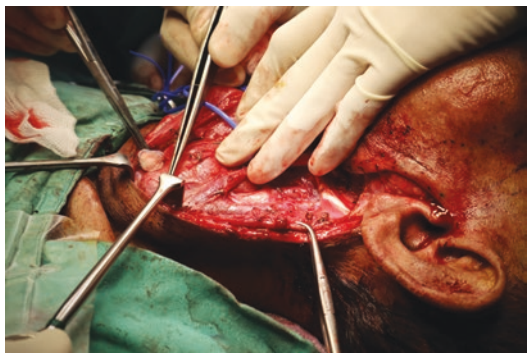


Fig. 13.29 The omohyoid is a critical landmark for the identification of IJV

started inferiorly, and retrograde dissection is performed. The branches of IJV can be retracted and preserved during dissection (Fig. 13.30). This reduces post-operative facial oedema.

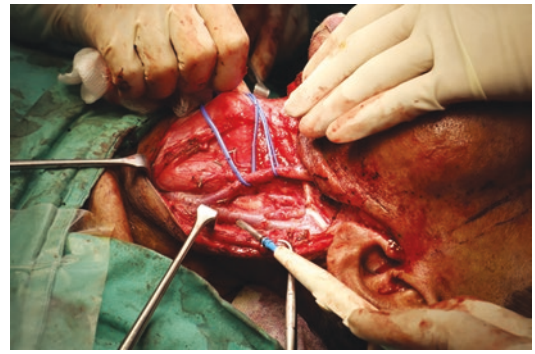


Fig. 13.30 The branch of IJV is retracted medially to facilitate dissection

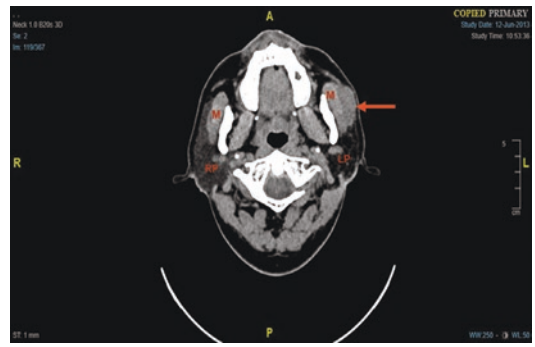


Fig. 13.31 Left recurrent parotid tumour (arrow) on the maxilla, with minimal subcutaneous tissue and possible skin infiltration. The tumour is abutting the masseter muscle (M). The difference in parotid region can be appreciated, where the parotid gland is still visualized (RP) with haziness in the region. The left parotid area is replaced with fatty tissue (LP), as the patient already had left total parotidectomy before

13.7.4 Case Illustration 3

A 45-year-old Malay male with a history of parotidectomy for acinic cell carcinoma in 2013. Now, the patient re-presented with a recurrent tumour at left zygoma. The tumour measures 2.0 cm × 1.0 cm, is mobile, and lies quite superficial, just underneath the skin at the zygoma (Figs. 13.31 and 13.32). The facial nerve examinations showed grade II left marginal mandibular nerve paresis. CT scan image showed a heterogenous mass with irregular border abutting the zygoma (Fig. 13.31).

Patient is planned for excision of left cheek recurrent tumour together with selective neck dissection at left level II–IV neck nodes.

The patient lies supine with neck hyperextended. The facial nerve stimulator is applied. The area is cleaned with dilute povidone iodine solution. Oral intubation is performed, and the tube is anchored to the right side of the mouth (Fig. 13.32).

A modified Blair skin incision is performed (Fig. 13.33). The skin flap is raised anteriorly to the level of the recurrent tumour to facilitate excision and clearance of the tumour with free surgical margin. Frozen section of tissue is carried out to ensure negative surgical margins. The skin superior to the mass is tense and thin but mobile.

The nerve stimulator is used to identify the facial nerve branches, which blend with fibrotic tissue due to previous surgery (Fig. 13.34). The anterior limit of skin flap is at the anterior border of the recurrent tumour to allow visualization and extirpation of tumour.

The branches of the facial nerve are away from the tumour, thus allowing easy dissection and removal of the tumour tissues. A good cuff of periphery tissue surrounds the tumour which is resected to ensure the adequacy of the surgical margins (Figs. 13.35 and 13.36).

Anterolateral neck dissection of ipsilateral left level I, II, III, and IV is carried out. All fibrofatty and lymphatic tissue from level Ia, Ib, II, III, and IV is dissected out (Figs. 13.37, 13.38, 13.39, and 13.40).

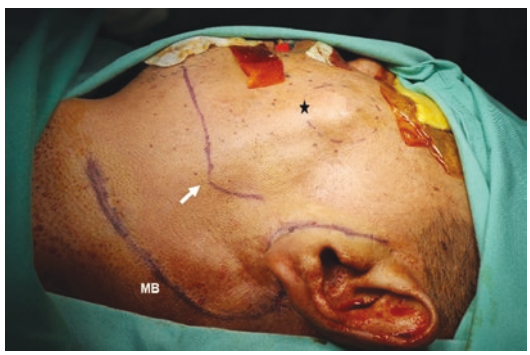


Fig. 13.32 Surgical landmarks are drawn: the outline of tumour margin (star), the inferior angle of mandible (arrow), and the modified Blair skin incision (MB). The drape exposes the angle of mouth and eyes to monitor contraction of the muscle during dissection

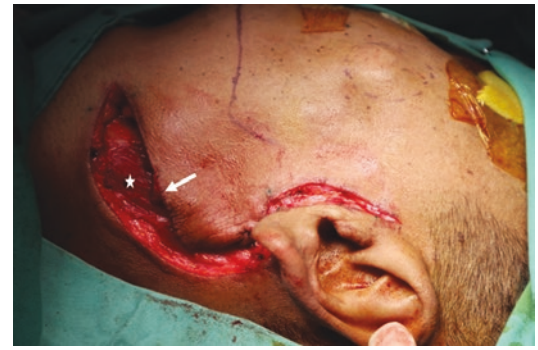


Fig. 13.33 A modified Blair skin incision has been done. The subplatysmal skin flap is raised (arrow), exposing the sternocleidomastoid muscle (star) underneath

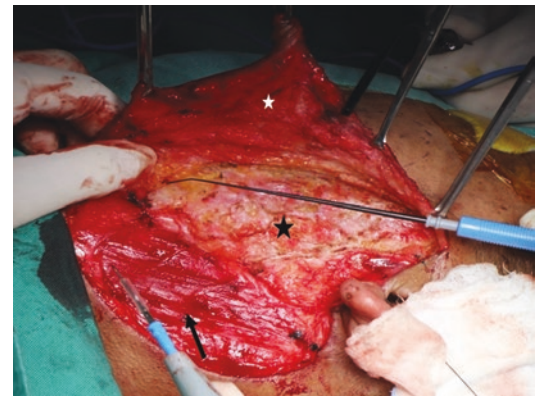


Fig. 13.34 The skin flap (white star) is retracted and reflected anteriorly exposing the whitish parotid bed (black star) and sternocleidomastoid muscle (arrow)

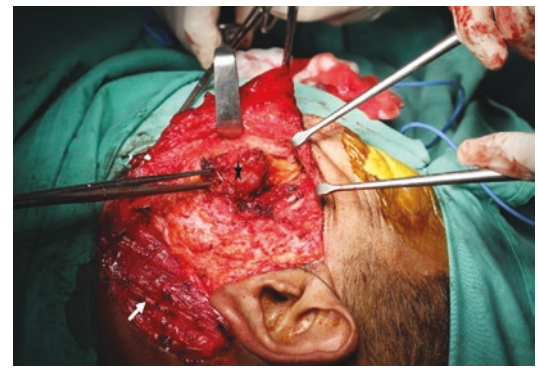


Fig. 13.35 The recurrent tumour (star) is retracted gently laterally, and deep tissue dissection is continued. The sternocleidomastoid muscle (arrow) will be rotated to cover the surgical defect post tumour removal

Sternocleidomastoid muscle is cut at its upper one-third and half of its width, and rotated supero-anteriorly to cover the defect caused by removal of recurrent tumour (Fig. 13.41). This enhances the post-op cosmesis, which is impaired if there is presence of cheek depression.

Post-operatively, the patient had significant facial nerve paralysis, especially the marginal mandibular nerve grade III House-Brackmann grading system (Fig. 13.42).

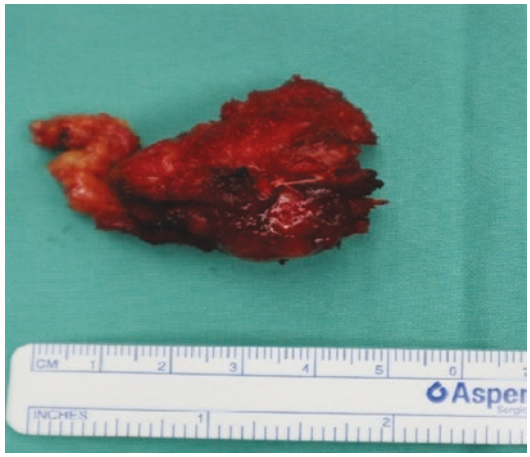


Fig. 13.36 The excised recurrent tumour measuring 4.8 cm × 3.0 cm which is solid and hard in consistency

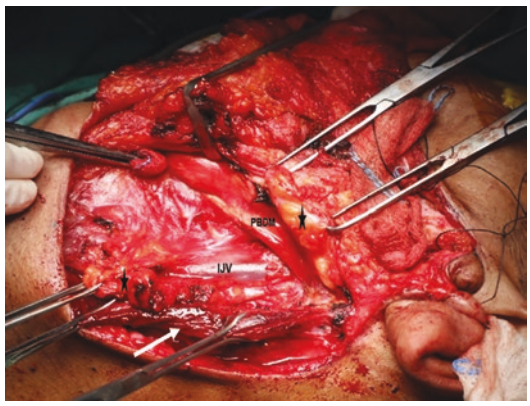


Fig. 13.37 The SCM is retracted lateral inferiorly, and the fibrofatty tissue (star) inferior to mandible is dissected and retracted inferiorly. The fibrofatty tissue (star) over the IJV is dissected, while traction is maintained inferiorly

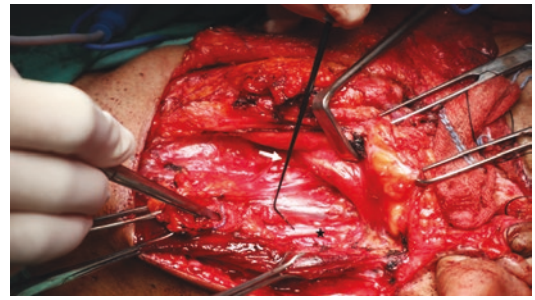


Fig. 13.38 Spinal accessory nerve (star) runs superficial to IJV and extends obliquely inferiorly to innervate the SCM

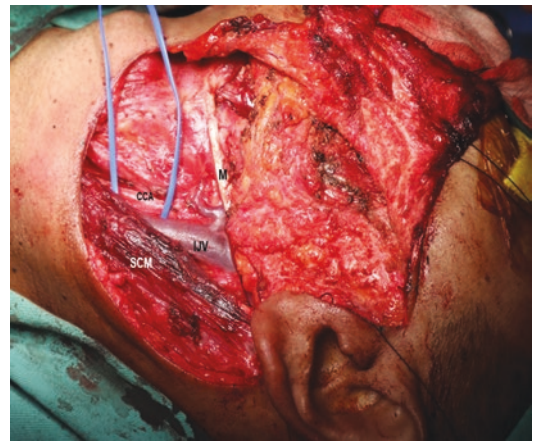


Fig. 13.39 The IJV and common carotid artery (CCA) are visualized medial to the sternocleidomastoid muscle (SCM). The fibrofatty tissue has been cleared and removed exposing the inferior border of mandible (M)

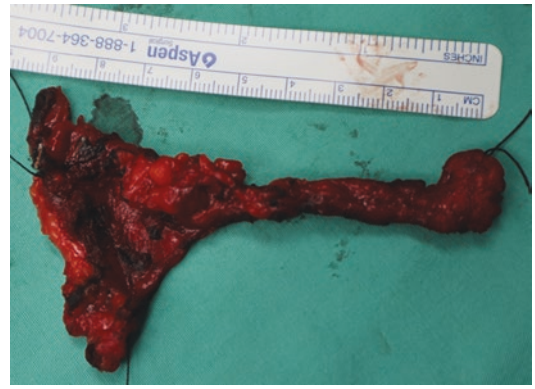


Fig. 13.40 The neck dissection specimen is labelled with suture to orientate for the histopathological examination

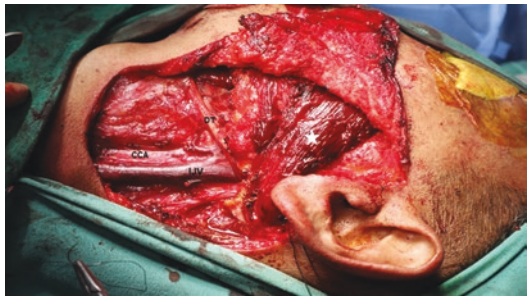


Fig. 13.41 The sternocleidomastoid muscle is rotated superior anteriorly (star) and sutured to subcutaneous tissue. IJV, common carotid artery (CCA), and digastric tendon (DT) are visualized

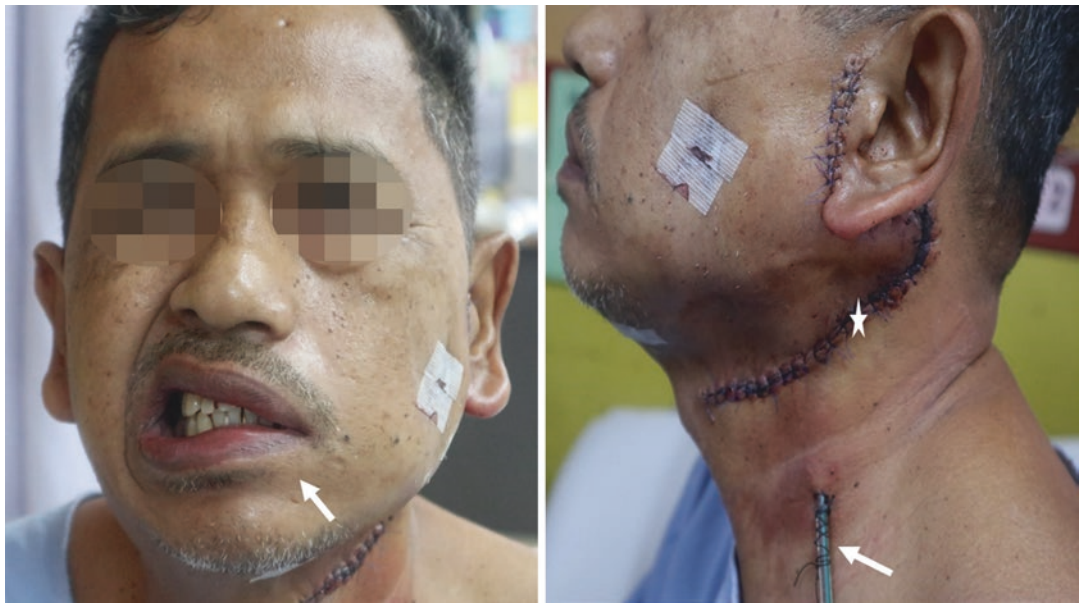


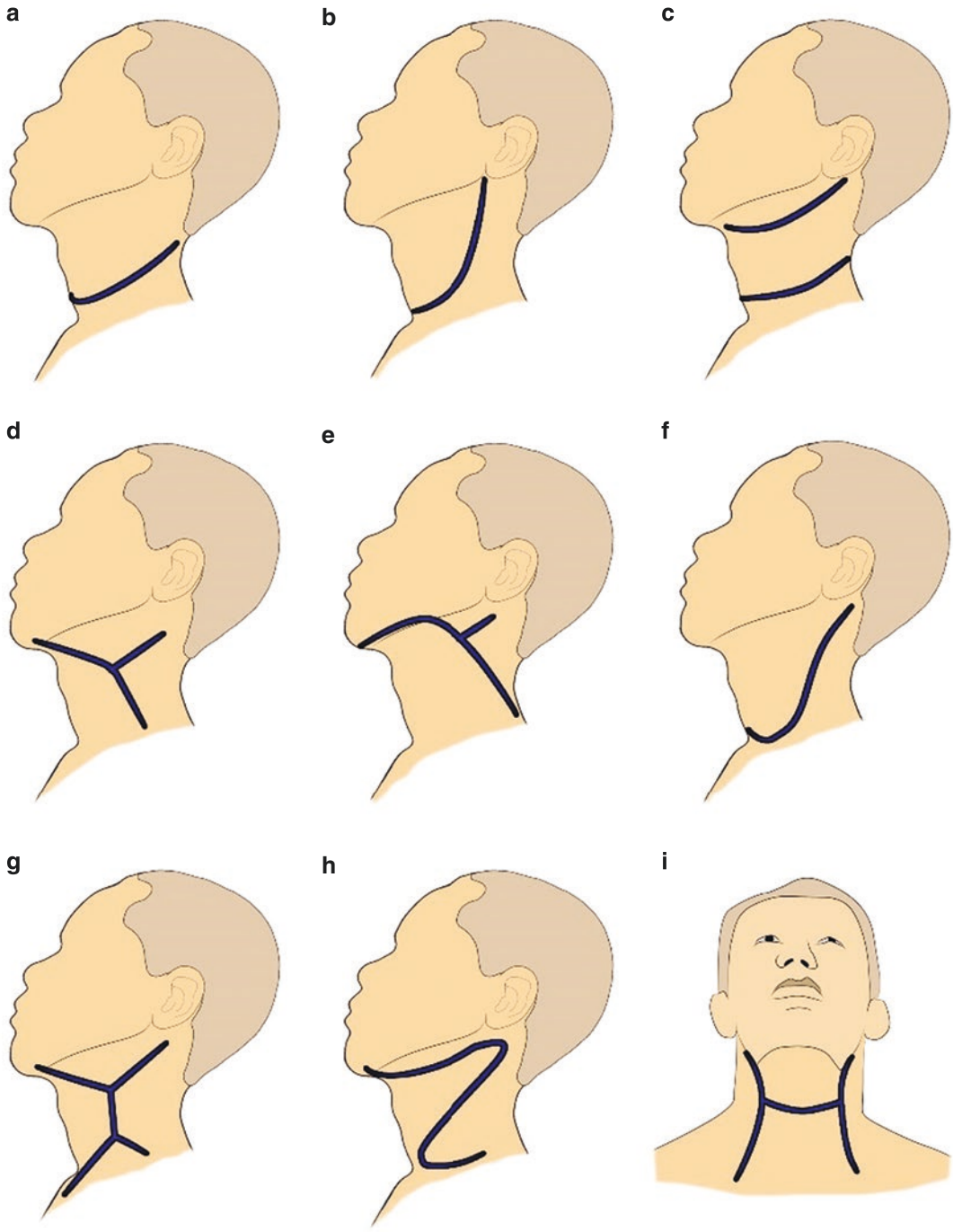
Fig. 13.42 Left marginal mandibular nerve paralysis (arrow) evident as loss of depression of left lower lip. Postoperative wound (star) and a drain are secured (arrow) in situ on the left neck

13.8 Modified Radical Neck Dissection

MRND is performed for neck metastasis disease with clinically significant palpable neck nodes. The MRND will address level I–V neck nodes with or without preservation of the three non-lymphatic structures. The classification of neck dissection is shown in Table 13.5.

The skin incision methods of MRND which are commonly used include:

1. J incision or hockey stick incision
2. Modified Gluck-Sorenson
3. U-shape incision
4. MacFee incision



Steps of MRND

1. Patient preparation, and patient lies supine with neck extension and face turned to the contralateral side.
2. Skin is draped and cleaned with dilute povidone iodine.
3. Skin marking and surgical landmarks are drawn with marker pen and tattooing done at the skin incision, to ensure asymmetry closure.
4. Skin incision is carried out with blade size 12; a subplatysmal skin is raised superiorly till

Table 13.5 Classification of types of modified radical neck dissection (MRND)

	Type of MRND	Description
1.	MRND type I	Dissection of lymphatic tissues and fibrofatty tissues at level I–V neck nodes with preservation of spinal accessory nerves
2.	MRND type II	Dissection of lymphatic tissues and fibrofatty tissues at level I–V neck nodes with preservation of spinal accessory nerves and IJV
3.	MRND type III	Dissection of lymphatic tissues and fibrofatty tissues at level I–V neck nodes with preservation of spinal accessory nerves, IJV, and SCM

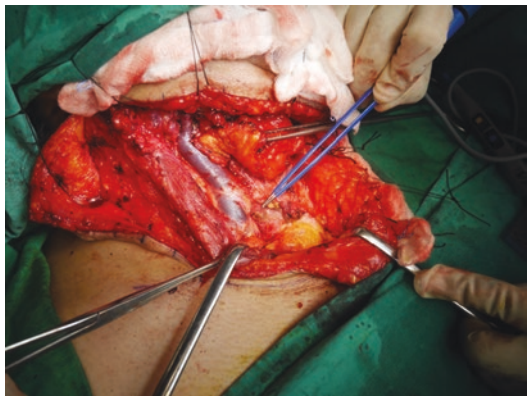


Fig. 13.43 Dissection at levels II, III, and IV will show the IJV from mandibular level to clavicle level. The SCM is reflected laterally

mandible, inferiorly till clavicle, and posteriorly till anterior trapezius muscle.

5. Dissection starts at level Ia and Ib of the neck.
6. Dissection continues to levels II, III, and IV overlying the internal jugular vein (Fig. 13.43).
7. Dissection at level V is performed, with the identification and preservation of SAN. The SCM is maintained retracted laterally (Fig. 13.44).
8. Further dissection at level V exposed the metastatic nodes (Fig. 13.45).
9. Spinal accessory nerve is identified and preserved (Fig. 13.46).

In this case, a clavicle osteotomy is required in order to remove the metastatic neck nodes with negative margins. This widened the surgical

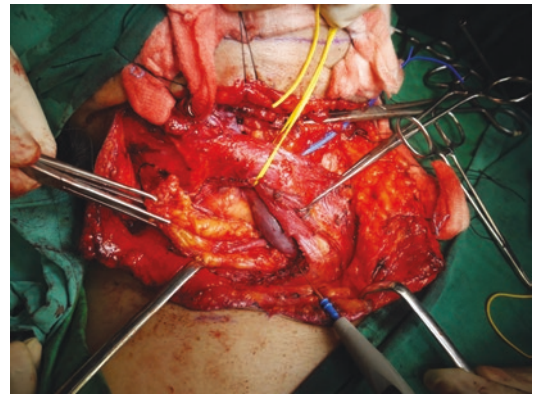


Fig. 13.44 The dissection at level V is carried out. The SCM muscle has to be retracted medially. The SAN needs to be identified and skeletonized along its course from SCM to trapezius muscle

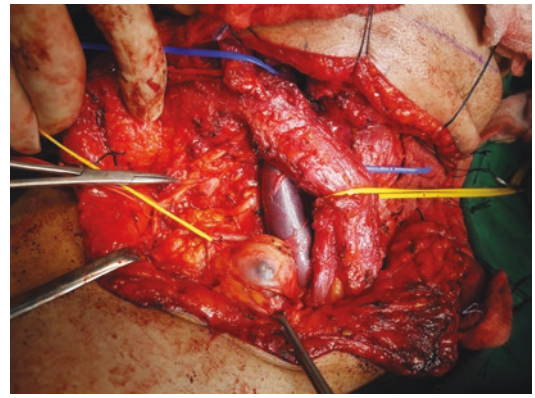


Fig. 13.45 Metastatic neck node dissection at levels V and IV necessitates clavicular osteotomy to facilitate dissection

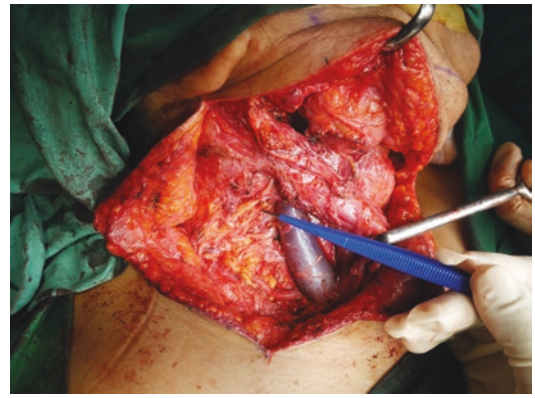


Fig. 13.46 Spinal accessory nerve is running from the posterior border of sternocleidomastoid to the anterior border of trapezius

access and allowed better manipulation of the adjacent IJV and vagus nerve in order to reduce iatrogenic injury to these vital structures. Lower dissection in the infraclavicular region also added the risk of lymphatic duct injury with resultant chylous leak.

In some forms of head and neck cancer, the total number of harvested lymph nodes (nodal yield) in a neck dissection specimen is an independent prognostic factor [12]. For patients who are clinically N1b, the American Thyroid Association (ATA) recently issued recommendations for a modified radical neck dissection (MRND) encompassing levels II–V. Only a few studies have compared the outcomes of the ipsilateral and bilateral MRND clinicopathologic characteristics. The author reported that patients who had a thyroidectomy and bilateral MRND had a better outcome [13].

13.9 Radical Neck Dissection

In our practice, radical neck dissection is rarely performed due to multiple factors. This factor mainly involves the patient's factors and tumour's factors. Many imperative patients' factors need to be considered before embarking on a radical neck dissection, as the complications which can occur post-operatively are very high. All these complications impair the patient's quality of life post-operatively. Additionally, a thorough understanding of the anatomy of the neck is essential to avoid injury to vital structures when performing radical neck dissection. The complicated anatomical relations of the various nerves, vessels, and muscles within the confined area of the neck can often be daunting especially for junior surgeons [14]. Unless the surgeons are well versed with the anatomic details, variations, and intraoperative findings, the complications are unavoidable.

In our practice, the majority of patients that present to us with neck metastases who are indicated for radical neck dissection are elderly patient population with multiple comorbidities. In addition to poor cardiopulmonary reserve, these patients also have other comorbidities such as hypertension and a history of cardiac events like angina, myocardial infarction, and stroke. This places this category of patients as poor surgical candidates.

Consideration of benefit versus risk is mandatory when deciding for the best surgical treatment intended for any head and neck cancer patients. The treatment outcomes need to outweigh the morbidity from the surgery. The radical neck dissection causes significant sequelae that can impair the patient's quality of life post-operatively. The effectiveness of radical neck dissection would not be questioned if the treatment outcomes would be perfect. When post-operative morbidity is associated with oncological shortage of radical neck dissection, either in functional or cosmesis embarrassment, other alternative therapeutic approaches should be considered [15].

13.10 Post-operative Care and Complications

Neck dissection is a fairly morbid operation. Many of the critical head and neck structures are at risk during the surgery. The complication, disturbance, and interruption to these organs' functions are so critical since they interfere with breathing, swallowing, neck movement, or shoulder abduction. In the past decades wherein radical neck dissection has been more frequently practised, the section of sternocleidomastoid muscle, spinal accessory nerve, and internal jugular vein causes a very debilitating post-operative sequelae. This includes facial oedema, frozen shoulder syndrome, thin neck and limited neck, and shoulder mobility. The long hours of surgery also cause more bleeding, tissue injury, increased post-operative drainage, and prolonged post-operative recovery. All of these complications significantly impair the patient's quality of life.

The sternocleidomastoid muscle, internal jugular vein, spinal accessory nerve, submandibular gland, and cervical plexus nerves used to be sacrificed during radical neck dissection. This was practised for decades as the standard operative procedure in the surgical management of lymph node metastases of head and neck cancers [16].

As severe complications related to the surgery began to be experienced by patients who have undergone RND with minimal increment in disease-free survival, many centres investigated the role of less extensive neck dissection which has a comparable treatment outcome. In this current era, more types of functional neck dissection have been introduced and practised. Numerous studies have shown that these types of neck dissection are more efficient with less surgery-related morbidities but patients have similar prognosis and survival rates.

Quality of life of a head and neck oncology patient is severely affected by the surgery. Selected patients require multiple surgeries due to recurrent tumours. This causes more detrimental complications, which are challenging to manage, especially in elderly patient group who have multiple medical comorbidities. The fibrotic tissue due to the initial surgery makes the identification of neurovascular structures more difficult with more risk of nerve palsies and bleeding. Shoulder dysfunction and discomfort, loss of sensitivity of the overlying skin, cranial nerve damage, and anatomic deformities are all common side effects of this operation, all of which have an impact on the patient's quality of life [17]. Thus, it is imperative to properly plan a neck dissection with meticulous techniques and practices during the dissection and a committed team should be involved for every head and neck oncology case.

When more neck node levels are dissected, more complications can be expected. This is especially true when neck node level V is addressed for a MRND or RND. Selected clinicians agree on the fact that level V dissection will result in less morbidity. On the other hand, maintaining such lymph node levels may result in a higher rate of regional failure, necessitating further care with re-surgery or combination of surgery and radiation, and likely resulting in a poorer prognosis [17]. In essence, it should be thoroughly assessed whether level V neck dissection should be incorporated or omitted during neck dissection for a primary tumour that has a potential of spread to this level.

The complication that arises from surgery is not only due to the direct transection of the neural structures or puncture to the big vessels. It can also arise from techniques of dissection, instrument used, assistant error, or inappropriate traction applied during the dissection. Shoulder complaints and functional impairment are common sequelae of neck dissection. This is often attributed to injury of the spinal accessory nerve by aggressive dissection or direct trauma. Nevertheless, shoulder morbidity may also occur in cases in which the spinal accessory nerve has been preserved [16]. This is mainly due to over-manipulation or traction applied during the dissection. Reported neck dissection surgery complications of spinal accessory nerve injury include decreases in the power and range of motion of the shoulder muscle, drooping shoulder, and shoulder pain [18].

In some centres, the spinal accessory nerve injury is significant as more MRND is performed since the majority of patients present with significant palpable neck node disease. Many symptoms and signs have been discussed and associated with SAN injury in the literatures. Trapezius paralysis or dysfunction, shoulder girdle depression, trapezius atrophy, scapular dyskinesia, failure of shoulder abduction, and shoulder and neck pain are all symptoms of spinal accessory nerve injury. Detecting these related symptoms is usually enough to make a diagnosis of spinal accessory nerve palsy [16].

The prevalence and incidence of dysfunction of the shoulder and neck following neck dissection vary according to the type of operation performed. Preoperative education for patients undergoing neck dissection should include informing the patients that the risk of developing musculoskeletal complications is reduced but not eliminated by SAN preservation [19]. The research data confirms that shoulder morbidity is increased by clearance of the posterior triangle of the neck [20].

Higher shoulder mobility, less loss of face and neck sensation, and better quality of life are associated with the preservation of cervical root branches of the cervical plexus following a functional neck dissection in which the spinal accessory nerve is spared [18, 21]. Shoulder dysfunction was the most common side effect in

patients with neck dissection, which was not seen in patients who received radiation as a single-modality treatment. In other researches, shoulder impairment caused by an injury to the accessory nerve has been identified as the most common side effect of neck dissection, and symptoms caused by accessory nerve injury have been reported to have an impact on quality of life [8].

13.11 Prognosis

There have been many debates on which types of neck dissection should be performed for a particular tumour in a quest to improve patient prognosis with only minimal surgery-related complications caused. The approach toward a more functional neck dissection has evolved with many refined dissection techniques. This is complemented by the advancement in head and neck imaging and enhanced immunochemistry and histology, which provides huge data on the adjacent tissue infiltration, extracapsular extension, and microscopic tumour spread. The choices of elective neck dissection versus a therapeutic neck dissection probably do not play a significant impact on the patient prognosis. What is important is the meticulous dissection of the areas in the positive nodes and accurately addressing the neck node level at higher risk of microscopic tumour seedling.

Elective management of negative clinical or radiological evidence of lymph node metastases in the neck N0 in early-stage T1–T2 oral squamous cell carcinoma has been the subject of much controversy. The END may significantly reduce the rate of regional nodal recurrence and improve DSS in patients with cT1T2N0 oral cavity carcinoma [22, 23]. Some centres practise a watchful and waiting policy with frequent follow-up schedule.

13.12 Conclusion

One of the many essences of managing head and neck tumours is to address the risk of neck disease meticulously and properly choose an ideal neck dissection type for every head and neck cancer case. Individual cases require different types of neck dissection, and the case should be considered together with other critical factors such as the details of tumour's factors and patient's factors. The ultimate goal is clearance of the disease, reducing the risk of recurrent tumour, and being able to provide the best quality of life for any given patients. Neck dissection is not without complications, and the surgery demands many working hours from the surgeon. It is best to ensure a complete extirpation of all macroscopic and microscopic tumours to ensure a better prognosis and survival of patients.

References

1. Nishio N, Fujimoto Y, Hiramatsu M, et al. Diagnosis of cervical lymph node metastases in head and neck cancer with ultrasonic measurement of lymph node volume. Auris Nasus Larynx. 2019;46(6):889–95. https://doi.org/10.1016/j.anl.2019.02.003.
2. Huang L, David O, Cabay RJ, et al. Molecular classification of lymph node metastases subtypes predict for survival in head and neck cancer. Clin Cancer Res. 2019;25(6):1795–808. https://doi.org/10.1158/1078-0432.CCR-18-1884.
3. Mat Lazim N. Head and neck malignancy: hallmarks of the inflammation ecosystem. Singapore: Bentham Science; 2021. p. 1–348. ISBN: 9811803234, 9789811803239.
4. Fang Q, Gao H, Gao Q, et al. Elective neck dissection versus wait-and-see policy in cT1N0 buccal squamous cell carcinoma. BMC Cancer. 2020;20(1):537. Published 2020 Jun 9. https://doi.org/10.1186/s12885-020-07006-w.
5. Pandey M, Karthikeyan S, Joshi D, Kumar M, Shukla M. Results of a randomized controlled trial of level IIb preserving neck dissection in clinically node-negative squamous carcinoma of the oral cavity. World J Surg Oncol. 2018;16(1):219. Published 2018 Nov 8. https://doi.org/10.1186/s12957-018-1518-z.
6. Koyfman SA, Ismaila N, Crook D, et al. Management of the neck in squamous cell carcinoma of the oral cavity and oropharynx: ASCO clinical practice guideline. J Clin Oncol. 2019;37(20):1753–74. https://doi.org/10.1200/JCO.18.01921.
7. Böttcher A, Betz CS, Bartels S, et al. Rational surgical neck management in total laryngectomy for advanced stage laryngeal squamous cell carcinomas. J Cancer Res Clin Oncol. 2021;147(2):549–59. https://doi.org/10.1007/s00432-020-03352-1.
8. Ahlberg A, Nikolaidis P, Engström T, et al. Morbidity of supraomohyoidal and modified radical neck dis-

section combined with radiotherapy for head and neck cancer: a prospective longitudinal study. Head Neck. 2012;34(1):66–72. https://doi.org/10.1002/hed.21689.
9. Gambardella C, Tartaglia E, Nunziata A, et al. Clinical significance of prophylactic central compartment neck dissection in the treatment of clinically node-negative papillary thyroid cancer patients. World J Surg Oncol. 2016;14(1):247. Published 2016 Sept 19. https://doi.org/10.1186/s12957-016-1003-5.
10. Eltelety AM, Terris DJ. Neck dissection in the surgical treatment of thyroid cancer. Endocrinol Metab Clin N Am. 2019;48(1):143–51. https://doi.org/10.1016/j.ecl.2018.11.004.
11. Wang L, Wang L, Song X, et al. The necessity of IIb dissection in T1-T2N0M0 oral squamous cell carcinoma: protocol for a randomized controlled trial. Trials. 2019;20(1):600. Published 2019 Oct 22. https://doi.org/10.1186/s13063-019-3683-y.
12. Möckelmann N, Lörincz BB, Knecht R. Robotic-assisted selective and modified radical neck dissection in head and neck cancer patients. Int J Surg. 2016;25:24–30. https://doi.org/10.1016/j.ijsu.2015.11.022.
13. Ryu YJ, Cho JS, Yoon JH, Park MH. Identifying risk factors for recurrence of papillary thyroid cancer in patients who underwent modified radical neck dissection. World J Surg Oncol. 2018;16(1):205. Published 2018 Oct 12. https://doi.org/10.1186/s12957-018-1496-1.
14. Khatri VP, Loree TR. A logical and stepwise operative approach to radical neck dissection. Arch Surg. 2002;137(3):345–51. https://doi.org/10.1001/archsurg.137.3.345.
15. Trivić AS, Djukić VB, Krejović-Trivić SB, Milovanović JP, Stanković PD, Milovanović AP. Acta Chir Iugosl. 2009;56(3):149–53. https://doi.org/10.2298/aci0903149t.
16. Bradley PJ, Ferlito A, Silver CE, et al. Neck treatment and shoulder morbidity: still a challenge. Head Neck. 2011;33(7):1060–7. https://doi.org/10.1002/hed.21495.
17. Govers TM, Patel S, Takes RP, Merkx T, Rovers M, Grutters J. Cost-effectiveness of selective neck dissection versus modified radical neck dissection for treating metastases in patients with oral cavity cancer: a modelling study. Head Neck. 2015;37(12):1762–8. https://doi.org/10.1002/hed.23833.
18. Sheikh A, Shallwani H, Ghaffar S. Postoperative shoulder function after different types of neck dissection in head and neck cancer. Ear Nose Throat J. 2014;93(4–5):E21–6.
19. Gane EM, Michaleff ZA, Cottrell MA, et al. Prevalence, incidence, and risk factors for shoulder and neck dysfunction after neck dissection: a systematic review. Eur J Surg Oncol. 2017;43(7):1199–218. https://doi.org/10.1016/j.ejso.2016.10.026.
20. Cappiello J, Piazza C, Giudice M, De Maria G, Nicolai P. Shoulder disability after different selective neck dissections (levels II-IV versus levels II-V): a comparative study. Laryngoscope. 2005;115(2):259–63. https://doi.org/10.1097/01.mlg.0000154729.31281.da.
21. Garzaro M, Riva G, Raimondo L, Aghemo L, Giordano C, Pecorari G. A study of neck and shoulder morbidity following neck dissection: The benefits of cervical plexus preservation. Ear Nose Throat J. 2015;94(8):330–44.
22. Abu-Ghanem S, Yehuda M, Carmel NN, et al. Elective neck dissection vs observation in early-stage squamous cell carcinoma of the oral tongue with no clinically apparent lymph node metastasis in the neck: a systematic review and meta-analysis. JAMA Otolaryngol Head Neck Surg. 2016;142(9):857–65. https://doi.org/10.1001/jamaoto.2016.1281.
23. de Bree R, Takes RP, Shah JP, et al. Elective neck dissection in oral squamous cell carcinoma: past, present and future. Oral Oncol. 2019;90:87–93. https://doi.org/10.1016/j.oraloncology.2019.01.016.

14 Head and Neck Surgical Access in the Management of Head and Neck Malignancy

Norhafiza Mat Lazim, Ahmad Zuhdi Mamat, and Wan Faisham Nu'man Wan Ismail

14.1 Introduction

Head and neck cancer occupies a critical region that interferes with many of the basic human functioning like breathing, swallowing, mastication, speech, hearing, and vision. This makes the surgery of head and neck tumour crucial, as many important organs and neurovascular structures need to be preserved in addition to ensuring a safe extirpation of tumoural mass. The malignant mass needs to be removed in total with the aim of achieving negative surgical margins. Negative surgical margin is a prerequisite for head and neck cancer surgery to reduce the incidence of locoregional recurrence and distant metastases. This will ensure a better treatment outcome and prognosis for this subset of oncology patients.

In achieving these objectives, adequate surgical access should be made available when dealing with malignant tumour surgeries in the head and neck region. This means, to access the tumour tissue in selected areas, the adjacent structures need to be addressed surgically, in order to provide an adequate access. The use of enhanced instruments offers some assistance in reducing the duration of surgery. Manipulation of adjacent structures like mandible, clavicles, and sternum poses high morbidities and risk of greater complications. This ranges across prolonged healing, risk of serious infections, osteoradionecrosis, longer ward admission, extra cost, and so forth. These morbidities can influence the treatment outcomes and patient's quality of life. The added cost to the health institution will also be significant. Hence, a meticulous consideration of these pros and cons of surgical intervention and access is necessary in order to perform a safe and effective surgery.

The objective of malignant tumour resection is to attain an enhanced oncological outcome with minimal complications as possible. Some techniques and instruments have been in practice for this purpose. Minimally invasive surgery in the setting of head and neck malignancy is paramount. This technique, while preserving the functions and quality of life, offers a radical oncology treatment. Transoral access using transoral laser microsurgery (TLM), electrosurgery, and transoral robotic surgery (TORS) is the primary surgical method. These techniques have been used especially in upper aerodigestive tract malig-

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N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_14

nancy. This minimally invasive surgery has been adopted in many areas of head and neck surgery to reduce patient morbidity during surgical resection. In order to achieve this, endoscopic instrumentation has been developed in conjunction with improved imaging and localization techniques to allow adequate resection of tumours with minimum damage to the surrounding tissues [1].

Chemoradiation is equally effective as a primary therapy in the first and second stages of cancer clinical progression. Late complications such as swallowing, breathing, and taste and odour disorders, however, have led to a recent re-emergence of minimally invasive surgery [2]. This technique has a comparable outcome with chemoradiation but with minimal morbidities.

Advanced malignancies of the head and neck with underlying osteo involvement often require aggressive oncological resection of large oral cavity segments, including the mandible or maxilla. Microvascular transplantation of osteocutaneous tissue such as fibular or scapula free flap provides reconstruction following these ablations. These transplanted free flaps require multiple osteotomies to reconstitute the premorbid bony and soft-tissue anatomical structures of the head and neck in complex three-dimensional orientations. Reconstruction accuracy has a significant impact on cosmetic and functional outcomes such as chewing, articulation, deglutition, and respiration, as well as a significant impact on the quality of life of the patient [3]. Virtual planning and creation of surgical guides for mandibular reconstruction can be applied to three-dimensional printing. In head and neck reconstruction, such systems are becoming increasingly prevalent. Access to this technology, even though a little expensive, will escalate the trajectory of head and neck cancer management.

14.2 Importance of Adequate Surgical Access

Sufficient surgical access and view of surgical bed are highly critical for the success of any surgeries (Table 14.1). Nowadays, the introduction of multi-angle endoscopes, image-guided surgery, and autofluorescence techniques has made the surgery of head and neck tumours safer and efficient. In selected cases, however, the cutting of bones like mandible, clavicle, and sternum is necessary in order to gain access to the primary tumour for effective resection.

In the treatment of laryngo-pharyngeal cancer, transoral surgery is a less invasive treatment that is becoming a common practice in most of the head and neck oncology centres. This is a minimally invasive approach that utilizes no skin incision and limits the extent of dissection of tissue. Subsequently, speech disruption, swallowing impairment, blood loss, damage to major neurovascular structures, and normal tissue injury can be avoided [4]. On the other hand, the transoral robotic surgery (TORS) procedure allows deeper access and dissection of suspicious lesions and neoplastic growths in the oral cavity and those that extend from the throat to the base of the

Table 14.1 Example of surgical access for head and neck tumour removal

	Access for head and neck tumour surgery	Indications
1	Lateral pharyngotomy	• Oropharyngeal tumour
2	Sublingual mandibular release	• Tongue base tumour • Tonsillar carcinoma
3	Mandibulotomy	• Tongue base tumour • Retromolar trigone tumour
4	Sternotomy	• Superior mediastinal tumour • Retrosternal goitre
5	Clavicle osteotomy	• Level IV recurrent tumour • Posterior triangle tumour
6	Endoscopic thyroidectomy	• Limited thyroid tumours
7	Endoscopic nasopharyngectomy	• Small recurrent NPC

skull. Robotic surgery allows the surgeon to operate in tight spaces without a large external incision [5]. This ensures less complications and improves the patient's quality of life.

14.3 Endoscopic Assisted Surgical Access

Nowadays, many of the head and neck tumours have been performed surgically with endoscopic assisted procedures. The emergence of multi-angle endoscope with enhanced view and magnification has favoured many endoscopic based procedures in treating head and neck pathology. For instance, the worldwide implementation of endoscopic thyroid surgery, which allows for more complex procedures through minimally invasive approaches, has been achieved, particularly in Asian countries such as Korea, Japan, Hong Kong, and China. Transoral access has been considered the most promising approach for thyroid dissection among these remote-access surgical options [5]. The aesthetic outcome is better, and no significant complications have been reported with this technique.

An enhanced endoscopy and a refinement in image-guided surgery techniques and imaging have transformed the endoscopic assisted procedures in most of the head and neck surgeries. The surgeon, especially junior surgeons, should have ample practice and more experience in manoeuvring endoscopes and multiple instruments at a particular time. This is a vital learning curve for a budding head and neck surgeon globally.

14.3.1 Endoscopic Thyroidectomy

Remote-access thyroid surgery has gained popularity and has advanced significantly over the past two decades. This has driven the patient desire to avoid cosmetically displeasing scarring. Because of superior diagnostic imaging technologies, the prevalence of low-risk differentiated thyroid cancer is dramatically decreasing. Due to the absence of a noticeable neck scar, remote-access endoscopic thyroidectomy is becoming more common. For transoral endoscopic thyroidectomy, vestibular approach is the only technique that could be called a true scarless surgery [7]. In addition, many institutions have reported a learning curve for endoscopic thyroid surgery. The learning curve for transoral thyroid surgery has been considered to be shorter than other methods [6]. The technique is indicated in patients without pre-existing neck operations for hemithyroidectomy.

The technical steps consist of a 10 mm incision followed by subplatysmal hydrodissection at the centre of the oral vestibule. A blunt dissector stick is inserted to create a space below the platysma in the anterior neck, and then three trocars are inserted in the vestibular area to the infrahyoid muscles. The thyroid isthmus is transected after separation of the infrahyoid muscles. Anatomical structures can be easily identified with magnification, such as the superior thyroid artery, parathyroid glands, and recurrent laryngeal nerve. Routine intraoperative neuromonitoring is used, adding safety to prevent nerve damage [8].

14.3.2 Endoscopic Nasopharyngectomy

This technique is indicated for resection of recurrent NPC, especially T1 and T2 tumours. There are different approaches for performing this surgery, and it depends on the detailed characteristics of the tumour. Description of this technique is given in Chap. 7 of this book.

14.4 Transoral Robotic Head and Neck Surgery (TORS)

At this juncture, with the advancement in the tumour imaging technology and resection, surgical care for the upper aerodigestive tract cancers has changed dramatically over the last three decades. Recent advances in mechanical instrumentation and energy equipment allow surgeons to remove head and neck cancers transorally via a robotic system [9]. Robotic head and neck sur-

gery applies minimally invasive principles to the unique anatomy and natural orifices for the surgery in the head and neck anatomic region. Robotic surgery has transformed head and neck surgery, extending from a tradition of minimally invasive endoscopic otolaryngology procedures [10] to a more sophisticated approach.

Transoral robotic surgery (Fig. 14.1) has been developed over the past decade with favourable oncologic and functional outcomes, changing the way a head and neck surgeon approaches both malignant and benign diseases [10]. TORS is a technique that utilizes a minimally invasive robotic approach through the mouth and throat to treat oral, throat, and skull base cancers [5]. TORS has recently become popular as a new treatment modality for laryngopharyngeal cancer, and since the US FDA approval in 2009, surgical robots have been widely used worldwide [4].

As new robotic platforms emerge, access will continue to improve and push the boundaries of minimally invasive approaches. TORS is the latest, cutting-edge method in the evolution of transoral techniques. TORS allows surgeons unprecedented access to and visualization of the upper aerodigestive tract [9]. Early reports of TORS in the head and neck are favourable for both primary and recurrent diseases. TORS plays a role in the assessment of patients with unknown primary and in the de-intensification of treatment in patients with human papillomavirus secondary cancers.

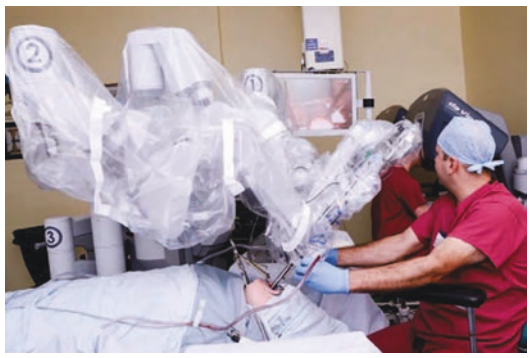

Fig. 14.1 TORS in use in a European head and neck oncology centre

Since 2009, the FDA has accepted the use of TORS in oropharyngeal cancer surgery. Since then, TORS indications have rapidly widened in the treatment of squamous cell carcinoma of the head and neck and currently include not only the oropharynx, but also the hypopharynx, supraglottis, and paralaryngeal spaces. In addition, this da Vinci system is also used in the surgery of cervical lymph nodes and thyroid glands in addition to transoral surgery. The main objective of TORS and other minimally invasive surgical methods is to gain a broad view of the surgical field while minimizing the need for surgical intervention, such as tracheotomy, pharyngectomy, or free flap reconstruction, which significantly decreases the quality of life of patients [2]. Even though this seems to be a versatile technique, it is expensive and available only in selected centres worldwide that can afford to use this robotic system. With this technique, however, surgeons are faced with significant challenges. The anatomic constraints impede visualization and constrain the surgical manoeuvres. Occasionally, additional assistants are required near the surgical areas to help with the suctioning of secretion in the oral cavity.

14.4.1 TORS in Laryngeal and Pharyngeal Surgery

Transoral robotic surgery allows surgeons to perform function-preserving oropharyngeal and supraglottic tumours through the mouth. Surgeons must be knowledgeable about the oral cavity anatomy and the medial-to-lateral perspective of the oropharynx [11]. Transoral robotic surgery (TORS) has emerged as a novel, safe, and feasible procedure for the resection of supraglottic laryngeal cancers. Together with bilateral selective neck dissection, en bloc tumour resection was performed with negative surgical margins. No perioperative or early post-operative complications were observed [12]. Of these procedures, TORS supraglottic laryngectomy remains the most commonly done. Initial oncology and functional results are promising and comparable to other treatment options with these procedures.

Transoral robotic supraglottic laryngectomy must permit complete oncological resection of the supraglottic tumour while at the same time preserving the anatomical and neurophysiological functions of the glottic larynx (protective, respiratory, and phonological functions) and of the tongue base. For these reasons, T-stage T1 and T2 and a few T3 cancers have been selected as preferential indications [13].

TORS has revolutionized head and neck cancer surgery. The use of an updated and evolving robotic technology enhances the ease of robotic head and neck procedures previously described and may allow surgeons to perform increasingly complex surgeries. In a study by Hans et al., there were no differences in the outcome with regard to the location of the tumour [14] and complications from the procedure.

The da Vinci system was used for laryngeal and hypopharyngeal resections with two vestibular and two submental ports, and an additional port for level II–IV neck dissections through a facelift incision [15]. A central common working space overlying the hyoid bone was initially created in all resections. Based on the traditional Sistrunk procedure, a novel endoscopic robotic approach to the larynx, hypopharynx, and neck is a versatile approach. The method should help improve primary lesion exposure and reduce access-related neck morbidity.

Other examples include transoral radical tonsillectomy with dissection and preservation of glossopharyngeal nerve branches, transoral supraglottic laryngectomy, and retroauricular thyroidectomy performed using the new robotic system. Using four robotic ports, each with 8 mm instruments, retroauricular thyroidectomy was performed [16]. With this, an excellent exposure was achieved without access difficulties. During those three procedures, no robotic arm collisions were noted.

14.4.2 TORS in Neck Dissection

TORS has also been used consistently in neck dissection in selected centres. Many approaches have been practised, and depending on the expertise and anatomical knowledge, surgeons can choose one particular topic compared to the other. On the other hand, the standard for comprehensive and selective robotic neck dissections is considered the retroauricular approach. In head and neck surgery, robotic technology has a growing role and has been used in most of the surgeries in the head and neck region. This TORS has shown encouraging results, being used routinely in some well-funded centres around the globe with well-equipped instruments [1].

Some authors reported that all endoscopic TORS and neck dissection were successful without serious intraoperative complications or the need to switch to open-label surgery. According to a survey, as per the answers given to a questionnaire, all patients were satisfied with the cosmesis. In some head and neck cancers, even though TORS is feasible and has shown a clear cosmetic benefit, the longer operating time is a disadvantage [18]. The cost is another limiting factor especially for centres in developing countries such as in the Southeast Asia region.

14.5 Sternotomy in Thyroid and Superior Mediastinal Tumour

Most definitions use the term retrosternal goitre (RSG) to refer to the thyroid gland's partial or total extension under the thoracic inlet or manubrium. Certain anatomical sites, such as the fourth thoracic vertebra, the aortic arch, and the level of the carina, are identified in various RSG definitions. In particular, the thyroid gland must extend to these anatomical points or be substernal by at least 50% [18]. A cervical approach is used to remove the majority of RSG. There are several technical manoeuvres which have been used in the removal of RSG (Table 14.2). This includes early ligation of the upper pole arteries, division of the thyroid isthmus, traction suture placement, and lifting the lower pole of the thyroid lobe upward from behind the sternum by finger. About 10% of mediastinal goitre needs to be addressed with cervicotomy with a total or partial sternotomy to allow a safe removal of the goitre [19].

Table 14.2 Proposed surgical approach for retrosternal thyroid

Types	Types of retrosternal goitre	Proposed surgical approach
Type A	Pyramidal Apex at inferior	Cervical
Type B	Pyramidal shape Apex at superior	Cervical + manubriotomy, sternotomy, or thoracotomy
Type C	Bilobed goitre with a small pedicle	Cervical + manubriotomy, sternotomy
Type D	Ectopic thyroid	Sternotomy + thoracotomy

Cvasciuc IT, Fraser S, Lansdown M. Retrosternal Goitres: A Practical Classification. Acta Endocrinol (Buchar). 2017;13(3):261–265. https://doi.org/10.4183/aeb.2017.261

A combination surgical approach with cervicotomy and partial or total sternotomy is required for around 2–8% of substernal goitres. In the event of a mediastinal goitre, a sternotomy expands the operating field, facilitating dissection, reducing the likelihood of recurrent nerve lesions, and aiding haemostasis in lesions [19].

Preoperative clinical and radiological risk factors, in conjunction with informed patient choice, can be used to predict the need for sternotomy in thyroidectomy for goitre with retrosternal extension. A history of goitre with retrosternal extension lasting more than 160 months is a clinical risk factor for sternotomy. Thyroid tissue density, posterior mediastinal position, and subcarinal extension, as determined by CT scan, are all independent risk factors for sternotomy prior to surgery (Figs. 14.2, 14.3, and 14.4) [20]. The most important component is thyroid tissue density, which raises the risk of sternotomy 47 times. When there is evidence of retrosternal extension to the aortic root, a minimal upper sternotomy or sternal split can be employed instead of median sternotomy [21]. Thyroid tissue density is a more effective criterion for predicting the sternotomy than posterior placement or subcarinal extension. The significant predictive factors for sternotomy were posterior mediastinal extension, extension below the

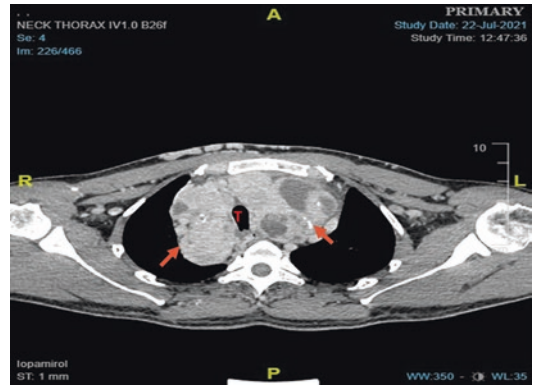

Fig. 14.2 CT scan of the thorax showing a massive retrosternal thyroid which is heterogenous (arrows). The mass has caused narrowing of the trachea (T)

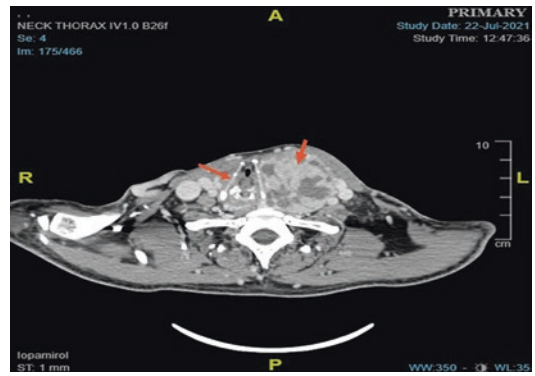

Fig. 14.3 CT scan of the neck and thorax shows left thyroid lobe enlargement which is cystic and heterogenous (thick arrow). It is abutting the left thyroid cartilage (thin arrow) and causes airway displacement to the right side

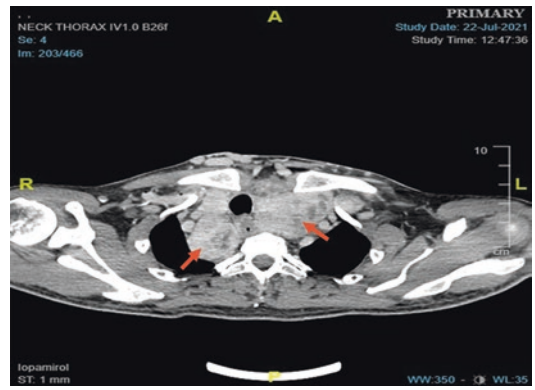

Fig. 14.4 CT scan of the neck and thorax showing a massive retrosternal thyroid which is heterogenous

carina, and a "conical" goitre in which the thoracic inlet becomes a ring of constriction [22].

Other indicative features include ectopic nodule, a dumbbell-shaped goitre, a conical-shaped goitre confined by an isthmic thoracic inlet, or a thoracic goitre component wider than the thoracic inlet. These characteristics of thyroid mass are indicative of the necessity for sternotomy on CT [21]. A massive thyroid volume that extends below the thoracic inlet is a key determining factor for an extra-cervical approach [18].

14.5.1 Surgical Steps of Sternotomy

Sternotomy is performed by making a midline vertical incision, starting from 1-2cm below the sternal notch and extending caudally until the level of the xiphisternum (Fig. 14.5). The wound is then deepened with cautery until the periosteum of the sternum is reached. One must be careful of the veins in the suprasternal and xiphisternum area, which can be large and if severed can cause some troublesome bleeding. The fibrous tissue at the superior part of the sternal notch is divided further, allowing a finger to be passed behind the notch, for the placement of the sternal saw. The sternal periosteum is then cauterized further to mark the central vertical line through which the sternal saw will cut (Fig. 14.5). The edges of the sternum on both sides are also palpated to ensure that the mark is in the midline.

The sternal saw is then hooked around the sternal notch, with the saw slightly pulled forward against the posterior part of the sternum while cutting caudally along the marking made earlier using the cautery. After haemostasis is secured, a suitable sternal retractor is then placed to expose the anterior mediastinum.

A partial sternotomy (Fig. 14.6) gives a more limited access to the mediastinum, but carries significant advantages in terms of cosmesis, speedier recovery with less pain, and very low risk of sternal dehiscence and instability. The level to which the sternal incision is made depends on individual cases. Under normal circumstances, a partial sternotomy to the fourth rib level allows access down to right atrial appendages. However, in most cases where sternotomy is performed for mediastinal mass, the position of the mediastinal structures varies due to the exten-

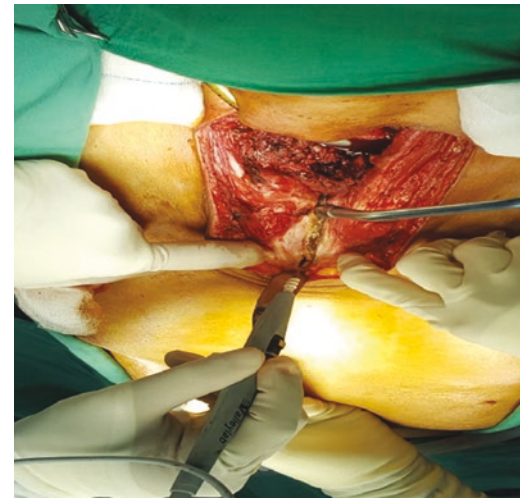

Fig. 14.5 Cautery is used to mark the midline of the sternum before sternotomy

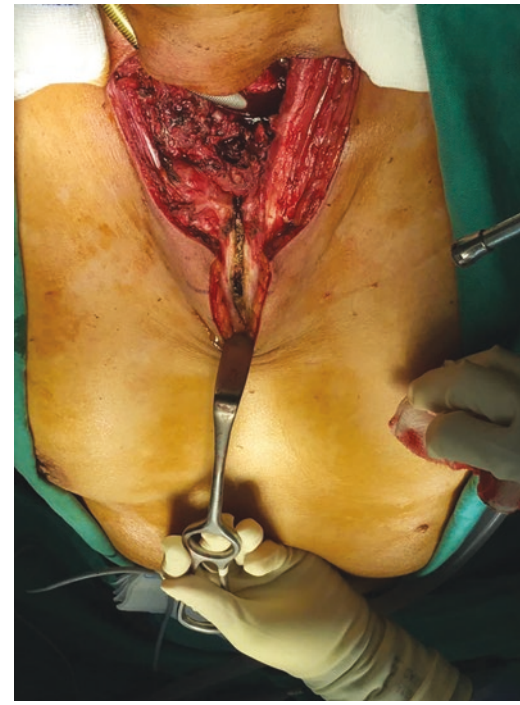

Fig. 14.6 A case of anaplastic thyroid carcinoma extending beyond the sternum, requiring a partial sternotomy

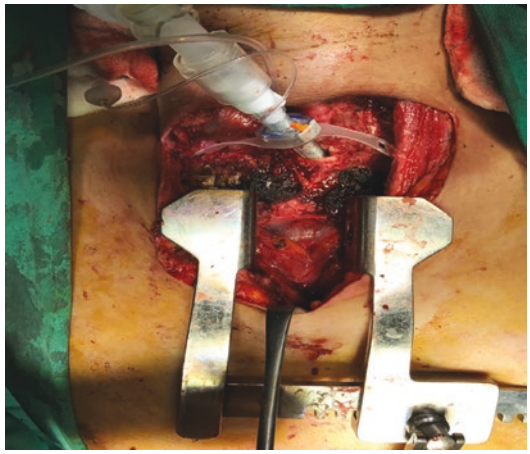

Fig. 14.7 Combined cervicotomy and partial sternotomy gives an excellent exposure to the neck and upper mediastinum, and also allows for a lower placement of the tracheostomy tube

sion of the mass. Hence, a preoperative planning from the CT images is essential for accurate incisions. When combined with cervicotomy, it gives an excellent access to the anterior mediastinum and the neck (Fig. 14.7).

The access can also be made "J-shaped", "reverse J-shaped", or a "reverse T-shaped", also depending on the extent of access needed. A "J-shaped" incision will allow more access to the right side of mediastinum and thorax, and a "reverse T-shaped" will allow a more central opening. To perform a "J-shaped" partial sternotomy, the saw is skewed to the right as it approaches the lower end of the intended incision. The sternotomy is however not completed until the sternal edge, and a sternal retractor is placed and forced open (Fig. 14.8). This will break the remaining sternum toward the edge. This manoeuvre is important so as not to sever the internal thoracic vessels that run 1–2 mm parallel to the sternal edge on both sides. After the tumoural mass is excised, the sternotomy can be closed with sternal wire and placement of tracheostomy tube (Fig. 14.9). The tracheostomy tube

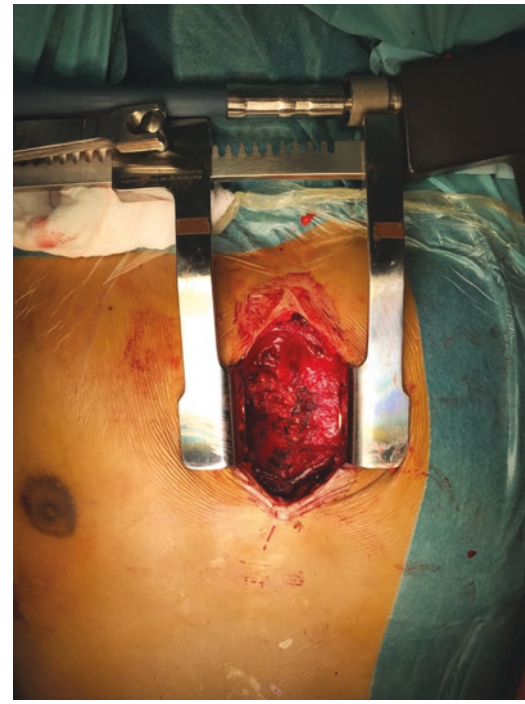

Fig. 14.8 A retractor is used to split open the sternum. This can be part of partial sternotomy exposing anterior mediastinal mass

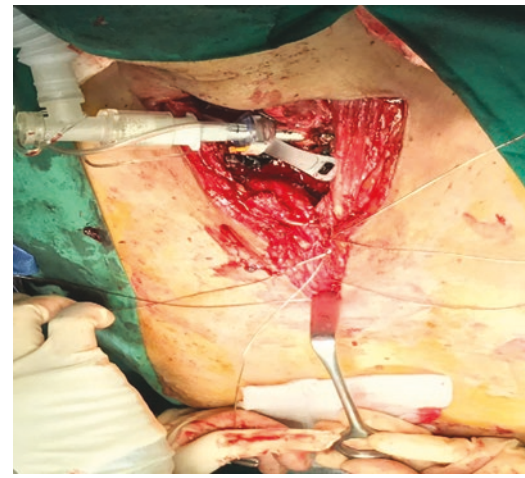

Fig. 14.9 Closure of sternotomy using sternal wires, with a tracheostomy tube placed beforehand

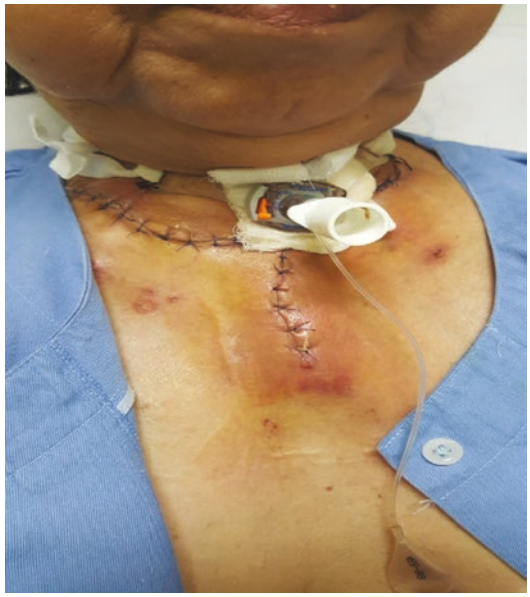

Fig. 14.10 Post-operative wound after combined cervicotomy and partial sternotomy

is important to provide adequate airways during healing post-operatively (Fig. 14.10). A more advanced access to either thorax can also be enhanced further by performing a clavicle osteotomy on the respective side.

14.5.2 Other Approaches in Thyroid and Superior Mediastinal Tumour

Most intrathoracic goitres lie anterior to the recurrent laryngeal nerve and anterolateral to the trachea. Goitres in the anterior mediastinum arise from the isthmus or the lower part of the thyroid lobes. As the mass grows, the great vessels may be displaced laterally. Goitres that grow posteriorly into the mediastinum arise from the posterolateral aspect of the gland and descend posterior to the great vessels. Most are right sided, and even the ones originating from the left lobe are reflected to the right by the left innominate vein, left carotid, and subclavian arteries. The trachea may also be pushed anteriorly in some cases.

Hence, at times an anterior approach, namely sternotomy, would give access to these tumours, especially the ones in the posterior mediastinum. In these circumstances, a lateral or posterolateral thoracotomy is a much easier approach.

14.6 Mandibulotomy and Mandibulectomy

Mandibulotomy is a mandibular osteotomy which is normally performed for surgical access to the oral cavity. This is an important bony approach for surgical removal of, for example, tongue cancer as it provides ample space and exposure for instrumentation and manipulation. Occasionally, it is also used for access and resection of maxillary carcinoma through the hard palate exposure and removal of tumours in the parapharyngeal space. The mandibulotomy may also be combined with midline glossotomy as an approach for pathology in the cervical spine region.

There are several types of mandibulotomy that are commonly performed. These include midline mandibulotomy, paramedian mandibulotomy, and lateral mandibulotomy (Fig. 14.11). Most of the time, lip split needs to be performed before exposing the mandible for osteotomy (Fig. 14.12). The paramedian mandibulotomy uses the cut that is placed lateral to the genioglossus and digastric muscle attachment in the midline (Fig. 14.13). This cut is also medial to the mental foramen.

The midline Z-type incision is better than a circummental lip split as the muscles, i.e. the mentalis, the depressor angular oris, and the depressor labii inferioris, will be somewhat disrupted. The canine is the best tooth to use as a dental abutment for tissue-borne dental prosthesis. Thus, the mandibulotomy should not compromise this tooth and its root.

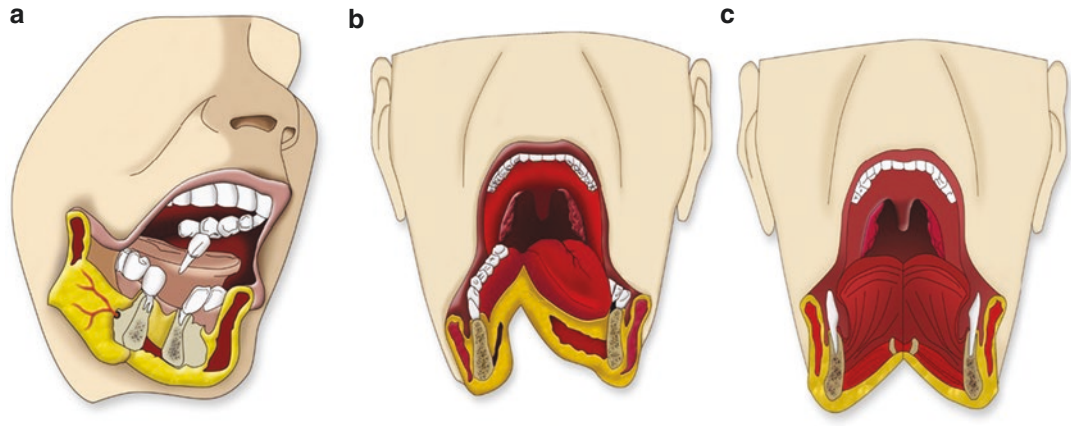

Fig. 14.11 A canine can be extracted before a mandibulotomy in selected cases. In majority of cases, this can be voided (**a**). Paramedian mandibulotomy (**b**) and midline mandibulotomy (**c**)

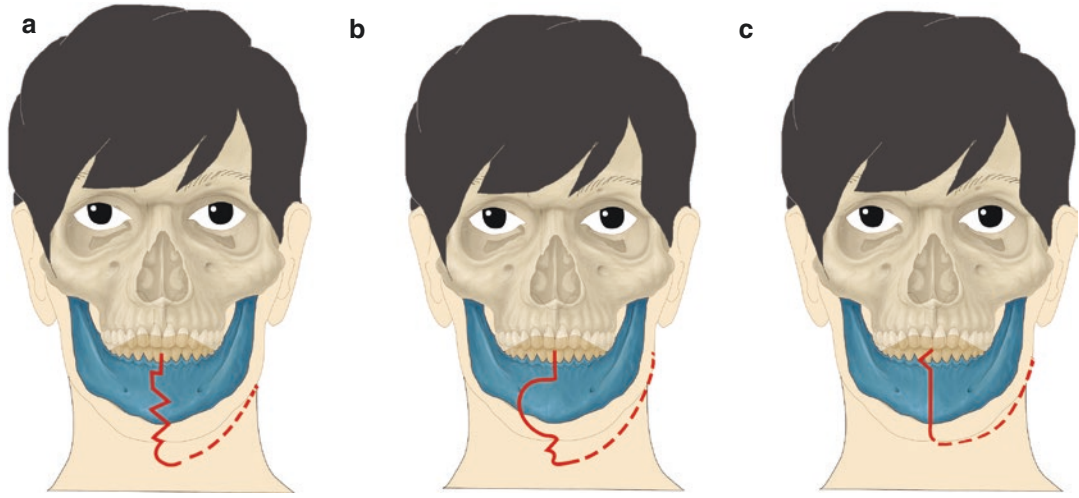

Fig. 14.12 (**a**–**c**) Types of lip split soft-tissue approach for mandibulotomy

Surgical Steps of Mandibulotomy

1. Before performing soft-tissue cut or lip split, any necessary dental extraction should be performed first.
2. Lip split (Fig. 14.12) is carried out by starting the incision on the lip mucosa with the assistant holding the lip with strong pressure on either side to reduce the bleeding, as the lips are highly vascularized.
3. The skin incision is extended inferiorly vertically from vermilion border about 1.0 cm above the mental crease. Then it is angled 1.0 cm away from the midline to unite with the mental crease. The incision is then descended horizontally for 2.0 cm or so before angled back to the midline.
4. A step at vermilion border allows incision at the lip, gingivolabial sulcus, and FOM to be in a paramedian on the side opposite the paramedian mandibulotomy. This incision places the incision through mucosa away from the intended mandibulotomy site.
5. The cut is then deepened using cautery till muscular layer in midline. Care should be taken not to injure the mentalis muscle.

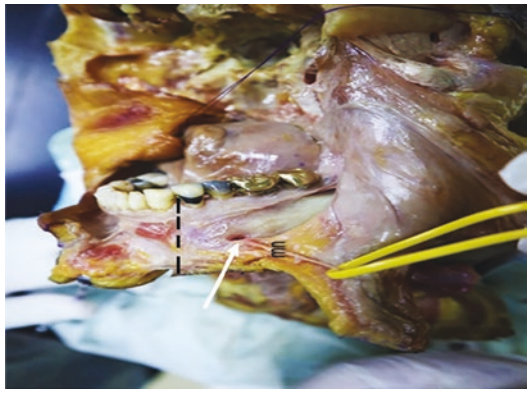

Fig. 14.13 Paramedian mandibulotomy (dotted lines) is the most commonly performed mandibulotomy as it spares the mental nerves (mn) and is not within the radiation field, if the patient requires adjuvant radiation postoperatively. The lower cheek flap must be made first before mandibulotomy can be performed

6. The mark for mandibulotomy is done. The cut is vertical between the medial and lateral incisors. Then the cut is angled to posterior direction, lateral to digastric muscle.
7. The plates are needed for mandibular stabilization. It can be contoured and mapped along the inferior border of mandible and the other 1–2.0 cm above this depending on the mandible height. At least a minimum of three screws should be used on either side.
8. The plates are removed to allow a bone cut on the mandible. In a dentate patient, care should be taken to avoid injury to the cuff of the bone around the roof if there is any.
9. In edentulous patients, there is no need to contour the plates prior to mandibulotomy. The risk of malocclusion is very low.
10. After extirpation of the tumour, the previous contoured plates are reapplied.
11. The closure of intraoral mucosa is performed meticulously. Any tear or breakdown may cause contamination of mandibulotomy site with leaky saliva.

14.7 Clavicle Osteotomy

Clavicle osteotomy is an effective approach for addressing the recurrent neck tumour at levels IV and V. This is vital in order to provide adequate surgical access and exposure to remove tumour with negative surgical margins. The neurovascular structures close to clavicle can be either compressed or pushed to this tight area, and this makes it difficult to explore and free them from the tumour. Mobilizing the attachments of pectoralis major and minor with clavicle osteotomy significantly opens the space for mobilizing the brachial plexus and major vessels. This ensures that a good oncological margin tumour extension below the clavicle can be achieved. Meticulous dissection is necessary in order to avoid inadvertent injury to these vital structures. This includes the subclavian artery and vein, brachial plexus, and deep muscle of the neck such as scalene muscle.

Extensive tumours that originate from the base of the neck may also require clavicle osteotomy for an adequate surgical access. This will allow en bloc removal of the tumour. Examples of this tumour include soft-tissue fibromas, fibromatoses, sarcomas, neuromas, or haemangiomas.

14.7.1 Case Illustration

14.7.1.1 Case 1

This is a case of female patient with papillary thyroid carcinoma who had modified radical neck dissection (MRND), and again had recurrent tumour at left level IV, where the inferior border of the mass was abutting the clavicle. After reviewing her CT scan, the decision for clavicle osteotomy was made, as the mass extended deep to the clavicle. Detailed examination revealed the left level IV nodes measuring 5.0 cm × 4.0 cm, and it was hard in consistency and fixed to the underlying structures. The endoscopy examination of larynx revealed a right vocal cord bowing with a minimal phonatory gap. Repeat CT scan in August 2016 showed the presence of left supraclavicular mass that compressed both the left subclavian vein and internal jugular vein (Fig. 14.14).

A multidisciplinary meeting consensus is that the best approach for the tumour clearance was to do a clavicular osteotomy for maximal exposure in view of the proximity of the tumour to the left subclavian vein and internal jugular vein. Access

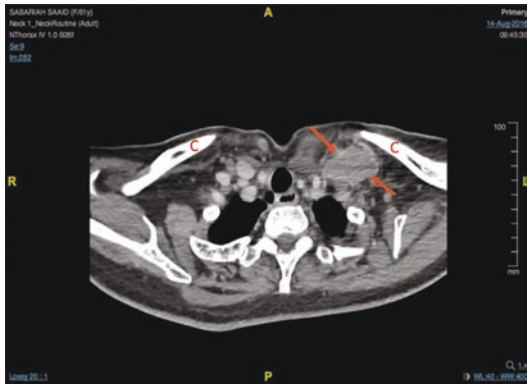

Fig. 14.14 The recurrent tumour at level IV neck node region with irregular margin (arrows)

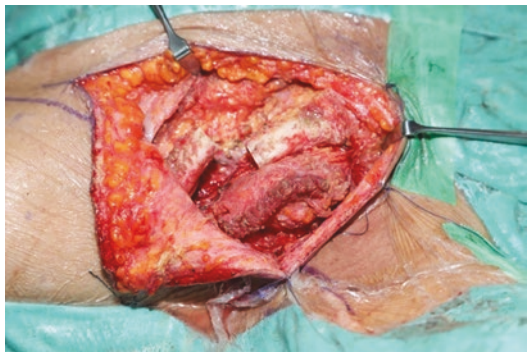

Fig. 14.15 An osteotomy on clavicle is performed. Its two end cuts are widely separated

to the tumour infraclavicular spaces was performed by detaching the pectoralis major and minor muscle. The platysma muscle was reflected superiorly to expose the entire mass and clavicle. Subsequently, the subclavian vein and artery were mobilized inferiorly from the tumour mass.

To get the entire medial and lateral marginal control of the mass, the clavicle was osteotomized at the middle segment and reflected subperiosteally (Figs. 14.15, 14.16, and 14.17). The entire mass was removed in total with a cuff of normal tissue to achieve wide resection oncological margin (Fig. 14.18) [23]. Post-operatively, the patient is well with evident titanium plate on the neck X-ray (Fig. 14.19) and clinically (Fig. 14.20).

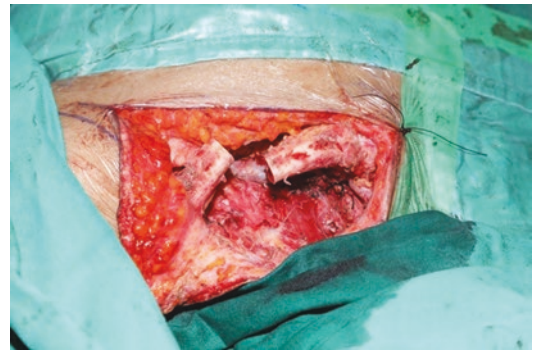

Fig. 14.16 Two cut ends of clavicle are separated for access and dissection of the tumour underneath this

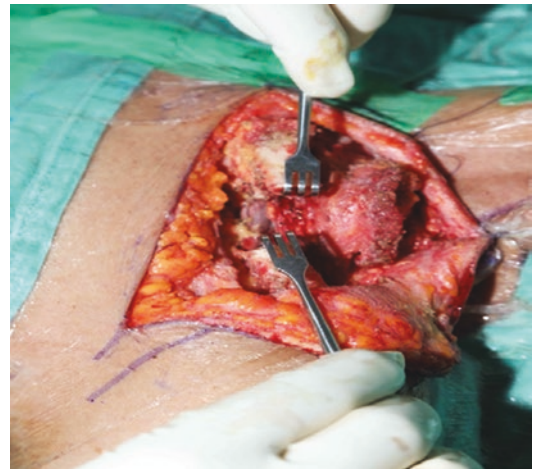

Fig. 14.17 The cut ends of clavicle are retracted with a cold retractor to facilitate the dissection of the tumour

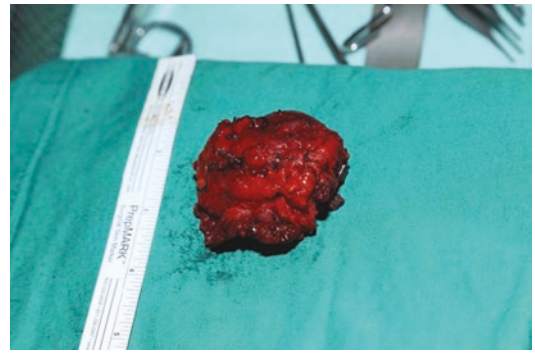

Fig. 14.18 The recurrent tumour is removed in total and measured before sending for histopathological examination

The use of a clavicle osteotomy as an approach for a low-lying recurrent neck tumour in the vicinity of the subclavicular area provides an optimal access to the surgical site. This approach is highly suggested for tumours that encroach the supraclavicular and subclavicular region so that a complete tumour resection can be carried out. In addition, the scapular tumour can also be accessed better via a clavicle osteotomy. This allows a safe tumour excision with free surgical margins as well as avoids the inadvertent injury to critical adjacent neurovascular structures.

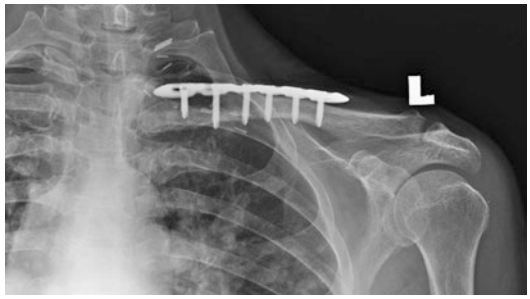

Fig. 14.19 Post-resection photo with plate and X-ray. The osteotomized clavicle is finally stabilized with titanium locking plate to allow rehabilitation of the shoulder motion

14.8 Base-of-Neck Tumour

Surgical technique that addresses the base of neck such as a huge scapula tumour is technically challenging. This is attributed to multiple factors, namely:

1. The close proximity of critical structures such as subclavian artery, subclavian vein, and brachial plexus.
2. In case of huge tumour, the surgical access will be very limited.
3. In a long-standing tumour, the infiltration to brachial plexus poses another treatment challenge.

Additionally, the attachment of bulky muscles to scapula and spine such as levator scapulae and erector spinal will add to the difficulty in manipulation and mobilization of the tumour. Anterior extension of the tumours may compress the major vessels and nerve in a tight and small compartment, which translates to difficult exploration of the vessels. In contrast, superior extension of the tumour between scalene muscles will cause difficulties in mobilization of the root of brachial plexus.

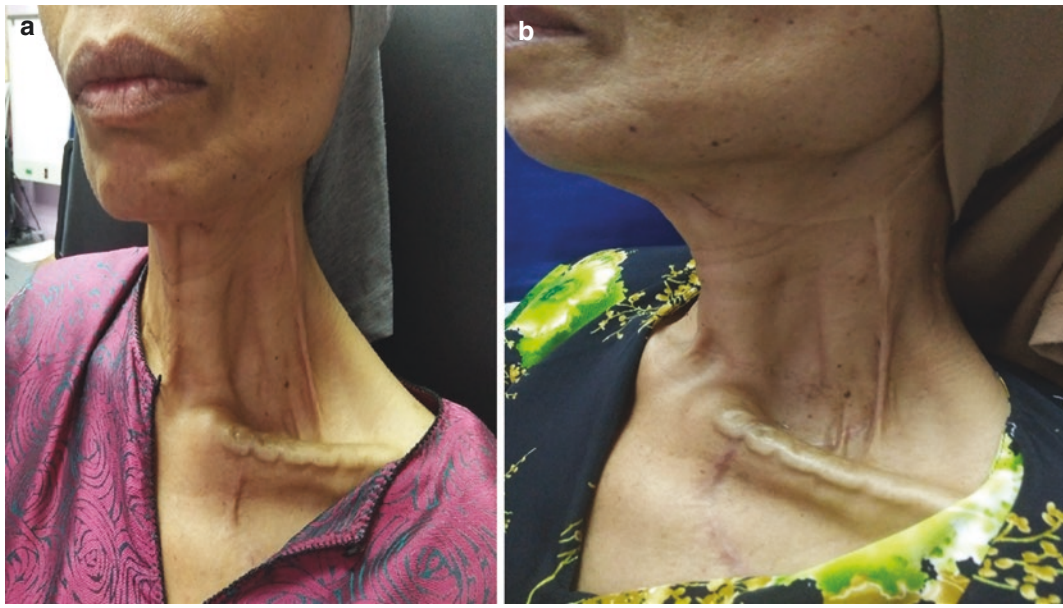

Fig. 14.20 Post-operative photo at 3-month follow-up (**a**) and 1-year follow-up (**b**)

Soft-tissue sarcoma and fibromatoses (Fig. 14.21) not uncommon occur around the base of neck or superior scapula border. The surgery is tedious due to close proximity with major vital structures of subclavian artery and brachial plexus. The surgical field is also tight due to direct pressure by the tumour that compresses vital structures, and manipulation to achieve margin is difficult.

A fine surgical technique is by mobilization of the entire scapula and upper limb anteriorly together with neurovascular bundle. Posterior scapula stabilizer muscles of trapezius, levator scapulae, rhomboid, and erector spinal are detached with clavicular osteotomy able to create a mobile window for resection of the base-of-neck tumour.

Fibromatoses which involve base of neck and extending inferiorly to the erector spinae, below the scapula: This tumoural mass pushes the entire brachial plexus and subclavian vessels anteriorly to create a tight surgical field for exploration.

Trapezius muscle which is not involved is mobilized to the tip of spinous process for future closure (Fig. 14.22). The erector spinae muscle is elevated and mobilized laterally and included as margin. Scapula is mobilized laterally by detaching all the medial muscle of rhomboid and levator scapulae (Fig. 14.23).

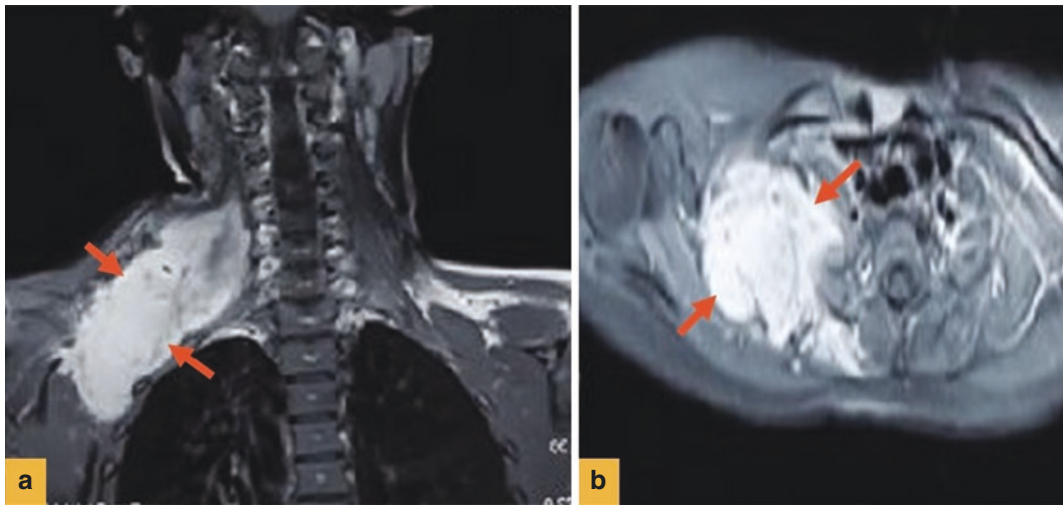

Fig. 14.21 (**a**, **b**) An enhanced tumour mass on the MRI with irregular border and mild heterogeneity. This is consistent with a fibromatosis

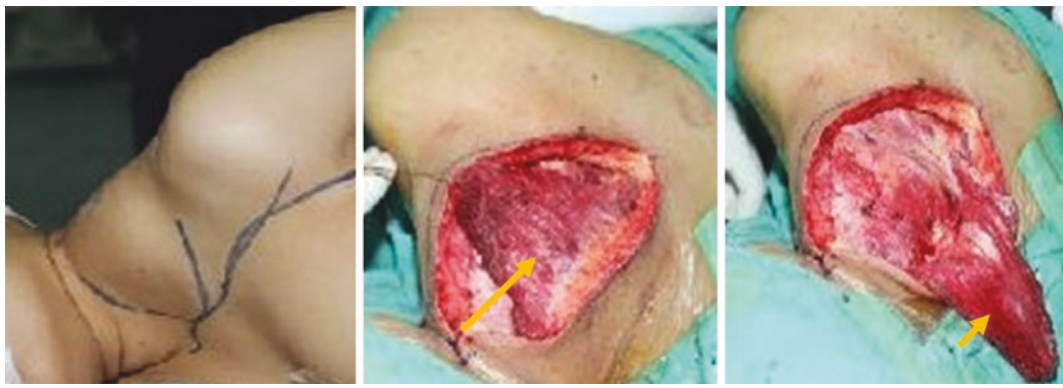

Fig. 14.22 The trapezius muscle is mobilized to facilitate a later closure

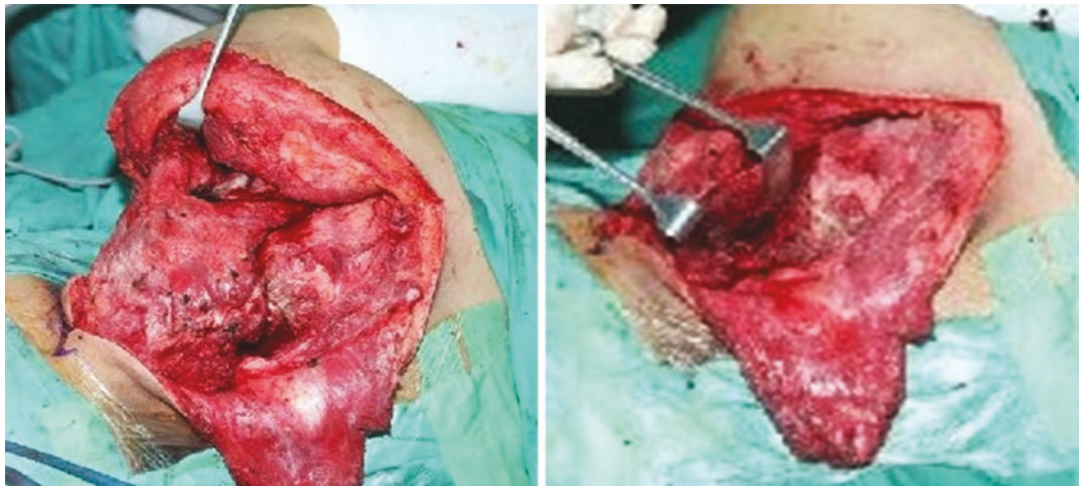

Fig. 14.23 The erector spinae muscle is mobilized laterally and all the medial muscles of rhomboid and levator scapulae are detached

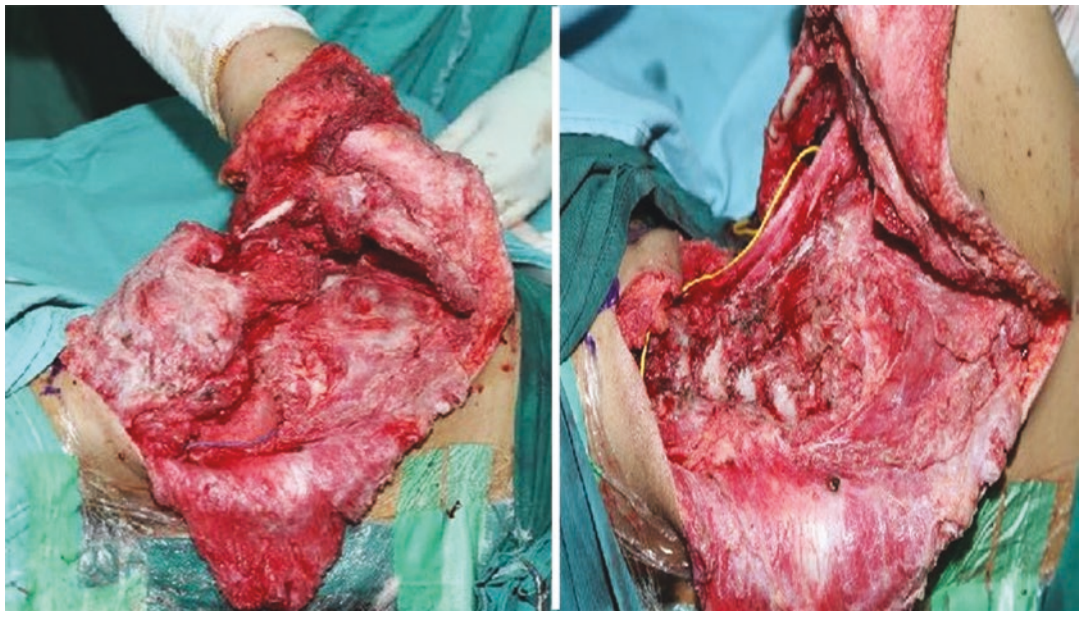

Fig. 14.24 The pectoralis major and minor were detached and released inferiorly. The entire tumour can be resected with good oncological margin, the dissection can be done directly over the thoracic cage, and the neurovascular structures are protected anteriorly to minimize the injury

The pectoralis major and minor were detached and released inferiorly followed by clavicular osteotomy (Fig. 14.24). This manoeuvre will open the anterior base of neck space and make exploration of plexus and subclavian artery possible (Fig. 14.25).

Shoulder stability is maintained by fixation of the clavicle by a plate and repair of the remaining medial soft tissue to the scapula and upper scapula (Fig. 14.26).

Evaluation of subclavian artery and brachial plexus at each level is important in view of the

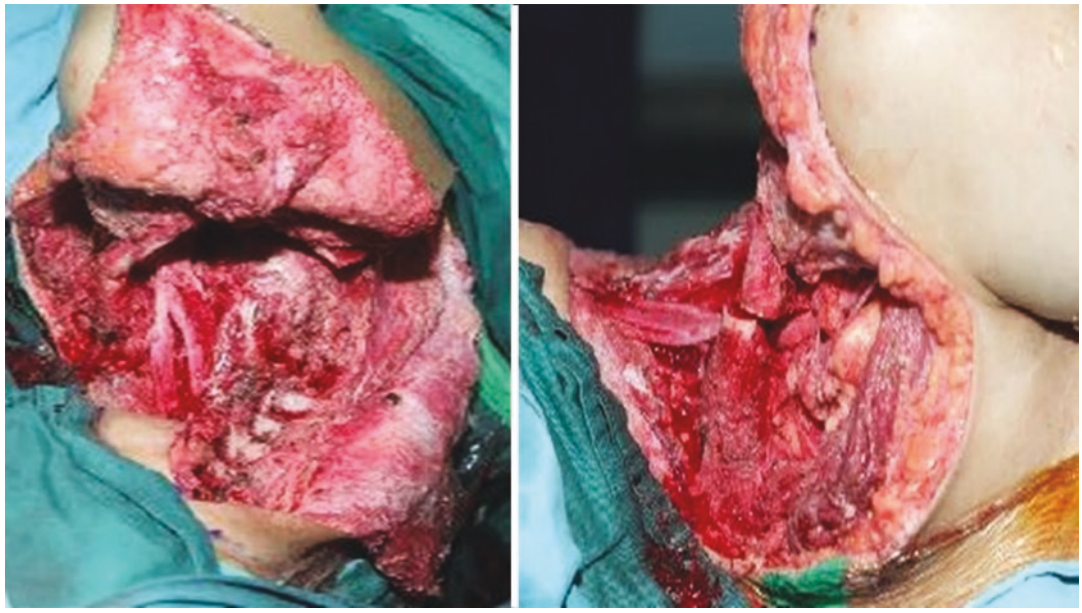

Fig. 14.25 A clavicular osteotomy is performed. This manoeuvre will open the anterior base of neck space and make exploration of plexus and subclavian artery possible

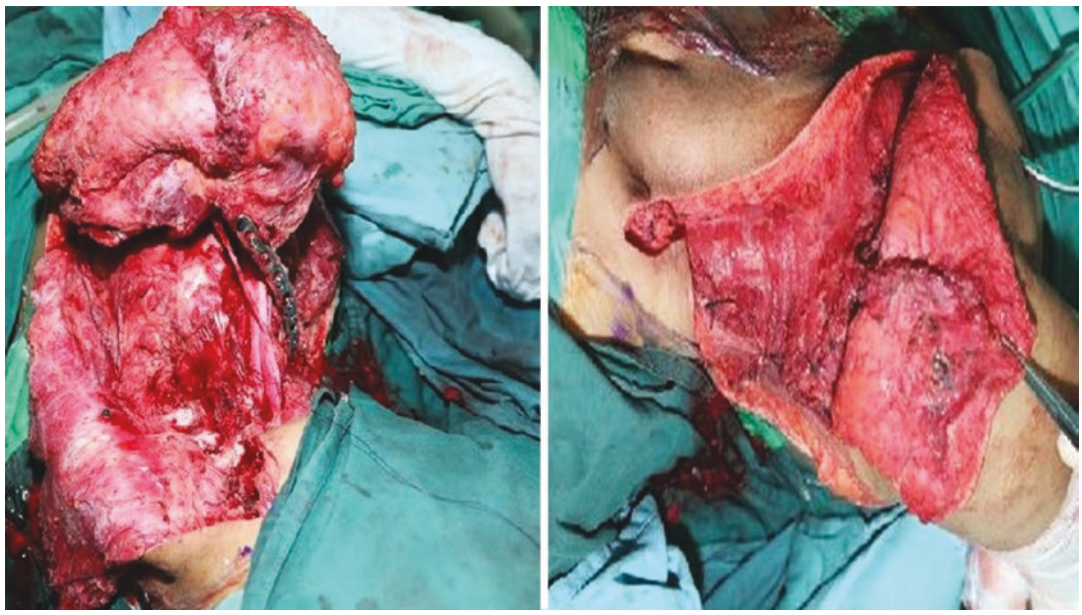

Fig. 14.26 Fixation of the scapula and repair of the soft tissue Extensive tumour at the base of neck (Fig. 14.27) needs more extensive exploration of brachial plexus proximally to the root. The posterior muscle of scalene can be resected and included together for better oncological margin

expected morbidities that may arise post-surgery and it is useful for planning for possibility of primary nerve reconstruction (Figs. 14.28 and 14.29).

The entire posterior muscle is attached to medial scapulae together with erector spinae (Figs. 14.28 and 14.29). The posterior base of

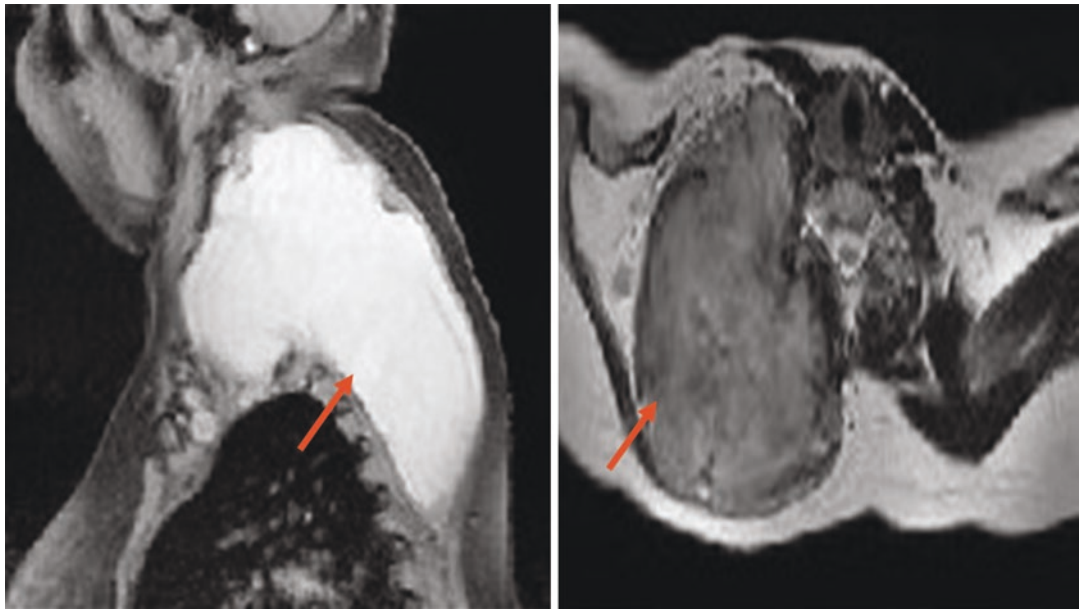

Fig. 14.27 An extensive base-of-neck tumour which is enhanced on MRI, with a well-defined capsule

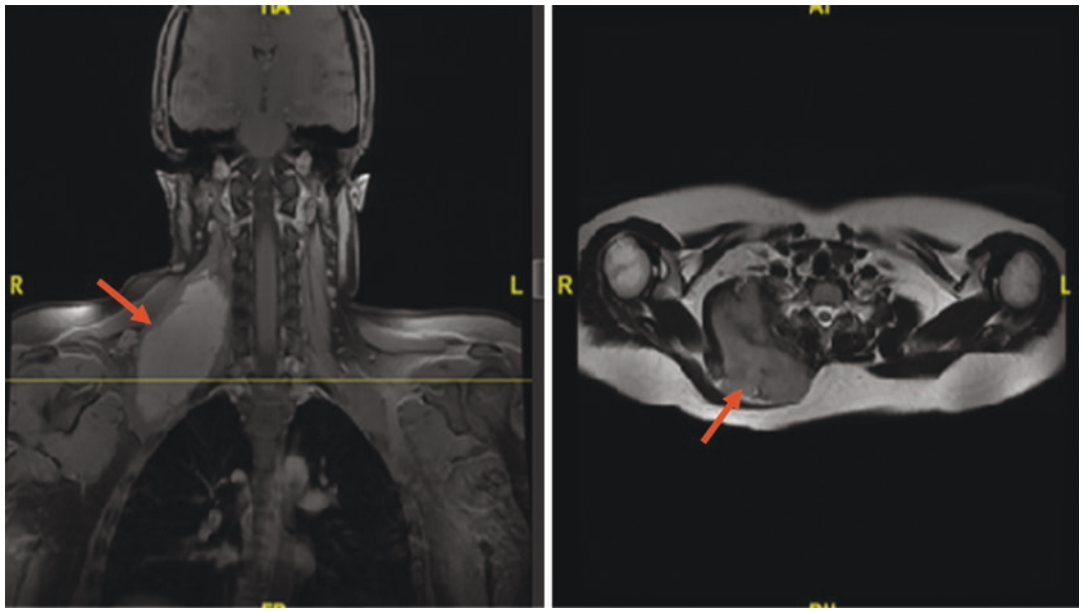

Fig. 14.28 An extensive base-of-neck tumour which is enhanced on MRI, with a well-defined capsule

neck including scalenus posterior was removed after mobilizing the root of brachial plexus (Fig. 14.30). Subclavian and brachial plexus were mobilized by mobilizing the lateral shoulder girdle including scapulae by detaching medial muscle attachment and clavicle osteotomy.

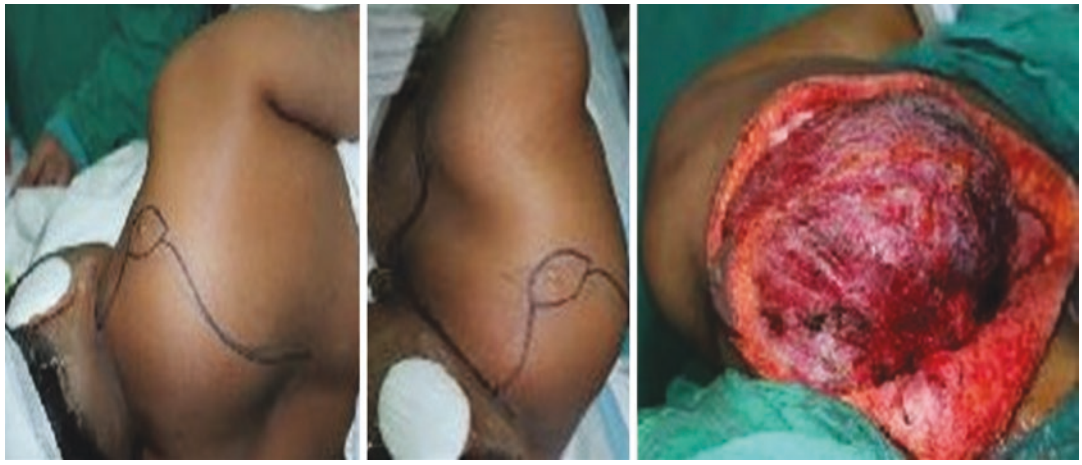

Fig. 14.29 Skin incision and flap creation for access to the base-of-neck tumour

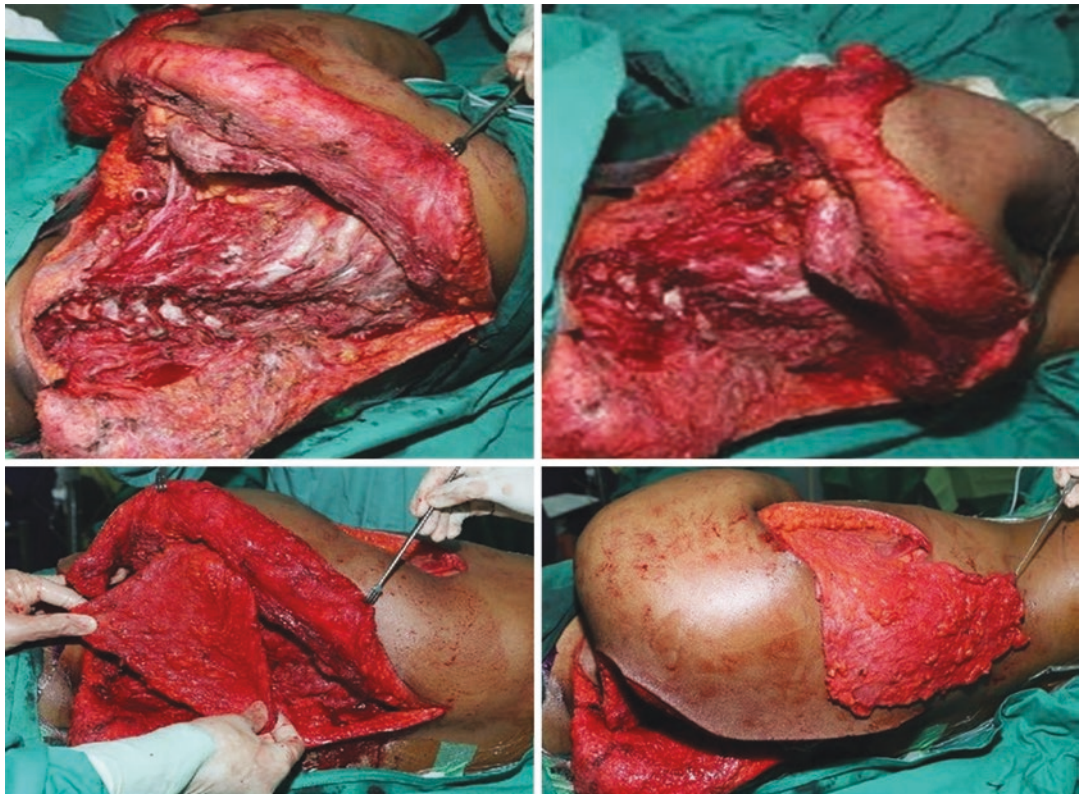

Fig. 14.30 The entire posterior muscle attached to medial scapulae together with erector spinae. Extensive tissue loss will create a scapular instability that requires a local rotational flap with latissimus dorsi flap for soft-tissue reconstruction

14.9 Impacts on Treatment Outcomes

Surgical access plays an important role in ensuring a complete resection of head and neck tumour. Limited view of surgical bed and inadequate space for dissection will make the surgery more difficult. In addition, many cold instruments like endoscopes, retractors, artery forceps, and ultrasonic cutter are used during surgery, which occupies more space.

Limited space will also limit the assistant's view for a better retraction. All of these factors lead to inefficient surgery with longer operation time. The surgery-related morbidities may also increase. Critically, the risk of leaving behind malignant cells is high if tumour clearance is not complete due to inadequate access and inefficient surgeon's performance.

14.10 Complications and Prognosis of Head and Neck Malignancy

Surgical treatment of head and neck malignancy is crucial as it is the main modality of treatment. Thus, surgery needs to be performed comprehensively so as to remove all the macroscopic and microscopic tumour margin. The involved margin carries higher chance of tumour recurrence and metastatic spread.

Importantly, a good surgical bed exposure and access will assist in a complete tumour removal. The bleeding can be controlled more efficiently, and the risk of injury to adjacent structures can be avoided. Complications of surgery in the head and neck regions are monumental. Multiple neural and vascular structures are at risk, which can lead to significant functional impairment. This in turn will impair the patient's quality of life.

Managing recurrent tumour is highly challenging. The majority of cases already reach the maximum dose of radiation or chemotherapy cycles. The head and neck region also becomes fibrotic and poses surgical difficulty. The dissection is difficult as tissues become thickened and hard. The anatomical landmarks and structures change and derange due to this fibrosis. Subsequently, the risk of bleeding, neural injury, and other related complications is high.

14.11 Conclusion

Adequate surgical access is a prerequisite in head and neck cancer surgery. This allows a negative resection margin, which is one of the determinants of patient prognosis. The risk of recurrence, occult metastases, and distant systemic spread is lessened, with the attained better oncologic resection of primary tumour. The soft tissue approach and bony approach are equally important in providing a wider adequate access for a surgery. Sternotomy, mandibulotomy, mandibulectomy, and clavicle osteotomy need to be considered in selected cases of head and neck malignancy in order to achieve a better tumour resection. The advent of minimally invasive surgery with the availability of multi-angle endoscopes and robotic systems has escalated the surgical approach of head and neck malignancy. The functionality is retained, and the morbidity is less.

References

1. Goh HK, Ng YH, Teo DT. Minimally invasive surgery for head and neck cancer. Lancet Oncol. 2010;11(3):281–6. https://doi.org/10.1016/S1470-2045(09)70379-1.
2. Golusiński W, Pieńkowski P, Majchrzak E. Robotic surgery (da Vinci Xi system) in head and neck cancer—own experience. Otolaryngol Pol. 2019;74(1):1–5. https://doi.org/10.5604/01.3001.0013.5262.
3. Luu K, Pakdel A, Wang E, Prisman E. In house virtual surgery and 3D complex head and neck reconstruction. J Otolaryngol Head Neck Surg. 2018;47(1):75. Published 2018 Dec 12. https://doi.org/10.1186/s40463-018-0320-9.
4. Tateya I, Shiotani A, Satou Y, et al. Transoral surgery for laryngo-pharyngeal cancer—the paradigm shift of the head and cancer treatment. Auris Nasus Larynx. 2016;43(1):21–32. https://doi.org/10.1016/j.anl.2015.06.013.
5. Yee S. Transoral robotic surgery. AORN J. 2017;105(1):73–84. https://doi.org/10.1016/j.aorn.2016.11.011.
6. Fu Y, Wu M, Fu J, et al. Transoral endoscopic thyroidectomy via submental and vestibular approach:

a preliminary report. Front Surg. 2020;7:591522. Published 2020 Nov 23. https://doi.org/10.3389/fsurg.2020.591522.
7. Jongekkasit I, Jitpratoom P, Sasanakietkul T, Anuwong A. Transoral endoscopic thyroidectomy for thyroid cancer. Endocrinol Metab Clin N Am. 2019;48(1):165–80. https://doi.org/10.1016/j.ecl.2018.11.009.
8. Zorron R, Bures C, Brandl A, et al. Tipps und technische Aspekte zur Durchführung der transoralen endoskopischen Thyreoidektomie mit vestibulärem Zugang (TOETVA): eine neue narbenlose Technik für die Halschirurgie [Tips and technical issues for performing transoral endoscopic thyroidectomy with vestibular approach (TOETVA): a novel scarless technique for neck surgery]. Chirurg. 2018;89(7):529–36. https://doi.org/10.1007/s00104-018-0658-6.
9. Hamilton D, Paleri V. Role of transoral robotic surgery in current head & neck practice. Surgeon. 2017;15(3):147–54. https://doi.org/10.1016/j.surge.2016.09.004.
10. Finegersh A, Holsinger FC, Gross ND, Orosco RK. Robotic head and neck surgery. Surg Oncol Clin N Am. 2019;28(1):115–28. https://doi.org/10.1016/j.soc.2018.07.008.
11. Gun R, Ozer E. Surgical anatomy of oropharynx and supraglottic larynx for transoral robotic surgery. J Surg Oncol. 2015;112(7):690–6. https://doi.org/10.1002/jso.24020.
12. Durmus K, Gokozan HN, Ozer E. Transoral robotic supraglottic laryngectomy: surgical considerations. Head Neck. 2015;37(1):125–6. https://doi.org/10.1002/hed.23645.
13. Gorphe P. A contemporary review of evidence for transoral robotic surgery in laryngeal cancer. Front Oncol. 2018;8:121. https://doi.org/10.3389/fonc.2018.00121.
14. Hans S, Chekkoury-Idrissi Y, Circiu MP, Distinguin L, Crevier-Buchman L, Lechien JR. Surgical, oncological, and functional outcomes of transoral robotic supraglottic laryngectomy. Laryngoscope. 2020 [published online ahead of print, 2020 Jul 23]. https://doi.org/10.1002/lary.28926.
15. Simon C, Holsinger FC, Rheinwald M, Kemper J, Lambercy K. A new endoscopic surgical approach to the larynx, hypopharynx, and neck lymphatics: the robotic-assisted extended "Sistrunk" approach (RESA). Head Neck. 2020;42(9):2750–6. https://doi.org/10.1002/hed.26273.
16. Sharma A, Albergotti WG, Duvvuri U. Applications of evolving robotic technology for head and neck surgery. Ann Otol Rhinol Laryngol. 2016;125(3):207–12. https://doi.org/10.1177/0003489415606448.
17. Byeon HK, Holsinger FC, Kim DH, et al. Feasibility of robot-assisted neck dissection followed by transoral robotic surgery. Br J Oral Maxillofac Surg. 2015;53(1):68–73. https://doi.org/10.1016/j.bjoms.2014.09.024.
18. Sormaz İC, Uymaz DS, İşcan AY, et al. The value of preoperative volumetric analysis by computerised tomography of retrosternal goiter to predict the need for an extra-cervical approach. Balkan Med J. 2018;35(1):36–42. https://doi.org/10.4274/balkanmedj.2017.0161.
19. Casella C, Molfino S, Cappelli C, Salvoldi F, Benvenuti MR, Portolani N. Thyroiditis process as a predictive factor of sternotomy in the treatment of cervico-mediastinal goiter. BMC Surg. 2019;18(Suppl 1):20. Published 2019 Apr 24. https://doi.org/10.1186/s12893-019-0474-z.
20. Sari S, Erbil Y, Ersöz F, et al. Predictive value of thyroid tissue density in determining the patients on whom sternotomy should be performed. J Surg Res. 2012;174(2):312–8. https://doi.org/10.1016/j.jss.2011.01.019.
21. McKenzie GA, Rook W. Is it possible to predict the need for sternotomy in patients undergoing thyroidectomy with retrosternal extension? Interact Cardiovasc Thorac Surg. 2014;19(1):139–43. https://doi.org/10.1093/icvts/ivu094.
22. Riffat F, Del Pero MM, Fish B, Jani P. Radiologically predicting when a sternotomy may be required in the management of retrosternal goiters. Ann Otol Rhinol Laryngol. 2013;122(1):15–9. https://doi.org/10.1177/000348941312200104.
23. Mat Lazim N, Abdullah B, Wan Ismail WFN. Approach for recurrent thyroid carcinoma with a clavicle osteotomy. Medeniyet Med J. 2018;22(4):336–41.

Orbital Exenteration in Head and Neck Malignancy

15

Norhafiza Mat Lazim, Giacomo Spinato, Roman Carlos Zamora, and Paolo Boscolo Rizzo

15.1 Introduction

Orbital exenteration is a delicate surgical procedure. It entails the removal of the entire orbital contents with a subperiosteal dissection. This includes the removal of all eye socket contents including the muscles, lacrimal gland system, optic nerve, as well as varying parts of the bone of the orbit. Orbital exenteration has long been considered the treatment of choice for managing periocular tumours invading the orbit or primary orbital malignancies. Importantly, this surgery causes significant aesthetic embarrassment especially in young patient category.

Orbital exenteration is indicated for tumours originating in the eyelids, the eye, the orbit, or the paranasal sinuses. Orbital exenteration is a physically debilitating procedure that may be indicated in the management of orbital malignancy. It requires a committed multidisciplinary approach, both preoperatively and post-operatively. The multidisciplinary team management is crucial, especially the rehabilitation team, that plays significant roles not only preoperatively, but also post-operatively. Additionally, strong and persistent family and adequate psychosocial support ensure the best treatment outcomes for this subset of patients. The preoperative and post-operative counselling should be made by a multidisciplinary team consisting of an ocularist, orbital surgeon, specialist wound care nurse, and a clinical psychologist.

Preoperative counselling with an ocularist is pivotal in deciding on the timing of surgery and the best surgical approach possible for the patient. For example, whether osseointegration is required at the time of exenteration and before radiotherapy will save the patient later need for hyperbaric oxygen [1]. Orbital invasion is frequently observed in tumours involving the maxillary, ethmoid, and frontal sinuses given the proximity of the orbit to the sinonasal tract and ventral skull base. For an extensive maxillary sinus carcinoma, the superior extension with the evidence of periorbital fat invasion is a clear indication for orbital exenteration together with total maxillectomy as a standard treatment approach.

Orbital exenteration is a severely disfiguring procedure that is indicated in primary orbital and adnexal malignancies that cannot be controlled by simple excision or radiotherapy. It is also occasionally indicated for non-malignant pro-

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N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_15

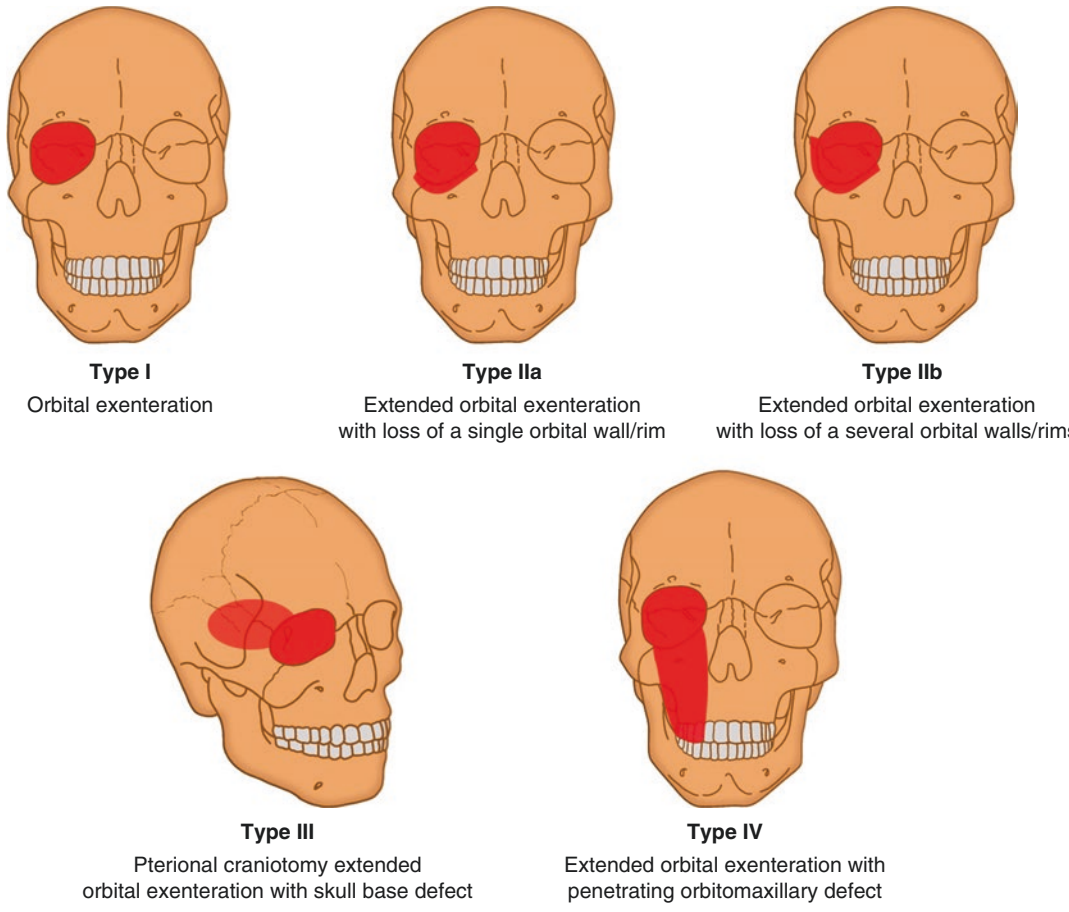

Fig. 15.1 Types of orbital exenteration which is commonly practised

gressive disease with intractable pain or orbital fungal infections, but the majority of cases are orbital malignancies [2]. Total exenteration involves the removal of the entire orbital content, including the eyelids. Extended orbital exenteration involves the removal of the entire orbital content together with the paranasal sinus and/or bony orbit (Fig. 15.1). Orbital exenteration with eyelid sparing is to remove the entire orbital content without the eyelids and is therefore best suited for posterior orbital tumours.

Surgical resection with negative margins represents the cornerstone of management for benign and low-grade malignant tumours. Histology-specific induction chemotherapy can be used for high-grade sinonasal cancers in order to downstage the tumour and increase the possibility of orbital preservation [3]. Tumour eradication, however, should take precedence over cosmetic concerns. Often, removal of part of the bony orbit is necessary adding to the post-operative facial rehabilitation management plan. Histology-specific induction chemotherapy can be used for high-grade sinonasal cancers in order to downstage the tumour and increase the possibility of orbital preservation. In the future, the development of tailored medicines and immunotherapies may alter our therapeutic decisions.

15.2 Orbital Exenteration

The most common indication for orbital exenteration is orbital invasion by periocular cutaneous malignant tumours, of which 90% are basal cell carcinoma. Other tumours that can present with

orbital invasion include inverted papillomas, fibro-osseous lesions, juvenile angiofibromas, low-grade malignancies, and high-grade cancers [4]. Orbital invasion can present with mass effect such as globe displacement or ptosis, or signs of tissue infiltration including restricted ocular motility, immobile eyelids, or fixation of the tumour to bone. When these signs are present, orbital exenteration is deemed necessary, be it for curative or palliative intent.

The decision about orbital exenteration in cases of sinonasal malignancies is facilitated if the patient already has clear clinical signs of intraconal invasion such as visual loss, restriction of ocular mobility, or infiltration of the eye globe [4].

However, in borderline situations, confirmation of orbital involvement should be performed intraoperatively. In selected cases with minimal orbital invasion without functional compromise, orbit-sparing surgery can be done with acceptable oncological outcomes [4]. Appropriate reconstruction of any surgical defects is essential in order to minimize complications and optimize functional and aesthetic outcomes. Orbital apex invasion represents a negative prognostic factor [3]. Orbital reconstruction depends on the surgeon's speciality: healing by secondary intention and split-thickness skin grafts are mostly performed by oculoplastic surgeons, whereas regional or free flaps are mostly performed by ENT surgeons [5].

Exenteration can be classified as total, subtotal, or extended; subtotal exenteration spares either or both the eyelids and the conjunctiva, and the extended type removes also the diseased bone or soft tissue. Although subtotal exenteration offers a better cosmetic outcome, faster healing, and less chance of sino-orbital fistula formation, it should not be chosen at the expense of a complete surgical cure. Typically, the detailed types of orbital exenteration include lid- and conjunctiva-sparing anterior exenteration, lid-sparing anterior exenteration, anterior exenteration, lid- and conjunctiva-sparing total exenteration, lid-sparing total exenteration, total exenteration, lid- and conjunctiva-sparing extended exenteration, lid-sparing extended exenteration, and extended exenteration [6].

The surgical specimen should be sent for checking of margin involvement, although a clear margin does not necessarily indicate a complete cure. Orbital exenteration allows surgical resection of R0 tumours in 42.5–97% of cases. Overall survival following orbital exenteration is 83% and 65% at 1 and 5 years, respectively [5].

15.2.1 Surgical Steps

15.2.1.1 Lid-Sparing Exenteration

1. The patient lies supine under GA.
2. A 4-0 black silk suture is threaded through the skin, orbicularis muscle, and superficial tarsus of the upper and lower lids and tied together. This allows traction during the procedure.
3. A skin incision is made 2.0 mm above the upper eyelash and 2.0 mm below the lower eyelash, inferior to both medial and lateral canthi. Only the skin and orbicularis oculi muscle are cut through. This is undermined superiorly and inferiorly until the periosteum outside the orbital rim is exposed (Fig. 15.2).
4. A monopolar cautery is used to make incision through the periosteum, 2.0 mm outside of the orbital rim, to expose the underlying bone.
5. A periosteal elevator is used to free the periosteum around the bony orbital margin and into the orbital cavity. The supraorbital nerve should be identified and preserved in order to preserve sensation to the forehead (Fig. 15.2).
6. Meticulous dissection should be practised when the periosteal elevator is used nasally to prevent fracturing the ethmoid bone lamina papyracea, which is extremely thin. When the periosteum is freed posteriorly, the enucleation scissors are inserted between the periosteum and bone on the inferonasal side and gently advanced to the orbital apex.
7. The tissues are then cut as near to the orbital apex as possible, and the orbital contents are removed by continued traction on the silk sutures in the eyelids while cutting the residual adhesions in the posterior orbit.
8. The socket is immediately packed with moist gauze, which is left in place for 5–10 min. The gauze is then removed, and the orbital

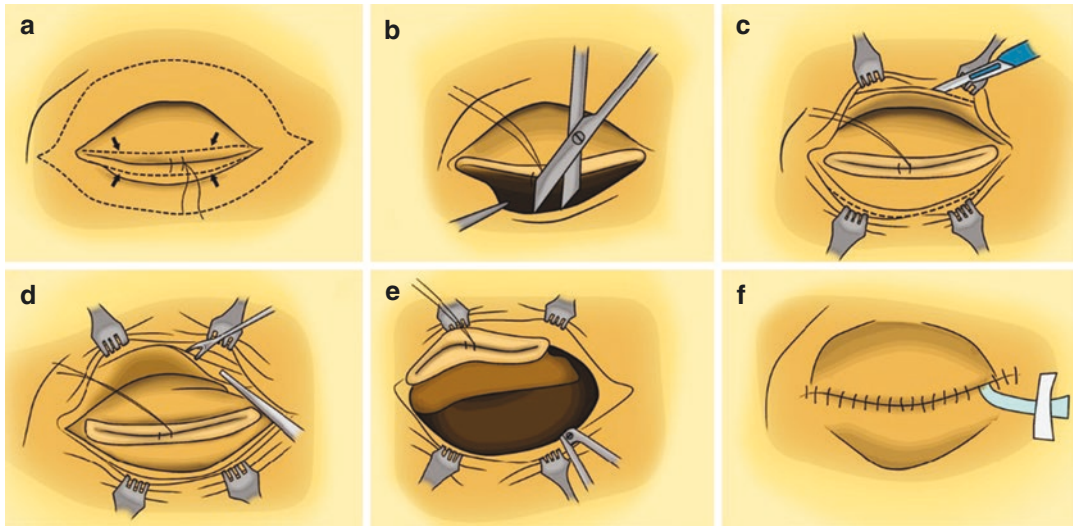

Fig. 15.2 Surgical steps during lid sparing exenteration: (**a**) lids are tie together; (**b**) incision is made above the lower lid; (**c**) skin flap raised till periosteum of orbital rim is exposed; (**d**) incision through periosteum via a monopolar; (**e**) the orbital content is removed with a traction suture; (**f**) the lids are sutured after removal of orbital content and small drain is secured

apex is inspected. Residual soft tissue at the orbital apex is removed piecemeal, and bipolar cautery and repeat packing are used until there is no further bleeding.

9. Some surgeons prefer to clamp the tissues at the orbital apex before excising the specimen. Caution should be used with Bovie cautery within the orbit to minimize the risk of CSF leak or damage to periorbital tissues.
10. A rubber drain is placed in the socket after complete haemostasis, and the skin of the upper and lower eyelids is sutured together with interrupted 5-0 silk sutures. This leaves the residual orbital cavity filled with air.
11. The drain suture is removed in 12–24 h post-surgery, and the drain is removed in 24–48 h depending on the drainage volume.

15.2.1.2 Total Exenteration

1. Two 4-0 silk tarsorrhaphy sutures are placed, which act as traction sutures during the procedure.
2. A monopolar cautery is then used to make an incision through the skin and orbicularis muscle around the orbital rim.
3. Dissection is carried out to the orbital rim laterally and inferiorly. The superior orbital rim is identified, and the periosteum is elevated.
4. The lateral orbital rim is incised along the periosteum. Superiorly, the periosteum is elevated from the orbital rim.
5. Laterally, the periosteum is elevated from the lateral orbital rim and lateral wall. In this area, the zygomatico-facial and zygomatico-maxillary neurovascular bundles should be identified.
6. This bundle should be transected with a monopolar cautery. Medially, the anterior ethmoidal neurovascular bundle is identified and cauterized. It is important not to compromise the thin bone of the medial orbital wall to prevent sino-orbital fistula formation.
7. Posteriorly, the posterior ethmoidal neurovascular bundle is identified and cauterized. After transection of the infraorbital fissure as well as the nasolacrimal duct, the curved scissors are used to transect the posterior obit.
8. In doing this, the ophthalmic artery is transected and there is significant bleeding. One can apply a ligaclip prior to transection. The periosteum is largely intact other than the posterior orbit.

9. Haemostasis is secured with bipolar cautery. The area is then packed for haemostasis prior to harvesting of the split-thickness skin graft.
10. Other options for covering the defect or reconstruction include granulation, use of local flaps such as a cheek lift and median forehead flap, and use of a free flap.

15.2.2 Case Illustrations

This is a case of advanced left maxillary sinus carcinoma with orbital involvement (Fig. 15.3). CT scan showed extensive maxillary tumoural mass, which invaded the orbital cavity and multiple small lymph nodes ipsilaterally. Patient was planned for left total maxillectomy, segmental mandibulectomy with left total orbital exenteration and left anterolateral neck dissection, and tracheostomy. The reconstruction of the defect was performed by plastic reconstructive team.

Intraoperatively, a modified Weber-Ferguson skin incision is used with lid incision for orbital exenteration and transcervical inferior limb extension for ipsilateral neck dissection (Figs. 15.4 and 15.5). Total maxillectomy was performed first. Subsequently, superior maxillectomy bony cut was incorporated with inferior orbital bony cut (Fig. 15.6). The periosteum was elevated from the orbital rim. Before cutting on the orbital tissues and its content, the neurovascular bundle needs to be identified (Fig. 15.7) and clipped. This avoids unnecessary bleeding. Once the orbital tissue is

Fig. 15.3 A patient with advanced left maxillary sinus carcinoma with left orbital involvement

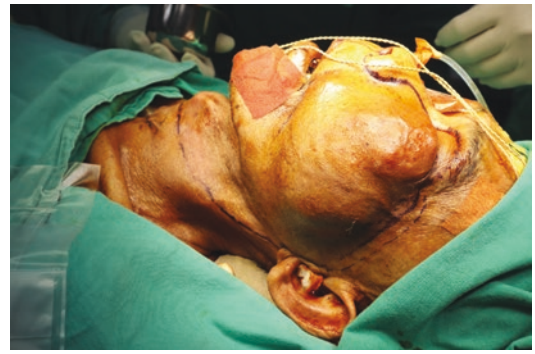

Fig. 15.4 A skin incision has been marked for left total maxillectomy, left orbital exenteration, and left anterolateral neck dissection

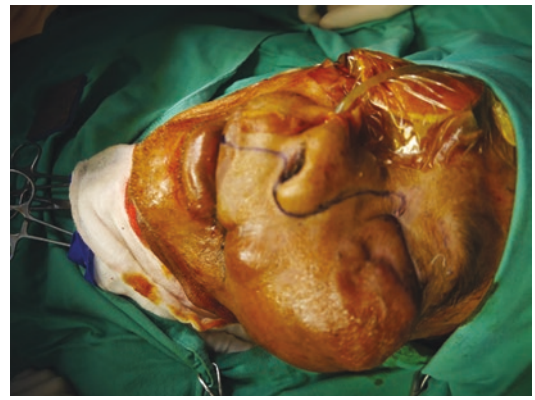

Fig. 15.5 A modified Weber-Ferguson skin incision for maxillectomy

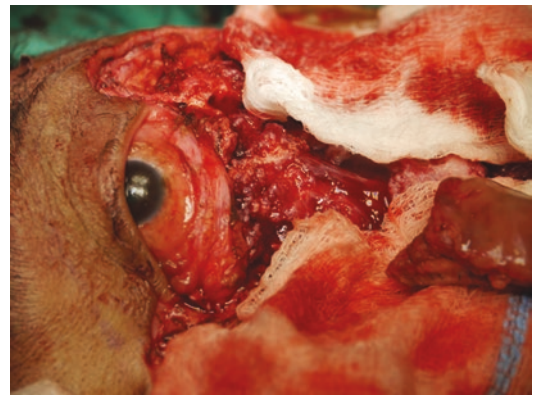

Fig. 15.6 An inferior cut of the orbital wall incorporating with maxillectomy osteotomy

removed, the residual tissue at the orbital apex can be removed by piecemeal technique (Fig. 15.8). The bleeding can be controlled with bipolar diathermy and a suction (Fig. 15.9). The total maxillectomy, segmental mandibulectomy, and total orbital exenteration were completed (Fig. 15.10). The left orbital tissue specimen (Figs. 15.10 and 15.11) is sent to pathology for detailed histology examination and determination of surgical margin involvement (Fig. 15.12).

15.2.3 Complications

There are multiple complications that can arise from the orbital exenteration. These complications can severely affect the patient's quality of life. Significant numbers of patients may develop sino-orbital fistulas from perforated sinuses occurring intraoperatively. The thin ethmoid bones can be fractured during the surgery, leading to an opening or fistula between the orbit and the nasal cavity. This can be very challenging to manage especially if the patients have comorbidities like diabetes mellitus, which impairs healing post-operatively.

The most common post-operative complications are ethmoid fistula and infection of the operative site, encountered in 0–50% and 0–43% of cases, respectively. Martel et al. reported that an ethmoidal fistula was the most common post-operative complication identified in their study [7].

Intracranial infection is another potential complication of orbital exenteration. This can be eliminated by obliterating the cavity in its entirety with soft-tissue free flaps. This allows a safer and more therapeutic management of the socket leading to improved post-operative management and cosmetic outcome. Other disadvantages of secondary healing of an exenterated orbit include delayed healing, prolonged post-operative socket care, and delayed facial rehabilitation.

Another critical complication is a recurrent tumour. A high rate of recurrence is reported to occur in medial canthal tumours. This is especially true for a high-grade tumour, and in most of the cases it requires adjuvant radiation post-operatively.

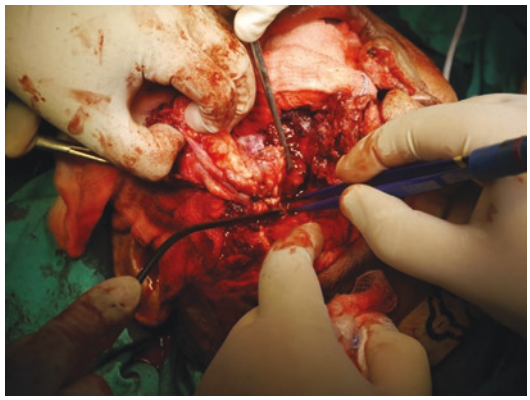

Fig. 15.7 Bipolar is used to cauterize the vascular bundle that may cause uncontrolled bleeding during dissection

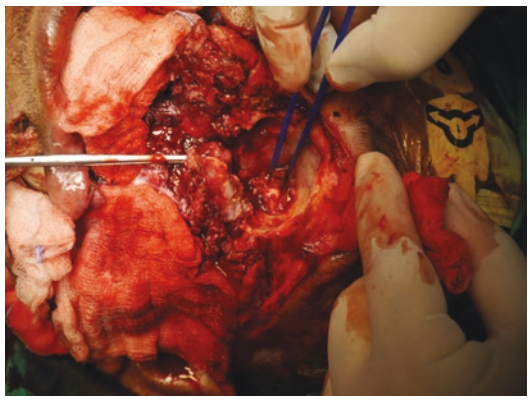

Fig. 15.8 Tissue at the orbital apex is removed by piecemeal technique

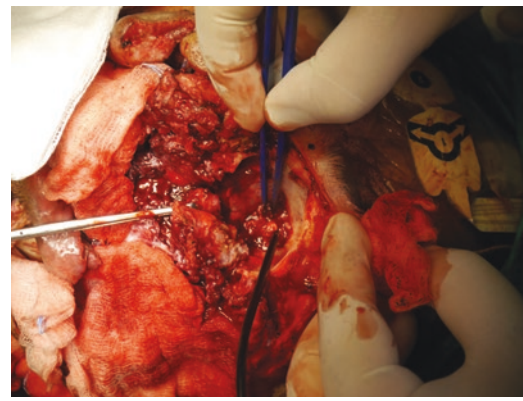

Fig. 15.9 Tissue at the orbital apex is cauterized with bipolar and suction

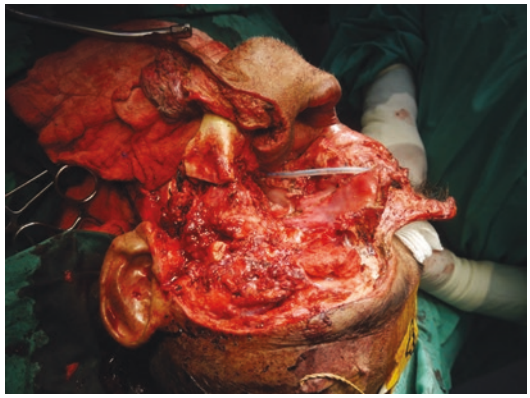

Fig. 15.10 Total maxillectomy is complete, left orbital is exenterated, and segmental mandibulectomy is performed

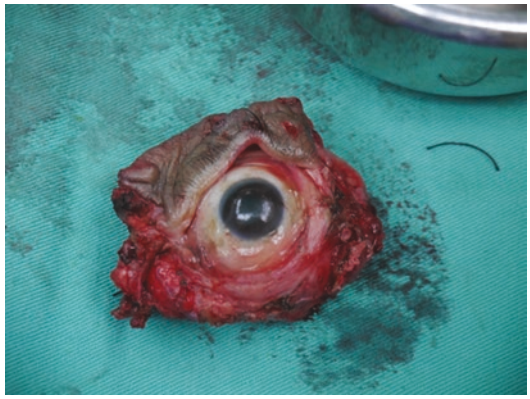

Fig. 15.11 The exenterated left orbit

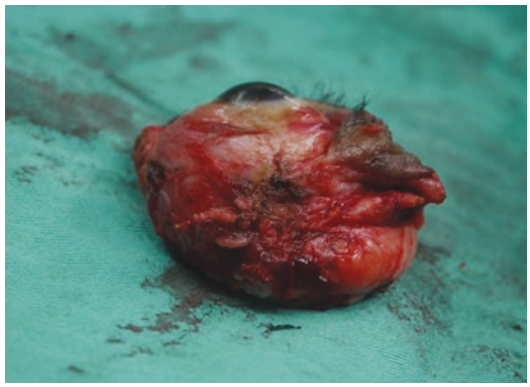

Fig. 15.12 The left orbit specimen

Cerebrospinal fluid leakage is the most common intraoperative complication. This can be repaired intraoperatively using an overlay fascia or fat graft. Post-operatively, the patient can be covered with intravenous antibiotic that crosses the blood-brain barrier such as the third-generation cephalosporin.

15.2.4 Reconstruction Option Following Orbital Exenteration

Goals of reconstruction include separating the sino-orbital cavities and creating a safe, stable wound that can withstand adjuvant radiation. Adjuvant radiation is indicated in the majority of patients who underwent orbital exenteration, as most of the tumours are T3 and T4 tumours. The reconstruction also allows improvement of cosmesis outcomes post-operatively. Additionally, the reconstructed flap will provide a good cutaneous coverage, ensure rapid healing, and allow closure of orbital nasal and sinus communications, or of orbital and cranial communications. This is imperative to enhance post-operative treatment outcomes.

When planning for orbital rehabilitation, it is important to create a concave cavity that can accommodate a prosthesis. This is primarily achieved through secondary granulation or split-thickness skin grafts [8]. The prosthesis application needs to be handled by a team of expertise, and patients need to be fully counselled regarding the necessary steps involved and the expected outcomes. As the eyes are the most important components of the face regarding aesthetics, the rehabilitation of patients undergoing exenteration is of importance. Patient confidence, self-esteem, and their return to normal social life are possible with the use of orbital prostheses. Most of the patients were consulted for rehabilitation, following near-complete epithelialization of the exposed area [9, 10]. Recently, the use of dermal allografts

has been investigated and has shown good success with epithelialization of the orbital cavity. For complex orbitomaxillectomy defects, musculocutaneous free tissue flaps remain the mainstay for reconstruction [8].

The majority of treated patients required a free flap reconstruction, especially when an extended exenteration defect or adjuvant treatment was anticipated. The anterolateral thigh flap was the most commonly used donor site [10]. Other choices of flap include latissimus dorsi and levator scapula flaps. Before reconstruction, the surgical specimen should be confirmed to have negative surgical margins. This reduces the risk of early recurrence, as early recurrence will certainly hamper the effort of flap reconstruction.

15.3 Impact of Orbital Exenteration

Over the past decades, attention has been directed toward reducing the perioperative morbidity by developing new surgical devices and new strategies and promoting cosmetic rehabilitation by providing adequate facial prostheses, following an orbital exenteration. Despite these advances, several studies have questioned the role of orbital exenteration in improving the overall survival [11]. This is in view of the fact that the majority of patients who underwent orbital exenteration had stage IV disease. The prognosis for stage IV disease is mostly poor.

In contrast, other proponents for orbital exenteration reported that although orbital exenteration has failed to demonstrate any overall survival benefit, it allows satisfactory local control of the disease with an increasingly less invasive procedure. The local control of the disease can be further improved with the addition of radiation.

Some of the identified risk factors for poor overall survival include age, tumour histology (worse prognosis with choroidal melanoma, better prognosis with basal cell carcinoma), non-R0 surgical resection, locally advanced tumours (size >2.0 cm), and presence of metastases at diagnosis. Recent studies have demonstrated favourable outcomes when managing locally advanced basal cell carcinoma, lacrimal gland cancer, and conjunctival melanoma with targeted therapies or immunotherapies without performing orbital exenteration [7]. These immunotargeted therapies, however, are costly and only available at a well-developed head and neck oncology centre globally. Importantly, not all patients will be suitable for targeted therapy. Only selected patients who met certain criteria like positive EGFR will have a better treatment response.

15.4 Conclusion

Orbital exenteration is a delicate procedure with multiple complications that can impair the patient's quality of life post-operatively. A meticulous consideration is necessary in deciding which patients are indicated for orbital exenteration and which groups of patients do not need orbital exenteration, as the majority of patients have stage III or stage IV disease. This allows an optimal treatment outcome for these subset of patients.

References

1. Rahman I, Cook AE, Leatherbarrow B. Orbital exenteration: a 13-year Manchester experience. Br J Ophthalmol. 2005;89(10):1335–40. https://doi.org/10.1136/bjo.2004.062471.
2. Kasaee A, Eshraghi B, Nekoozadeh S, Ameli K, Sadeghi M, Jamshidian-Tehrani M. Orbital exenteration: a 23-year report. Korean J Ophthalmol. 2019;33(4):366–70. https://doi.org/10.3341/kjo.2018.0052.
3. Castelnuovo P, Lambertoni A, Sileo G, et al. Critical review of multidisciplinary approaches for managing sinonasal tumors with orbital involvement. Acta Otorhinolaryngol Ital. 2021;41(Suppl. 1):S76–89. https://doi.org/10.14639/0392-100X-suppl.1-41-2021-08.
4. Vartanian JG, Toledo RN, Bueno T, Kowalski LP. Orbital exenteration for sinonasal malignancies: indications, rehabilitation and oncologic outcomes. Curr Opin Otolaryngol Head Neck Surg. 2018;26(2):122–6. https://doi.org/10.1097/MOO.0000000000000441.
5. Martel A, Baillif S, Nahon-Esteve S, et al. Orbital exenteration: an updated review with perspectives.

Surv Ophthalmol. 2021;66(5):856–76. https://doi.org/10.1016/j.survophthal.2021.01.008.
6. Baum SH, Oeverhaus M, Saxe F, Mohr C. Modified types of orbital exenteration, survival, and reconstruction. Graefes Arch Clin Exp Ophthalmol. 2020;258(10):2305–12. https://doi.org/10.1007/s00417-020-04812-7.
7. Martel A, Hamedani M, Lagier J, Bertolotto C, Gastaud L, Poissonnet G. L'exentération orbitaire a-t-elle encore sa place en 2019? [Does orbital exenteration still has a place in 2019?]. J Fr Ophtalmol. 2020;43(2):152–74. https://doi.org/10.1016/j.jfo.2019.04.021.
8. Yesensky J, Lebo N. Reconstructive options following orbital exenteration. Curr Opin Otolaryngol Head Neck Surg. 2020;28(5):352–4. https://doi.org/10.1097/MOO.0000000000000662.
9. Kesting MR, Koerdt S, Rommel N, et al. Classification of orbital exenteration and reconstruction. J Craniomaxillofac Surg. 2017;45(4):467–73. https://doi.org/10.1016/j.jcms.2017.01.003.
10. Fleming JC, Morley I, Malik M, et al. Orbital exenteration and reconstruction in a tertiary UK institution: a 5-year experience. Orbit. 2021;40(4):306–15. https://doi.org/10.1080/01676830.2020.1775262.
11. Martel A, Oberic A, Moulin A, et al. Orbital exenteration and conjunctival melanoma: a 14-year study at the Jules Gonin Eye Hospital. Eye (London). 2020;34(10):1897–902. https://doi.org/10.1038/s41433-020-0767-6.

16 Temporal Bone Diseases and Tumours and Its Related Surgery

Gabriela Ramírez Arroyo, Carolina Tella Vega, Daniella A. Monroy Llaguno, and Juan Carlos Cisneros Lesser

16.1 Introduction

To fully understand the three-dimensional anatomy of the temporal bone is one of the most challenging tasks a head and neck surgeon faces. The temporal bone also stands out for the variety of pathology affecting it. It is merely impossible to discuss extensively all the diseases and tumours affecting this anatomical region and their surgical management in a single book chapter. This chapter intends to help the reader comprehend the most common surgical approaches to treat the diseases and tumours that affect the lateral skull base more frequently.

It is important to mention that these approaches are largely designed for adult patients because such lesions are more common in this population. Nevertheless, the development of cochlear implants has radically increased the number of young children undergoing temporal bone surgery, a population that implies unique challenges [1].

Specimen dissection is perhaps the most valuable tool to properly identify surgical landmarks and eventually perform increasingly complex approaches in the diseased ear; therefore, the reader is encouraged to attend the laboratory as often as possible. Besides a solid knowledge of temporal bone anatomy and its variants, having adequate otologic instruments and properly preparing and positioning the patient are crucial steps for a safe procedure.

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16.2 Surgical Pathology of the Temporal Bone

Most patients undergoing temporal bone surgery are afflicted by benign pathology, which can be inflammatory, traumatic, congenital, idiopathic, or neoplastic. Cardinal symptoms of temporal bone disease are hearing loss, otorrhea, facial paralysis, pain, and vestibular manifestations. Unilateral facial paralysis and pain that do not respond to treatment or are unproportioned to the signs observed during the physical exam should draw suspicion of malignant disease.

16.2.1 Benign Pathology

16.2.1.1 Chronic Otitis Media with Cholesteatoma

Cholesteatoma is defined by the presence of squamous epithelium in the middle ear. It is a benign pathology, but it is locally invasive and has a destructive nature. It can be congenital or more

N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_16

often acquired. Congenital cholesteatomas are usually discovered during a routine physical exam. In contrast, patients with acquired cholesteatoma tend to have a long history of otorrhea and conductive hearing loss. Most patients seek medical attention when hearing loss interferes with social activities; tinnitus is another common cause of consult. During the physical exam, tympanic membrane retraction and/or perforation, scutum and/or ossicular chain erosion, foul-smelling discharge, and an encapsulated white lesion full of greasy keratinaceous debris are common signs [2]. An aural polyp may also be found, and its presence should raise suspicion of malignant disease. Despite a slow growth rate, cholesteatomas frequently get infected and can lead to intratemporal and intracranial complications. Diagnosis is clinical, but audiometric testing is essential to evaluate the degree of conductive hearing loss and to identify sensorineural hearing loss, which might alert the surgeon of a labyrinthine fistula. Bone erosion is a classic feature of cholesteatoma, but beyond diagnostic confirmation, the real value of computed tomography (CT) scanning is its ability to determine the extent of disease, rule out complications, identify anatomical variants, and make a differential diagnosis with neoplastic disease [3, 4]. Treatment is essentially surgical, and the main goal is to eradicate the disease. Canal wall down procedure is the most effective to remove the matrix, but functional results are poor [5]. The use of endoscopes and the possibility to perform sequential magnetic resonance with diffusion-weighted imaging have allowed surgeons to perform less extensive surgeries with good results [6–8].

16.2.1.2 Temporal Bone Fracture with Facial Nerve Palsy

Adult patients with a temporal bone fracture have a 7–10% risk of developing a facial nerve injury; the risk is closer to 3% amongst children. The most common site of injury is the perigeniculate region, followed by the second genu. The tympanic and mastoid portions of the facial nerve may also be affected [9].

To decide between conservative and surgical management, the two main factors to consider are the time of onset (immediate vs. delayed) and the severity of injury (complete vs. partial). With regard to the time of onset, paralysis is immediate in 27% of cases, while in the remaining 73% facial motion will be normal at initial evaluation and paralysis installs 1–16 days later. Paralysis is complete in 25% of cases [10].

Surgical decompression should be considered in cases of immediate-onset complete facial nerve paralysis. Cases of complete paralysis in which the onset of paralysis is unknown should be treated as immediate. The selection of patients for surgical management is controversial, as 63% of patients with immediate-onset complete facial nerve paralysis will recover with high-dose steroids. If the nerve has suffered an unrecoverable injury, the outcome after conservative management is poor; hence, performing electrodiagnostic tests is paramount for selecting those patients that will benefit from surgery. Electroneurography (ENoG) is performed 3–14 days after injury, to allow Wallerian regression to take place. Two weeks after the onset of paralysis, electromyography (EMG) is preferred. Surgery is recommended if ENoG shows more than 90% of facial nerve degeneration or EMG fails to reveal voluntary motor unit potentials and only shows fibrillation potentials [11].

Ideally, surgery should be performed within the first weeks after trauma [12]. Other authors consider it appropriate to perform surgery during the first 2 months [13]. A translabyrinthine approach is preferred in patients with total hearing loss. In those with residual hearing, there is some controversy on the extension of the procedure. Alternatives are to perform a limited exploration based on clinical evaluation and imaging or to perform a total facial nerve exploration and decompression by a middle fossa and transmastoid/supralabyrinthine approach [9, 14]. When compared to the transmastoid approach, the middle fossa approach allows better exposure of the geniculate ganglion, the greater superficial petrosal nerve, and the tympanic segment of the facial nerve. The middle fossa approach also enables the identification of the labyrinthine segment, while the transmastoid approach does not. Currently, the surgical management of Bell's palsy is controversial.

16.3 Sensorineural Hearing Loss and Cochlear Implant Surgery

Cochlear implant (CI) surgery is the most remarkable progress in otology in the twentieth century, allowing rehabilitation of patients who received little or no benefit from hearing aids. Bilateral severe or profound neurosensorial hearing loss continues to be the most frequent indication. Outstanding results and rapid technological advances have widened the selection criteria for candidacy, in both children and adults [15]. One of the major changes in selection criteria concerns the tendency to lower the age of CI surgery, in response to evidence showing that an early diagnosis and implantation allow for better language development. In 1990, the U.S. Food and Drug Administration (FDA) considered that the minimum age for CI surgery was 2 years old. Currently, the FDA approves CI surgery in 1-year-old children, and several centres worldwide support CI surgery in younger children [1]. Those implanted younger than 1 year of age represent a surgical challenge due to higher possibilities of intraoperative bleeding, facial nerve injury, and device migration. Difficulties to evaluate response to hearing aids and an increased anaesthetic risk should also be considered.

Electrode insertion through the round window is the preferred technique for cochlear implantation. The preferred approach is to perform a simple mastoidectomy followed by a posterior tympanotomy (Fig. 16.1). The main risk associated with this classic approach is facial nerve injury; the current rate is less than 1%.

Anatomical variations like cochlear ossification, chronic otitis media, and cochlear malformation were considered a contraindication to CI. However, possible auditory benefits of cochlear implantation have led surgeons to develop alternatives to the standard technique. Non-mastoid approaches, including suprameatal, transcanal, and pericanal approaches, have been developed to reduce the risk of facial nerve and chorda tympani injuries and are useful tools in the context of cochlear malformations or unfavourable facial recess anatomy. Nevertheless, non-mastoid approaches are not ideal when the goal is hearing preservation, as most require creating a cochleostomy or providing a limited angle to the round window precluding a non-traumatic insertion [16]. The previous techniques might be contraindicated in patients with an open cavity in the context of chronic otitis media. In these complex cases, the middle fossa approach is a valid alternative for CI surgery [17].

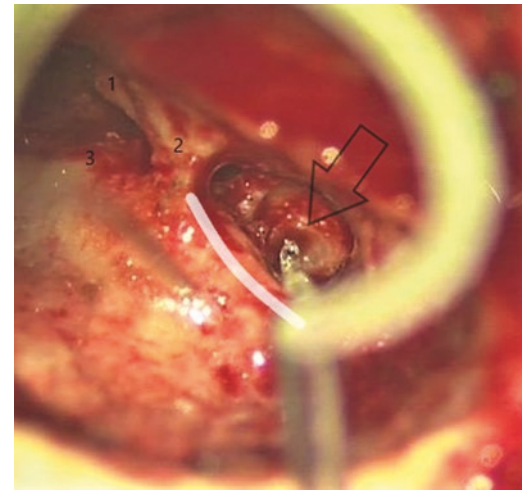


Fig. 16.1 CI insertion through the round window, incus (*1*), incus buttress (*2*), lateral semicircular canal (*3*), facial nerve (*white line*), round window (*black arrow*)

16.4 Vestibular Disorders

Injury to the peripheric vestibular system may manifest with a myriad of symptoms, such as vertigo, dizziness, or chronic imbalance. These symptoms may or may not be triggered by postural changes and visual or auditory stimuli. Vestibular symptoms frequently present themselves with auditory and vegetative symptoms. Clinicians should suspect central vestibular system pathology if these are absent or if focal neurological symptoms are present, especially in the context of an acute vestibular syndrome. An aetiologic diagnosis is challenging and requires a careful history and a specific battery of tests, which are not included in the purpose of this chapter. Surgical management of peripheral vestibular disorders is needed in the minority of

cases, yet surgery is a valuable resource in selected cases. Menière's disease and superior semicircular canal dehiscence are two examples of the role of surgery for vestibular disorders.

16.4.1 Ménière's Disease

Ménière's disease is a well-known cause of episodic vestibular syndrome. It consists of recurrent episodes of spontaneous vertigo usually associated with unilateral fluctuating sensorineural hearing loss (SNHL), tinnitus, and aural fullness. Specific diagnostic criteria have been proposed by the Bárány Society [18]. The exact cause of Ménière's disease is still a matter of discussion; nevertheless, endolymphatic hydrops seems to play a role in pathogenesis. Treatment options for intractable Ménière's disease are endolymphatic sac surgery, intratympanic gentamicin, vestibular neurectomy, and labyrinthectomy with simultaneous cochlear implantation [19, 20]. Endolymphatic sac surgery is a specific procedure for Ménière's disease, intended to control endolymph flow and stabilize the disease. After a series of studies by a Danish group suggesting that endolymphatic sac surgery was comparable to simple mastoidectomy with a considerable placebo effect, the procedure fell from favour [21, 22]. Re-evaluation of data found inconsistencies in Thomsen's study, and endolymphatic sac surgery has proven to have better control of vertigo than mastoidectomy [23]. In a systematic review published by Sood and colleagues, both sac decompression and mastoid shunt procedures were effective at controlling vertigo in the short term (between 12 and 24 months of follow-up) and long term (>24 months) in at least 75% of patients with recalcitrant Ménière's disease [24]. Since endolymphatic sac surgery can preserve inner ear function and hearing, some suggest that it should be the first strategy for intractable Menière's disease [25]. Nevertheless, controversy regarding the efficacy of endolymphatic sac surgery remains, and a systematic review concluded that high-quality evidence on the matter is still lacking [26]. Hearing preservation with intratympanic gentamicin and vestibular neurectomy is comparable, but the latter is associated with better control of vertigo. Yet, the simplicity of intratympanic gentamicin has reduced the number of patients treated surgically [27].

16.4.2 Superior Semicircular Canal Dehiscence

Superior semicircular canal dehiscence (SCCD) consists of a bony defect in the roof of the superior semicircular canal (SSC). Minor was the first to describe the relationship between the anatomical defect of the temporal bone and a third window phenomenon [28]. Vertigo induced with loud sounds and/or pressure changes, egophony, tinnitus, chronic disequilibrium, and mild conductive hearing loss are frequent symptoms. Clinical diagnosis based on clinical manifestations is elusive, as symptoms can be vague, and SCCD is frequently mistaken with otosclerosis, perilymphatic fistulae, and otosyphilis, amongst others. Patients with SCCD have bone conduction hyperacusis and intact tympanic reflexes, while patients with otosclerosis do not. CT is necessary to confirm the anatomic defect, and slices should be thin (0.5 mm) with reconstructions in the planes of Stenvers and Pöschl (Fig. 16.2a, b). Yet, most patients with anatomic dehiscence will be asymptomatic. Moreover, in the face of a patient with an anatomic defect and symptoms, surgeons should also bear in mind that the otovestibular symptoms might not be explained by dehiscence. This is relevant when selecting surgical candidates, as surgical treatment of SCCD is highly effective for severe vestibular symptoms in well-selected patients, but then in many cases, it implies a medial fossa approach. Vestibular evoked myogenic potential (VEMP) testing can offer a 91% sensitivity and 96% specificity for diagnosing SCCD, and they are also valuable for follow-up and assessing surgical outcomes [29].

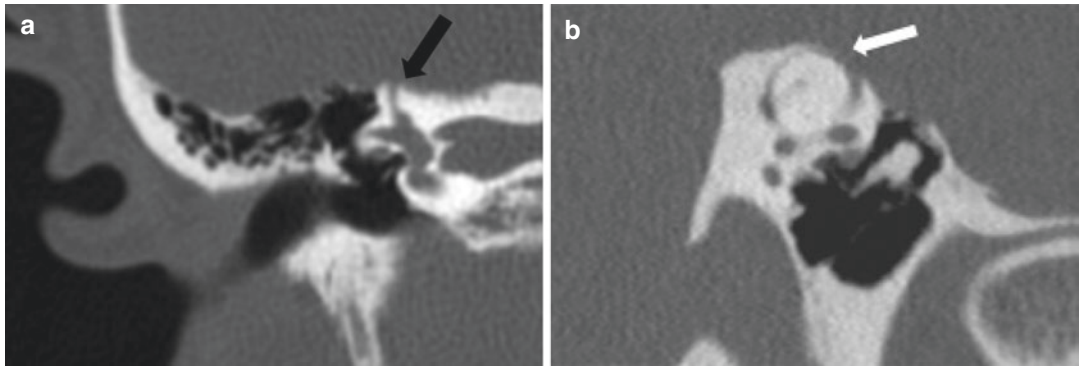


Fig. 16.2 (**a**) CT scan of superior semicircular canal dehiscence (*black arrowhead*), (**b**) CT scan of superior semicircular canal dehiscence (*white arrowhead*) in Pöschl plane

16.5 Benign Tumours of the Temporal Bone

Tumours affecting the temporal bone, especially malignant ones, are rare. Amongst benign neoplasms, the most common histologic types are adenomas, paragangliomas, schwannomas, and mesenchymal tumours like lipoma, chordoma, hamartoma, and bone-related neoplasms.

To perform an extensive revision of temporal bone tumours escapes the scope of this chapter. We will only mention the most representative lesions, with emphasis on their surgical management.

16.5.1 Middle-Ear Glandular Neoplasms: Adenoma, Neuroendocrine Adenoma, and Carcinoid Tumours

Adenoma and its variant, the neuroendocrine adenoma, are rare benign neoplasms. They are not easily distinguishable from carcinoid tumours. Literature is characterized by heterogeneous terminology, making it difficult to find standardized reports amongst centres. Adenomas, neuroendocrine adenomas, and carcinoid tumours are currently considered primary low-grade glandular neoplasms with metastatic potential and have epithelial and/or neuroendocrine differentiation [30].

The most frequent symptoms are aural fullness and mild hearing loss, most often conductive. Otoscopy shows a retrotympanic mass with no distinctive traits. On CT, they are a well-circumscribed, soft-tissue mass without bone erosion. On MRI, they show a low-to-intermediate intensity on T1 with enhancement after administration of gadolinium and high intensity on T2-weighted images [31].

Since the clinical presentation and the imaging tests are not specific, the diagnosis depends on histologic and immunohistochemical examination. Based on immunohistochemical markers and the presence of metastasis, Saliba proposed a classification of middle-ear glandular neoplasms (Table 16.1).

Treatment is surgical resection; the procedure depends on the extension. When the ossicular chain is involved, it should be removed to reduce recurrence. The rate of recurrence is 18–22% in those patients in whom the removal of the ossicles was not performed [33]. Long-term follow-up is recommended.

16.5.2 Vestibular Schwannoma and Other Cerebellopontine Angle Neoplasms

Vestibular schwannoma (VS), previously known by the confusing name of "acoustic neuroma", is a benign, slow-growing neoplasm arising from

Table 16.1 Classification of middle-ear glandular neoplasm (modified from Saliba and Evrard [32])

Type	Description	Immunohistochemistry	Metastasis	Frequency (%)
I	Neuroendocrine adenoma	Positive	Negative	76
II	Adenoma	Negative	Negative	20
III	Carcinoid tumour	Positive	Positive[a]	4

[a]Metastasis is more frequently found in the ipsilateral parotid gland

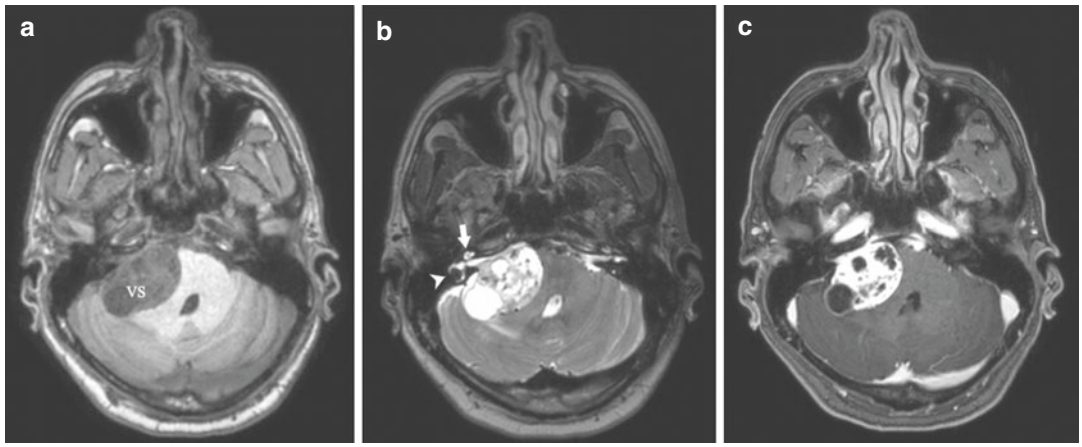


Fig. 16.3 Vestibular schwannoma MRI, (**a**) T1-weighted, vestibular schwannoma (VS), (**b**) T2-weighted, cochlea (*arrow*), lateral semicircular canal (*arrowhead*), (**c**) T1 post gadolinium

the Schwann cells of the vestibulocochlear nerve. The vestibular branches are affected in 95% of cases. They represent 6% of all intracranial tumours and 80–90% of all cerebellopontine angle (CPA) neoplasms. 90% are unilateral, and the most frequent clinical presentation is asymmetric sensorineural hearing loss and/or tinnitus. Differential diagnosis of a CPA mass is made with meningioma, epidermoid cyst, facial nerve haemangioma, and facial nerve schwannoma (FNS) [31].

Imaging studies are useful to differentiate VS from other CPA masses. VS is typically T1-isointense and T2-hyperintense and enhances homogeneously with contrast (Fig. 16.3). Meningiomas are also enhancing lesions but have a broad dural base and are isointense to grey matter on T1 and T2, and epidermoid cysts show diffusion restriction. FNS involving the CPA and/or the internal acoustic segment of the facial nerve is indistinguishable from a VS unless it extends to the labyrinthine segment [34]. MRI is also helpful for prognosis, as VS with cystic changes is associated with more rapid growth, a deeper hearing loss, and an unfavourable surgical outcome [31].

Treatment options of VS include watchful waiting with MRI, surgical resection, and stereotactic surgery. Treatment selection depends on tumour size, growth rate, symptoms, patient's age and preference, and the centre's resources.

The goal of surgery is tumour control with as little morbidity as possible, preserving facial nerve function and, if feasible, hearing. Hence, subtotal resection with long-term surveillance is currently a valid alternative to preserve function. The approach is selected according to preoperative hearing, tumour size, and tumour location. Plausible approaches are the middle fossa, the retrosigmoid, and the translabyrinthine. The translabyrinthine approach is only suitable when the patient does not have a useful hearing. If hearing preservation is intended, the retrosigmoid or the middle fossa approaches are preferred. The middle fossa is indicated for small lateral tumours with less than 1 cm of CPA component and retrosigmoid for medial VS with a larger CPA component [35].

16.5.3 Temporal Bone Paraganglioma

Temporal bone paragangliomas (TBP) are benign vascular tumours that arise from neural crest cells. They are rare, with an incidence of 1 case per 1,000,000 habitants per year [36]. Despite their rarity, they are the most common middle-ear benign neoplasms. TBP may be further classified into tympanic and jugulare paraganglioma. Tympanic paraganglioma (TP) develops from paraganglion cells in the tympanic plexus associated with Jacobson's (IX) and Arnold's (X) nerves, and jugulare paraganglioma (JP) from adventitia of the jugular bulb. Nevertheless, these lesions share histologic characteristics, epidemiology, and large tumours that will eventually affect both the mesotympanic area and the jugular fossa, making it clinically irrelevant to determine where the lesion first started. Hence, we find the umbrella term jugulotympanic paraganglioma more useful. Most cases are unilateral and sporadic, present in the fourth or fifth decade of life, and are three times more frequent in women. The classic clinical presentation of lesions affecting the tympanic cavity is unilateral conductive hypoacusis, pulsatile tinnitus, and aural fulness. Large tumours may affect cranial nerves VII, IX, X, XI, and XII; affection of the lower nerves indicates jugular fossa compromise. Small tumours might be asymptomatic. A pulsatile, vascular, and retrotympanic mass is the characteristic otoscopic finding. Unlike paragangliomas located in the abdomen, lesions in the skull base are seldom related to catecholamine release. Less than 5% undergo malignant transformation; malignancy is defined by the presence of metastasis. The two main systems of classification are the Glasscock-Jackson classification [37], which proposed one classification system for TP and another for JP, and the Fisch classification, which includes both [38]. We consider that the classification proposed by Fisch is more practical, as it helps the surgeon to decide surgical management regardless of the site of origin of the paraganglioma.

The diagnostic protocol should include a thorough neurological examination, nasopharyngolaryngoscopy, audiology, and imaging tests with and without contrast. Angiography and embolization 24–72 h before resection should be considered in Fisch C and Fisch D tumours (Fig. 16.4). Measurement of catecholamines is

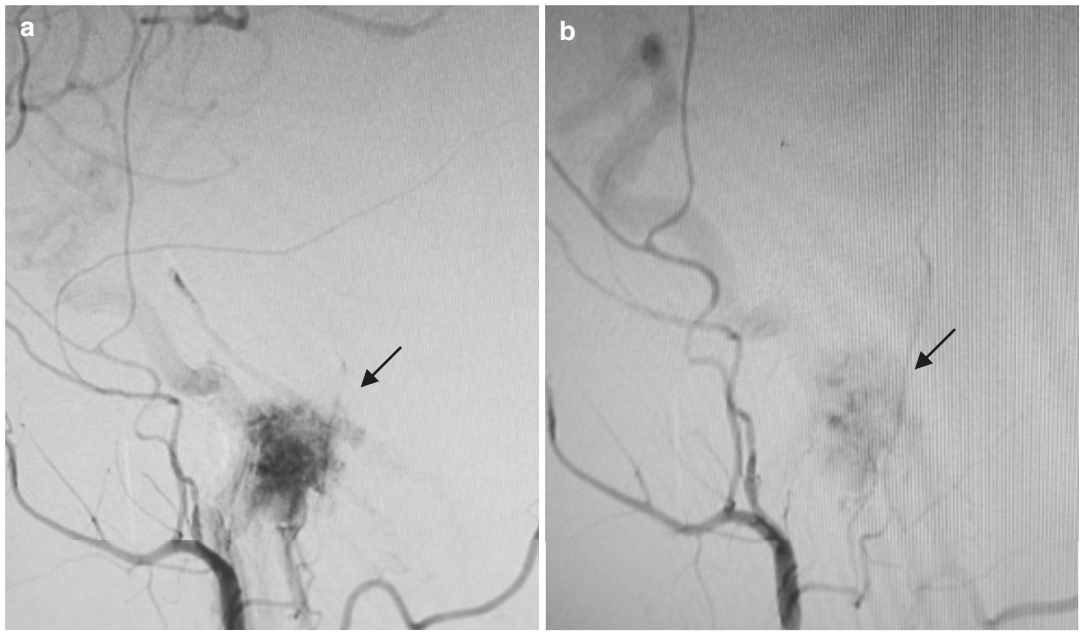


Fig. 16.4 Embolization of glomus jugulare, (**a**) angiography before embolization, (**b**) angiography after embolization, vascular tumour (*black arrow*)

not recommended in all patients, but the clinician should carefully look for symptoms suggesting the presence of a secretory neoplasm. Due to the small number of cases, management is controversial. Radiotherapy, surgical excision, and wait and scan are the three main treatment alternatives. The selection of treatment depends on the patient's age, comorbidity, tumour size and growth, preoperative hearing and cranial nerve status, and presence of bilateral disease.

Surgical resection is the preferred modality of treatment for small TBP, especially for small TP that can be resected through a transcanal approach. Fisch B tumours can be removed by a transmastoid approach; according to tumour size, a canal wall up or a subtotal petrosectomy might be necessary [39]. For resection of larger tumours (Fisch C and D), Fisch described the infratemporal approach, which requires an anterior transposition of the facial nerve in 70% of cases. In Fisch's series, 85% of patients had a preserved facial nerve function 2 years after surgery. In the same series, preservation of cranial nerves IX, X, XI, and XII was difficult to achieve [38]. Due to the higher morbidity to resect Fisch C and D tumours, some authors rather leave macroscopic disease and irradiate if growth is observed during follow-up. This alternative is associated with better local control and fewer complications than complete surgical resection [40]. Others have described cranial nerve preservation techniques like the intrabulbar dissection technique [41] or modifications of the infratemporal Fisch approach [42]. Radiotherapy is reserved for the elderly, as it increases the risk of malignant tumours and cerebrovascular accidents [40].

16.6 Malignant Neoplasms

Malignant neoplasms of the temporal bone are rare; they represent less than 0.2% of all tumours of the head and neck [43]. The estimated incidence of malignant tumours is close to 1 case per 1,000,000 inhabitants per year.

These tumours include lesions of the skin of the pinna that invade the temporal bone, primary tumours of the external auditory canal, middle ear or the petrous apex, and secondary tumours. Secondary tumours result from either distant metastasis or direct infiltration; the latter accounts for most cases of temporal bone malignancies [44]. Carcinomas of the breast, lung, and prostate are the main locations of primaries that cause distant metastasis affecting the temporal bone. Direct infiltration is typical from carcinomas of the periauricular skin and the parotid; infiltration from temporomandibular and advanced nasopharyngeal neoplasms may also occur [45]. Primary malignancies are represented by acinic cell carcinoma, adenocarcinoma, adenoid cystic carcinoma, basal cell carcinoma, chondrosarcoma, osteosarcoma, squamous cell carcinoma (SCC), and haemato-lymphoid tumours.

Differential diagnosis differs widely between adult and paediatric patients. For instance, SCC accounts for 60–80% of temporal bone malignancies in adults; meanwhile in children, rhabdomyosarcoma is the most common malignancy [46]. The main risk factors are sun exposure and a history of radiotherapy to treat another head and neck malignancy. Chronic otitis media and infection with papillomavirus have also been associated with the development of malignancy [43].

16.6.1 Squamous Cell Carcinoma of the Temporal Bone (SCCTB)

SCCTB is an aggressive malignancy (Fig. 16.5). Initial symptoms like otorrhea, pain, hypoacusis, and bleeding are non-specific, leading to a delayed diagnosis and a poor outcome. Non-resolving otitis externa should raise suspicion of malignancy.

Preoperative imaging with a CT is essential for staging; it can detect bone erosion of 2 mm or greater. It is recommended to extend it to the chest for evaluation of distant metastasis. MRI is complementary and allows evaluation of perineural spread and intracranial involvement. An alternative to rule out distant metastasis is to perform a PET scan from the skull base to the lower extremities [47].

Unlike most carcinomas, the staging system for temporal bone carcinoma proposed by the American Joint Committee on Cancer (AJCC) is

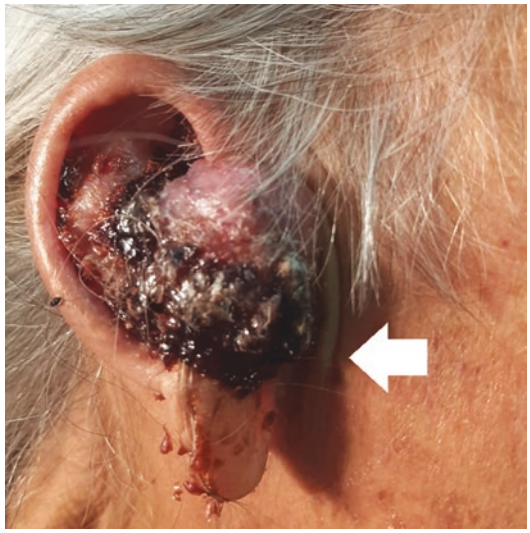


Fig. 16.5 Squamous cell carcinoma of the temporal bone arising in the right pinna (white arrow)

not widely used. The modified University of Pittsburgh staging system is the most accepted in literature (Table 16.2) [48]. According to Moody et al. (2000), the 2-year overall survival (OS) rates were 100% for T1 tumours, 80% for T2, 50% for T3, and 7% for T4 [49]. In a retrospective review including 11 studies and 195 patients, the 5-year OS rates based on the same system were 94.1% for T1, 80.8% for T2, 62.5% for T3, and 46.3% for T4. Two ominous signs are facial nerve paresis and dural infiltration, and as shown in Table 16.2, the presence of either classifies the tumour as a T4 lesion. Dural infiltration is the strongest negative factor affecting survival. A study concluded that the predictive performance of the modified Pittsburgh staging system is acceptable [50]. Mortality most often results from uncontrolled locoregional recurrence rather than from distant metastasis [51].

The mainstay treatment is surgical resection with or without radiotherapy (RT). Post-operative RT is recommended in T2, T3, and T4 tumours. Primary radiation is an alternative for T1 tumours. Definitive chemoradiotherapy (CRT) may be appropriate for cases with unresectable tumours or distant metastasis.

Sleeve resection, lateral temporal bone resection (LTBR), subtotal temporal bone resection (STBR), and total temporal bone resection (TTBR) are the different techniques designed to treat temporal bone malignancies. Sleeve resection does not include resection of the bony external auditory canal and is only suitable for the management of low-grade tumours. The minimal procedure for the management of SCC is an LTBR, and it is recommended for T1 and T2 lesions. For T3 and T4 lesions, STBR or TTBR is a recommended alternative; nevertheless, TTBR is a very morbid procedure, and survival benefit has not been proven. Curative surgery when dura is infiltrated is doubtful, because despite resection the rate of recurrence is high, and survival is poor. Therefore, even when resection is technically possible, palliation may be a reasonable alternative.

Table 16.2 The University of Pittsburgh TNM staging system for external auditory canal cancer (modified from Morita et al. [51])

T status	**Description**
T1	Tumour limited to external auditory canal without bony erosion or evidence of soft-tissue involvement
T2	Tumour with limited external auditory canal bone erosion (not full thickness) or limited (<0.5 cm) soft-tissue involvement
T3	Tumour eroding osseous external auditory canal (full thickness) with limited (<0.5 cm) soft-tissue involvement, or involvement of the middle ear and/or mastoid
T4	Tumour eroding cochlea, petrous apex, medial wall of the middle ear, carotid canal, jugular foramen, or dura, or with extensive soft-tissue involvement (>0.5 cm), or patients presenting with facial paralysis
N status	**Description**
N0	No regional lymph node metastasis
N1	Regional lymph node metastasis
M status	**Description**
M0	No distant metastasis
M1	Distant metastasis
Stage classification	
I	T1N0M0
II	T2N0M0
III	T3N0M0, T1N1M0
IV	T4N0M0, T2N1M0, T3N1M0, T4N1M0, any T any N M1

Superficial parotidectomy is indicated when the tumour infiltrates the gland, and it has a prophylactic role in T3 and T4 lesions. Neck dissection is indicated only with curative intent.

16.7 Investigation Tools for Temporal Bone Diseases

Investigation tools for temporal bone diseases have had impressive development. The numbers of tests available to the clinician may be overwhelming, and the detail of each test is beyond the scope of this chapter. Tests can be divided into three major groups: audiology tests, vestibular tests, and imaging.

16.7.1 Diagnostic Audiology

When evaluating hearing in adults, a pure-tone audiogram is the screening test of choice. This simple test allows the surgeon to determine the hearing threshold of the patient before and after surgical treatment, and it is also useful for differential diagnosis. Nevertheless, it is only suitable to determine hearing acuity and type of hearing loss. Then, audiometry should be complemented with speech discrimination tests. Patients with sensorineural hearing loss demonstrate lower scores on speech discrimination tests than expected from the audiogram. Pure-tone audiogram and speech discrimination tests require the patient's cooperation; when this is not possible, objective tests like otoacoustic emissions, auditory steady-state response, and auditory brainstem response are valuable alternatives. Tympanometry and stapedial reflexes are simple and useful tools to evaluate middle-ear function.

16.7.2 Vestibular Tests

Parallel to the complexity of vestibular physiology is the number of tests available for the evaluation of vestibular function. The goal of vestibular testing is to identify the presence of a balance disorder, locate the lesion, and evaluate the residual function and the possibility of recovery. The main tests to consider are videonystagmography (VNG), video hit impulse test (vHIT), posturography, and vestibular evoked myogenic potential (VEMP).

VNG has replaced electronystagmography and is currently the most used method for recording eye movements. It comprises a series of subtests that assess the function of the vestibular end organs and the central vestibulo-ocular pathways. The caloric test is one of the subtests of the VNG; it was the main test to assess peripheral vestibular function. Currently, the caloric test is being replaced by vHIT, because it is a quick, innocuous test that evaluates the vestibular-ocular reflex (VOR) of the six SCCs independently, and results are more reliable [52]. Posturography evaluates the ability of the patient to maintain balance and analyses the specific contribution of the three major systems involved: vestibular, visual, and somatosensory. Finally, VEMP testing is a method used mainly in tertiary reference centres and in research. It has an increasing role for diagnosing peripheral vestibular disorders, especially for diagnosis and follow-up of SCCD, and for follow-up of intratympanic gentamicin treatment in patients with Menière's disease (Fig. 16.6). Their role in the topographic diagnosis of central disorders is under research [53].

16.7.3 Imaging

A high-resolution computed tomography (HRCT) of the temporal bone is the workhorse imaging study for temporal bone disease. It is an important preoperative investigation tool for cholesteatoma surgery, temporal bone fracture, middle-ear glandular neoplasms, TBP, SCCD, and malignant neoplasms (Fig. 16.7). It is useful to confirm the diagnosis of SCCD and essential for staging of SCCTB. In cholesteatoma, temporal bone fracture, TBP, and neoplasms, it is helpful to determine the disease extent and identify the presence of anatomical variants and potentially dangerous difficulties such as a high-riding jugular bulb, a low-lying dura, facial canal dehiscence, erosion of tegmen, or semicircular canal erosion, consequently assisting surgeons in elaborating a surgical plan [54]. The use of contrast is

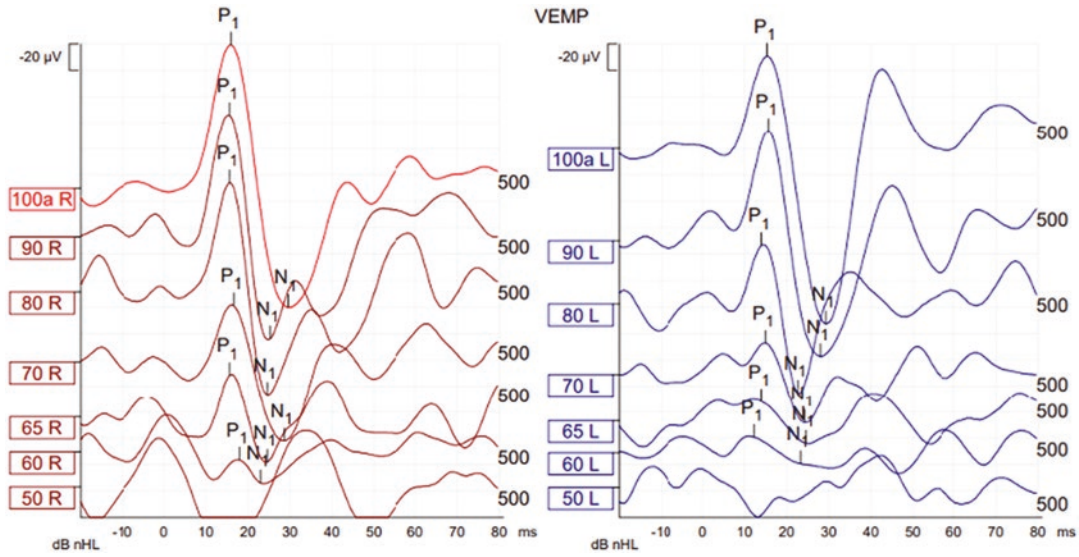


Fig. 16.6 VEMP in a patient with semicircular superior canal dehiscence; note the amplitude and low threshold

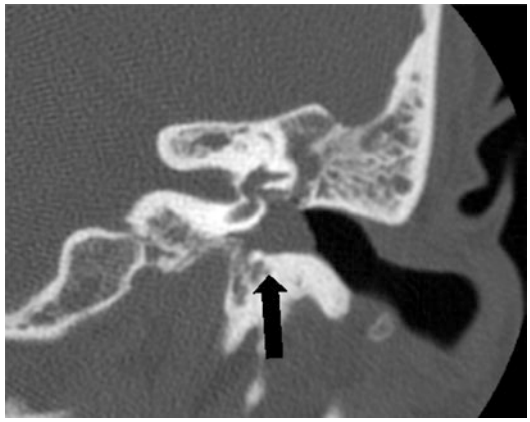


Fig. 16.7 CT scan in a patient with a middle-ear neoplasm

necessary if there is a concern of a vascular mass or clinical assessment suggests an abscess. Angiography and embolization should be considered for large jugular paragangliomas. MRI is the main tool for the evaluation of non-osseous components. Hence, it is useful for the assessment of VIII cranial nerve in candidates of cochlear implantation, evaluation of CPA neoplasms, facial nerve neoplasms, and lesions with dural extension or exposure. The use of DWI-MRI has reduced the number of second-look surgeries in patients with cholesteatoma. In contrast to most head and neck neoplasms, ultrasound has a limited role in the evaluation of temporal bone diseases. It might be useful for the evaluation of periauricular cystic lesions. Nuclear medicine studies are used for diagnosis and follow-up of skull base osteomyelitis, a major differential diagnosis of SCCTB. Finally, PET or PET/CT may be used for the assessment of temporal bone masses or nodal metastases.

16.8 Anatomical Landmarks and Surgical Procedures

16.8.1 Surgical Approaches and Incisions

Every incision used in otologic surgery should create broad access to the surgical field, allow a direct extension to adjacent anatomical areas, permit the use of adjacent skin as a free or pedicled flap, and provide an acceptable cosmetic result [55].

Depending on the approach chosen, different incisions can be used. The postauricular, transcanal, and endaural incisions are the most common, as they allow a posterior, transmeatal, and anterior approach. Each approach has advantages and limitations and should be chosen based on the location and extension of the disease.

16.8.2 Postauricular Incision

A postauricular incision allows a great surgical exposure and harvest of temporalis fascia. It is useful for tympanoplasty, in cases of anterior tympanic membrane perforations in patients with prominent anterior wall canals, and it is the workhorse incision for transmastoid approaches.

Postauricular incisions can be performed either on the postauricular sulcus or 0.75–1.0 cm posterior to it (into the hairline). The incision should begin at the highest level of the helix and must extend to the mastoid tip, always taking into account the descending segment of the facial nerve, which exits from the stylomastoid foramen between the mastoid tip and styloid process (Fig. 16.8). It is essential to keep in mind that in paediatric patients, the facial nerve is more superficial [56].

After cutting through the skin and subcutaneous tissue, the auricular muscles are generally divided to access and incise the periosteum overlying the mastoid bone. Depending on the surgery, a small amount of temporalis fascia may be harvested, but the underlying muscle must be left intact [57].

16.8.3 Transmeatal Incisions

This approach is appropriate for otologic procedures limited to the tympanic membrane and posterior tympanic compartment (e.g. stapedectomy, tympanoplasty).

The transmeatal incision consists of two vertical incisions made in the external auditory canal (EAC) skin, starting from the annulus at the 6 and 12 o'clock positions (along the tympanomastoid and tympanosquamous suture lines). These incisions extend radially and are connected by a third horizontal semilunar incision in the medial or external third of the ear canal (Fig. 16.9) [58].

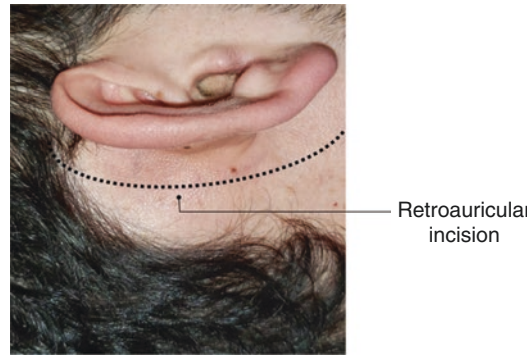


Fig. 16.8 Retroauricular incision in the right ear

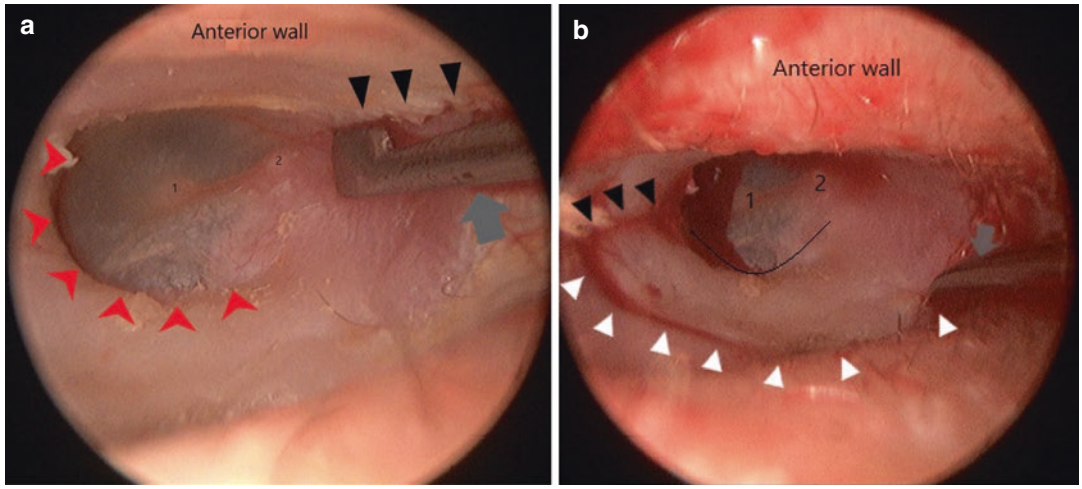


Fig. 16.9 Transmeatal incision, endoscopic view of left ear. (**a**) First vertical incision (*black arrowheads*), annulus (*red arrowheads*), flap knife (*grey arrow*), umbo (*1*), short process of the malleus (*2*). (**b**) Second vertical incision (*black arrowheads*), horizontal incision (*white arrowheads*), round cutting knife (*grey arrow*), annulus (*grey line*), umbo (*1*), short process of the malleus (*2*)

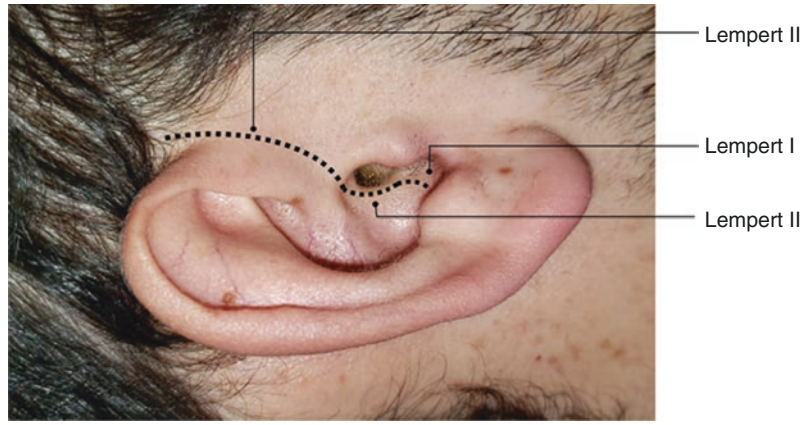


Fig. 16.10 Endaural incisions: Lempert types I, II, and III

The canal skin and tympanic membrane (tympanomeatal flap) are elevated together up to the tympanic annulus, granting access to the middle-ear space.

16.8.4 Endaural Incisions

These incisions, described by Lempert in 1938, are external to the meatus and expand the surgical field [59]. In some cases, an anterior canal bulge can hide the anterior half of the tympanic membrane and therefore is necessary to make an endaural incision to improve exposure. It is indicated for most tympanoplasties and some mastoidectomies.

The first part of the incision (Lempert I) is made in a semi-circumferential way between 6 and 12 o'clock on the back wall of the EAC at the bony cartilaginous junction. This intercartilaginous incision is prolonged vertically between the helix and tragus (Lempert II) to obtain a wider posterior flap that gives a better exposure to the mastoid cortex. The incision could be extended down (Lempert III) enough to retract soft tissue and fully expose the cortex and tip of the mastoid (Fig. 16.10).

16.8.5 Incisions for the Middle Fossa Approach and Infratemporal Fossa Approach

There are two main types of incision for a middle fossa approach, each designed for a different flap. When using an anterior/inferiorly based skin flap, the incision starts anterior to the tragus, extends posteriorly to the temporal region, turns superiorly 5–6 cm, and turns anteriorly again reaching the temporal hairline, making an "S" shape. This is also known as a question mark incision. For the posteriorly based skin flap, the incision starts behind the temporal hairline, extends anteriorly for 6.0 cm, turns superiorly for 6 cm, and turns posteriorly again for 6 cm, in the shape of a rounded box. Other alternatives are to simply extend a retroauricular incision anteriorly following the hairline or to do a vertical preauricular incision (Fig. 16.11). The skin incision for the infratemporal fossa approach is a neck extension of the C-shaped retroauricular incision.

16.9 Anterior Atticotomy

In an anterior atticotomy, only the posterior superior bone portion of the EAC, known as scutum, is removed. The procedure is used in limited attic cholesteatomas since the scutum is the first bony structure to be eroded.

After making an endaural or postauricular approach, the superior and posterior bone portion of the canal is exposed, and the lateral epitympanic wall is removed with a burr until a thin layer of bone is left over the ossicles [60]. This layer is then removed using curettes to expose the tegmen tympani and ossicular chain. Once the procedure is finished, the defect can be reconstructed with a cartilage graft or autologous bone [58].

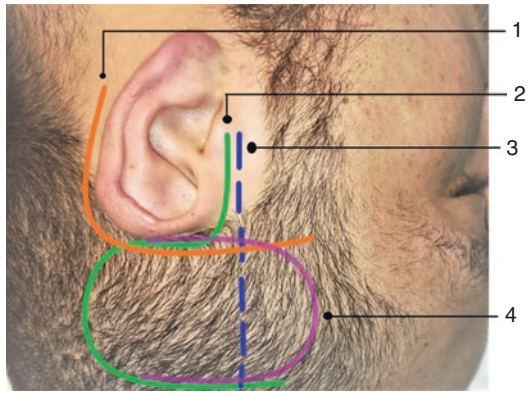


Fig. 16.11 Incisions for the middle fossa approach, anterior extension of a C-shaped retroauricular incision (*1*), preauricular incision for an anterior based flap (*2*), vertical linear preauricular incision (*3*), incision for a posterior based flap (*4*)

16.10 Transmastoid Approaches

The mastoidectomy is often performed for chronic otitis media with and without cholesteatoma. It is the initial step for several otologic procedures, including cochlear implantation, endolymphatic sac decompression, and most presigmoid approaches to the lateral skull base [61].

In 1873, Schwartze and Eysell published a paper describing for the first time the mastoidectomy procedure [62]. They highlighted the importance of finding and exposing the mastoid antrum as one of the key steps during the procedure [63]. The surgery starts in the lateral surface of the mastoid bone by drilling the cortical bone to expose the mastoid air cells. Thorough anatomical knowledge is an essential prerequisite of mastoid surgery [64]. Mastoidectomies are classified as either "wall up" or "wall down" depending on whether the posterior wall of the EAC is maintained.

16.10.1 Canal Wall Up (Intact Canal Wall) Mastoidectomy

Under microscopic vision and using a round cutting burr with continuous suction-irrigation, drilling is initiated along the linea temporalis (the lowest point of the middle fossa dura). A second line is drilled perpendicular to the previous one, tangent to the posterior margin of the EAC, behind the spine of Henle (small bony prominence anterior to the supramastoid pit at the posterosuperior margin of the bony EAC) [65]. These drill lines outline a triangular area posterior to the EAC, whose apex lies over the lateral semicircular canal, known as the MacEwen triangle (Fig. 16.12) [66].

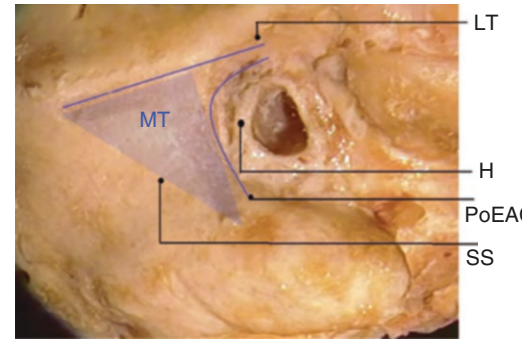


Fig. 16.12 Anatomical landmarks for mastoidectomy. Right temporal bone specimen, linea temporalis (*LT*), spine of Henle (*H*), posterior margin of the EAC (*PoEAC*), line representing the approximate location of the sigmoid sinus (*SS*), MacEwen triangle (*MT*)

Drilling is done in this area until air cells appear, removing cortical bone and thinning the posterior wall of the EAC. The superior limit is the tegmen mastoideum (level of the temporal line), and the anterior limit is the root of the zygomatic process [67]. Identifying the dura is often a meaningful step during mastoidectomy, as it represents an important anatomical landmark [68]. The bone should be drilled away evenly, orienting the surgical instrument parallel to the patient's skull to avoid inadvertent damage to the ossicular chain. During this step of the dissection, the most important landmark is the sigmoid sinus, which is identified by its bluish colour and thin bony plate [58]. The sigmoid sinus and the tegmen mastoideum meet in an angle known as the sinodural angle (Citelli's angle). Drilling is continued toward the mastoid tip, removing cells from the digastric ridge area. The facial nerve exits at the stylomastoid foramen, immediately anterior to the digastric ridge. Knowledge of this area is essential when performing mastoid surgery [69]. In case of exten-

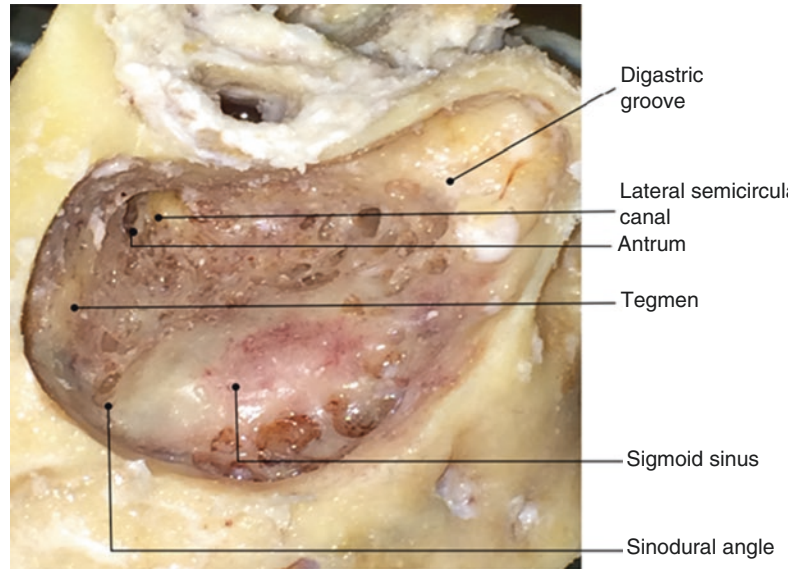


Fig. 16.13 Right mastoidectomy and antrum

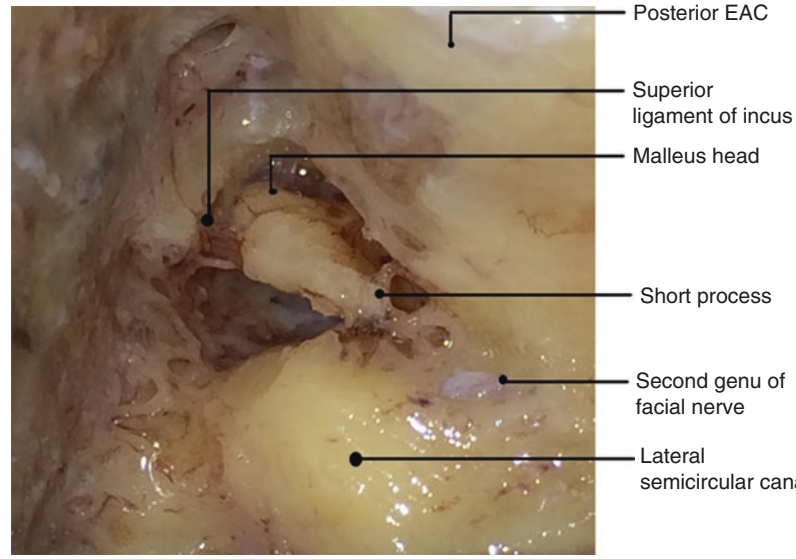


Fig. 16.14 Identification of the incus; note that the bone at the horizontal or lateral semicircular canal, the relationship of the canal, and the short process of the incus with the second genu of the facial nerve are noteworthy

sive mastoid pneumatization, neighbouring structures like the dura of the middle and posterior cranial fossae, the sigmoid sinus, and the facial nerve may lack a bony hull, making them prone to injury [68]. The dissection is continued medially reaching Körner's septum, a thick plate of bone that represents the persistence of the petrosquamous suture line, which divides the mastoid process into a superficial squamous portion and a deep petrous portion [70, 71]. This structure is removed to reach the mastoid antrum, the largest air cell in the mastoid cavity, connected to the posterior epitympanum via the *aditus ad antrum* (Fig. 16.13) [61].

Once identified, sculpt the EAC and tegmen toward the root of the zygoma to fully visualize the rest of the tegmen and the short process of the incus inside the *fossa incudis*. The horizontal semicircular canal (one of the most critical landmarks), characterized by its compact and ivory-coloured bone coat, should be identified at this point (Fig. 16.14) [72].

In case the incus is not visible, drilling is done anteriorly and inferior to the tegmen dura; this region has the widest distance between the ossicles and the *tegmen tympani*. The surgeon should remain superficial to the horizontal semicircular canal to avoid damage to adjacent structures. Figure 16.15 shows an intact canal wall mastoidectomy.

16.10.2 Canal Wall Down Mastoidectomy

Canal wall down mastoidectomies are indicated when the disease is extensive enough to cause damage to the posterior wall of the EAC or when there is a suboptimal visualization of the cavity and no certainty of complete eradication of the cholesteatoma. This procedure, also known as radical mastoidectomy, requires a complete mastoidectomy plus removal of the posterior superior osseous canal wall, exteriorizing the mastoid into the ear canal to form a single cavity [61]. In most cases, it is necessary to remove the ossicles affected by cholesteatoma, taking extreme care when manipulating the stapedius footplate. It is essential to drill superficial to the facial nerve and superficial to the semicircular canal; the objective is to create smooth transitions between the floor of the EAC and the mastoid cavity (single cavity). If the Eustachian tube is modified or the tympanic membrane or the mucosa of the middle ear or the ossicular chain is preserved, the procedure is referred to as a modified radical mastoidectomy.

16.10.3 Posterior Tympanotomy

A posterior tympanotomy is indicated in cholesteatoma eradication procedures (intact canal wall mastoidectomy), cochlear implantation, and middle-ear hearing device implantation [73]. It grants access to the middle ear and enables the surgeon to operate in the hypotympanum, the sinus tympani, and the region of the round window without lifting the tympanic membrane. This technique generates an opening between the facial nerve and the posterior wall of the EAC, in a region called the facial recess, which is a triangular area limited by the incudal buttress (superior), the vertical segment of the facial nerve (posterior), and the chorda tympani (anterior) (Fig. 16.16) [74].

The facial nerve is carefully skeletonized at the mastoid genu to avoid exposure of the nerve sheath; the nerve and blood vessels can be seen through bone [58]. After identifying the chorda-facial angle, the chorda tympani are followed superiorly into the middle-ear space, thereby creating the opening of the facial recess (Fig. 16.17).

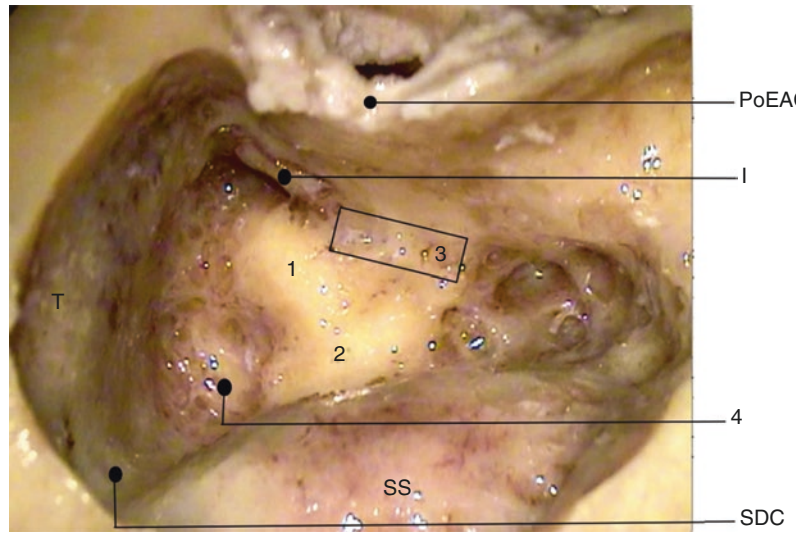


Fig. 16.15 Canal wall up mastoidectomy, tegmen (*T*), sinodural angle (*SDA*), sigmoid sinus (*SS*), incus (*I*), posterior wall of external auditory canal (*PoEAC*), horizontal semicircular canal (*1*), posterior semicircular canal (*2*), fallopian canal (*3*), superior semicircular canal (*4*)

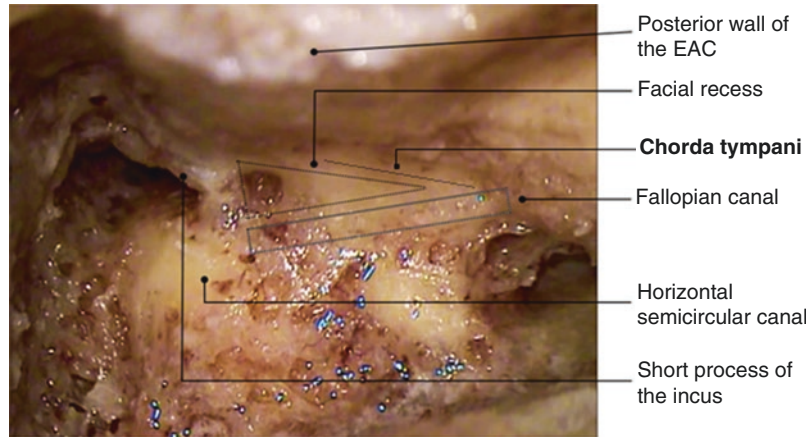


Fig. 16.16 Posterior tympanotomy: Anatomical landmarks, right ear, facial recess area outlined by a triangle: borders are the incus buttress, upper mastoid segment of the facial nerve, and chorda tympani

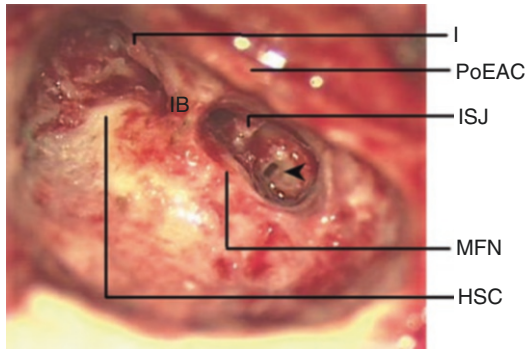


Fig. 16.17 Opened facial recess, incus (*T*), incus buttress (*IB*), posterior wall of the external auditory canal (*PoEAC*), incudo-stapedial joint (*IST*), horizontal semicircular canal (*HSC*), mastoid facial nerve (*MFN*), round window (*black arrowhead*)

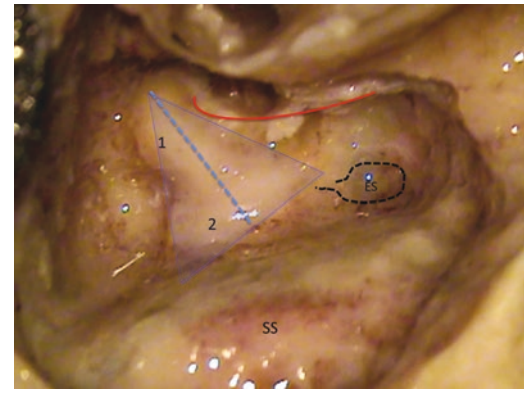


Fig. 16.18 Endolymphatic sac anatomy, surgical landmarks of endolymphatic sac, sigmoid sinus (*SS*), horizontal semicircular canal (*1*), posterior semicircular canal (*2*), distribution of facial nerve (*red line*), Donaldson's line (*blue line*), triangle outlining the hard angle (*blue triangle*), approximate location of endolymphatic sac (*ES*)

16.11 Endolymphatic Sac Decompression

Endolymphatic sac decompression is performed in patients with Menière's disease that do not respond to medical treatment. The surgery starts with a simple mastoidectomy and identification of the posterior and horizontal semicircular canals, using Donaldson's imaginary line as a reference. This line can be drawn along the horizontal semicircular canal, intersecting perpendicularly the posterior semicircular canal. The endolymphatic sac is posterior and inferior to this intersection and can be identified as a white and dense thickening of the dura (Fig. 16.18). After properly identifying the sac, it is opened and drained. A valve from the endolymphatic space to either the mastoid or the subarachnoid space can be inserted (shunt procedure).

16.12 Subtotal Petrosectomy

Indications of subtotal petrosectomy are chronic otitis media with or without cholesteatoma, meningoencephalic herniation, cerebrospinal fluid leak, and temporal bone tumours, amongst others. The most frequent indication is still infections of the temporal bone with necrosis, as it is a useful technique to debride as much bone as possible with preservation of facial function and cochlear reserve.

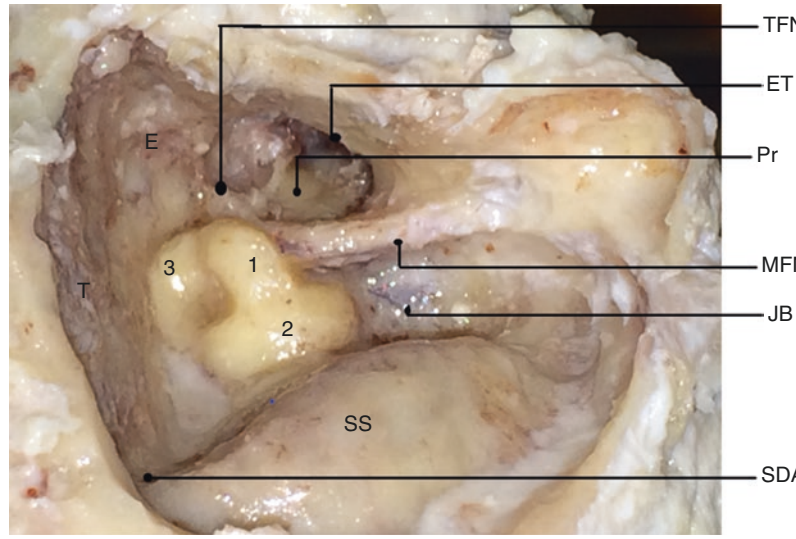


Fig. 16.19 Canal wall down mastoidectomy, right mastoidectomy with skeletonization of facial nerve and semicircular canals. Tegmen (*T*), sinodural angle (*SDA*), sigmoid sinus (*SS*), epitympanum (*E*), Eustachian tube (*ET*), promontorium (*Pr*), tympanic facial nerve (*TFN*), mastoid facial nerve (*MFN*), area of the jugular bulb (*JB*), horizontal semicircular canal (*1*), posterior semicircular canal (*2*), superior semicircular canal (*3*)

A wide retroauricular incision or a question mark incision is made in the skin, to expose the temporal muscle and mastoid process. The temporalis muscle is elevated anteriorly off the skull, and the muscle will be used later for the reconstruction. A mastoidectomy is performed; the semicircular canals, sigmoid sinus, posterior fossa dura, middle fossa dura, and vertical portion of the facial nerve are skeletonized; and the ossicles are removed with exception of the footplate of the stapes (Fig. 16.19). The sigmoid sinus is followed medially to the facial nerve to the jugular bulb performing a fallopian bridge technique. An elevator is used to remove the bone pieces from the sigmoid sinus and middle and posterior fossa. Classically, the concept of subtotal petrosectomy included removal of all cell tracts of the temporal bone, including antral, infralabyrinthine, pericarotid, retrosigmoid, retrofacial, retrolabyrinthine, supralabyrinthine, and supratubal cells. Currently, it is considered that the amount of temporal cells drilled is determined by the extent of the disease and is possibly more limited when the indication of surgery is cochlear implantation [75].

When the petrosectomy is finished, the ET is obliterated with muscle or bone wax, and the temporalis muscle is divided into its anterior third to rotate a muscular flap underneath the temporal lobe and over the mastoid cavity defects. An alternative is to obliterate the cavity with abdominal bone. Finally, the temporal bone flap is repositioned, and the EAC is closed by everting meatal skin and suturing it.

16.13 Translabyrinthine Approaches

Through this approach, it is possible to reach the internal auditory canal (IAC), the posterior cranial fossa, and the cerebellopontine angle, without disturbing the integrity of the external auditory canal and tympanic cavity. This approach is suitable for the resection of CPA tumours without serviceable audition, endolymphatic sac tumours, management of vestibular disorders, and trigeminal neuralgia. A great advantage of this approach is that there is less retraction of the cerebellar mass in comparison with others, decreasing the risk of dysmetria and thrombosis of the sigmoid sinus.

A simple mastoidectomy with skeletonization of the sigmoid sinus and tegmen and exposure of the mastoid antrum and lateral semicircular canal is performed. When the bone over the sigmoid sinus and the posterior fossa is thin enough, a Freer elevator is used to retract the sigmoid sinus posteriorly. It is possible to leave a small island of bone above the sinus to protect it from the retractor, commonly known as Bill's island. The mastoid emissary vein is transected and coagulated

with bipolar cautery. If the sigmoid sinus is vulnerated, bleeding can be stopped with gentle pressure and by applying a haemostatic agent. The superior aspect of the jugular bulb must be skeletonized because it marks the inferior portion of the dissection. The posterior limit of dissection is the sigmoid sinus, while the superior limit is the superior petrosal sinus. Malleable retractors are placed between the posterior and middle fossa dura, then the drilling begins until the superior petrosal sinus, and the vertical segment of the facial nerve is identified. With the posterior fossa retraction, a tether can be seen indicating the position of the endolymphatic duct; it can be transected with an 11 blade scalpel, and then the retractor is advanced till the porus acusticus is identified.

The labyrinthectomy is performed using a diamond burr to extend the vestibule's opening posteriorly toward the ampulla of the posterior semicircular canal (the ampullated ends of the superior and horizontal semicircular canals open into the anterior vestibule, which is medial to the horizontal segment of the facial nerve) (Fig. 16.20).

The medial wall of the vestibule contains the spherical recess and the elliptical recess; the former contains the saccule and the latter the utricle (Fig. 16.21). The vestibule marks the location of the fundus of the IAC; therefore, the surgeon must continue drilling the temporal bone parallel to the posterior fossa dura to find the porus acusticus that lies deeper than the fundus. When the porus acusticus is identified, superior and inferior troughs must be drilled and traced to the vestibule; it is important to keep the dura intact especially in the superior trough because the facial nerve could be displaced, especially when the indication of the procedure is a CPA tumour.

When thinning the bone near the fundus, the surgeon must drill in a more lateral position, compared to the medial position taken when working with the porus acusticus. When the bone is thinned, it should be carefully removed starting along the inferior dura of the IAC, then along the transverse crest, and at last along the superior portion of the IAC (Fig. 16.22). The transverse crest divides the fundus of the IAC in an upper

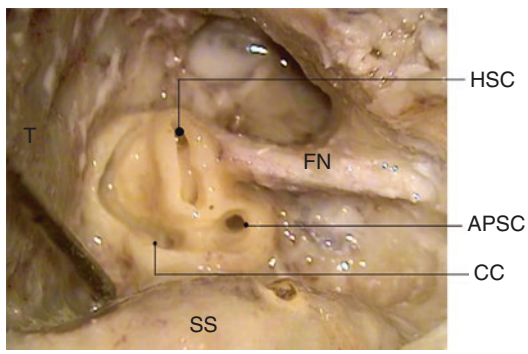


Fig. 16.20 Drilling of semicircular canals, right mastoid, tegmen (*T*), sigmoid sinus (*SS*), mastoid facial nerve (*FN*), horizontal semicircular canal (*HSC*), common crus (*CC*), ampulla of posterior semicircular canal (*APSC*)

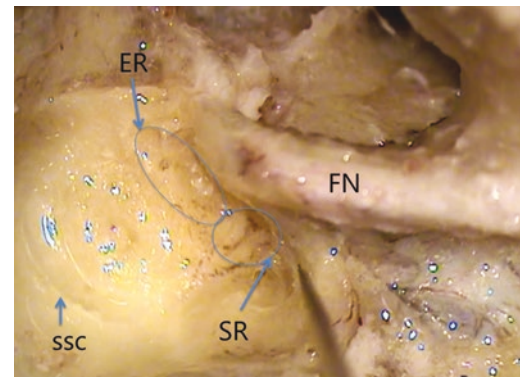


Fig. 16.21 Vestibule, right vestibule, elliptical recess (*ER*), spherical recess (*SR*), mastoid facial nerve (*NF*), superior semicircular canal (*SSC*)

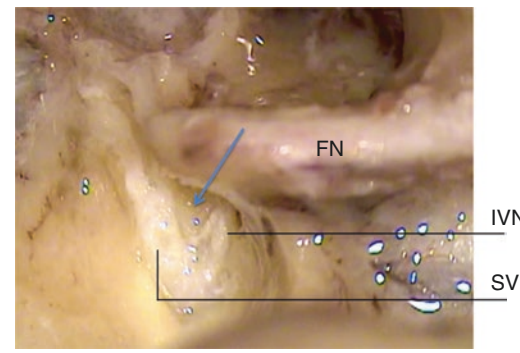


Fig. 16.22 Transverse crest, right mastoid after drilling of semicircular canals, mastoid facial nerve (*FN*), transverse crest (*blue arrow*), inferior vestibular nerve (*IVN*), superior vestibular nerve (*SVN*). Note that vestibular nerves are located posteriorly and hence are more superficially encountered than the facial and cochlear nerves in the translabyrinthine approach

part, containing the facial nerve and the superior vestibular nerve, and a lower part containing the inferior vestibular nerve and the cochlear nerve.

The dura is opened after removing the bone completely. Once the dura is opened, stimulation of the posterior portion of the tumour is done to locate the facial nerve. Then, a window in the surface of the tumour is performed to start debulking the tumour afterwards, and the capsule is removed in pieces. Subsequently, the dura of the IAC is opened to remove this part of the tumour, the superior and inferior vestibular nerves must be transected at the fundus, and resection of the tumour is completed. Open petrous apex cells must be plugged with bone wax, the aditus ad antrum is closed with fascia or dural substitute, and then the cavity is obliterated with abdominal fat.

16.14 Transcochlear Approach

It is an anteromedial extension of the translabyrinthine approach in which the cochlea is drilled out and the external ear canal is closed in a blind sac. This approach is indicated for cases where hearing preservation will not be attempted; it allows a wider exposure to the posterior fossa, ventral brainstem, and central skull base.

After exposing the dura over the IAC, the incus is removed, the facial nerve is exposed from the geniculate ganglion to the stylomastoid foramen, the greater superficial petrosal nerve (GSPN) is transected, and the facial nerve is transposed posteriorly so that the facial canal, petrous apex, and cochlea are drilled away until the edge of the clivus is reached exposing the inferior petrosal sinus and the petrous carotid. Since the facial nerve is transposed for greater exposure, a House-Brackmann grade III–IV facial palsy can be expected.

The transotic approach is similar to the transcochlear approach, with the difference that the facial nerve is kept in its bony canal and the EAC is closed in a blind sac.

16.15 Presigmoid-Retrolabyrinthine Approach

This approach can combine supra- and infratentorial craniotomy and a range of mastoid and labyrinthine resections. This approach provides access to the sigmoid sinus, presigmoid posterior fossa dura, and middle fossa dura. It can be useful to perform a vestibular neurectomy, microvascular decompression surgery, and resection of small CPA tumours that do not involve the internal third of the IAC.

With the presigmoid-retrolabyrinthine approach, the surgeon performs a "minimal mastoidectomy" that exposes the presigmoid dura, which is opened to gain access to the cerebellopontine angle (CPA). A Bill's island can be used to reject the sigmoid sinus posteriorly and have a wider exposure (Fig. 16.23). A more extensive degree of exposure is achieved by skeletonizing the semicircular canals and the vertical portion of the facial nerve.

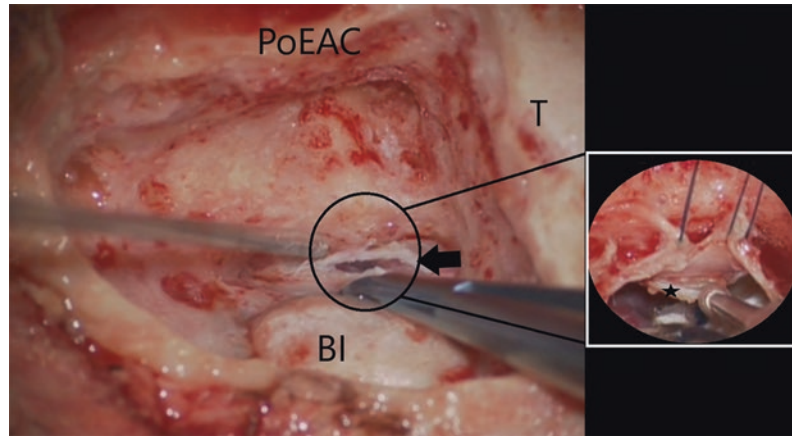


Fig. 16.23 Presigmoid-retrolabyrinthine approach, left mastoid, posterior external auditory canal (*PoEAC*), tegmen (*T*), Bill's island (*BI*), opened presigmoid dura (*black arrow*), close up to posterior semicircular canal after opening the dura (*black star*)

In a partial labyrinthectomy, usually the superior and posterior semicircular canals are drilled away with preservation of the lateral canal. The surgeon must keep in mind that hearing loss is likely to happen with this approach. Removing the posterior canal gives access to the posterior fossa and the superior canal to the middle fossa and petrous apex. This approach is mostly used to treat acute infections with intracranial complications such as sigmoid sinus thrombosis, epidural abscess, and subdural abscess.

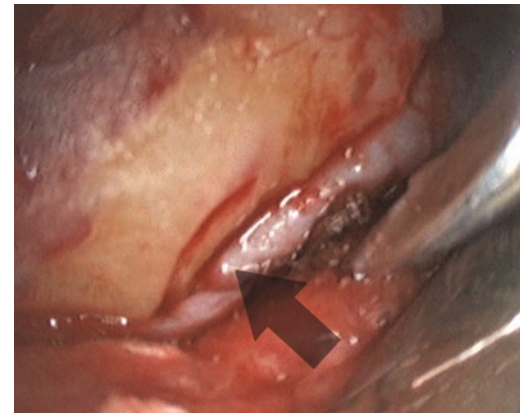


Fig. 16.24 Dehiscent superior semicircular canal viewed from a middle fossa approach, facial nerve (*black arrow*)

16.16 Middle Cranial Fossa

Through this approach, it is possible to access the petrous apex, the IAC, and the posterior cranial fossa by retracting the temporal lobe. It can be useful to perform a vestibular neurectomy, resection of a lesion involving the geniculate and pregeniculate area of the facial nerve, management of a meningoencephalocele and SCCD, and resection of small schwannomas with acceptable audition preservation (lesions should not extend more than 1 cm medially into the CPA) and lesions involving the trigeminal nerve. However, temporal lobe retraction can cause injuries such as contusions, strokes, cerebral oedema, seizures, CSF leak, and injury to the carotid artery.

The skin, temporoparietal fascia, temporalis muscle, and periosteum are elevated by a single flap to expose the temporal squama to drill a sufficient temporal craniotomy (5 cm × 5 cm) centred over the zygomatic root; an endoscope can be used to reduce the size of the craniotomy. The middle fossa dura is separated from the bone flap using an elevator; this bone must be preserved for repairing the craniotomy at the end of the surgery. A Freer or a Joseph elevator can be used to elevate the dura off the temporal floor in a posterior-to-anterior manner, and the first landmark is the middle meningeal artery. If a larger exposure is needed, the middle meningeal artery can be divided to allow exposure to the posterior fossa. The next relevant anatomic structure is the arcuate eminence, which is absent in cases of SCCD (Fig. 16.24).

The structure encountered next is the GSPN. While elevating the dura, the GSPN should be carefully identified to decrease the risk

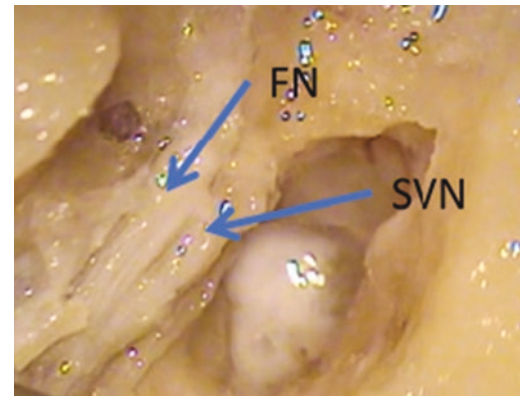


Fig. 16.25 Facial and superior vestibular nerves in the IAC, facial nerve (*FN*), superior vestibular nerve (*SVN*)

of injuring the geniculate ganglion, which is dehiscent in up to 15% of the patients [76]. Relevant anatomical references to locate the IAC are the GSPN and the arcuate eminence. The axis of the IAC intersects a 120° angle formed by the axis of the SSC and the GSPN. Others locate the IAC only relying on the arcuate eminence, as the axis of the IAC runs along an imaginary line located at a 60° angle from the axis of the SSC. The IAC and posterior fossa are reached by drilling away the petrous bone preferably medially, near the porus acusticus, though a diverse amount of techniques have been described [77]. The facial nerve and the superior vestibular nerve are the first nerves encountered when the IAC is opened; they are divided by Bill's bar (Fig. 16.25).

16.17 Infratemporal Fossa (IFT) Approach: Type A

This approach provides great exposure of the sigmoid sinus, jugular bulb, internal jugular vein, and internal carotid artery. It is used for tumours such as jugular paraganglioma, jugular foramen neuroma, jugular foramen meningioma, large parotid tumours of the deep lobe with infratemporal fossa extension, large schwannomas of the facial nerves, and lesions of the lower cranial nerves (IX, X, XI, and XII) [78].

The open approach to the ITF was classically described by Fisch, which is delineated into three types [79]. The type A approach provides exposure of the infralabyrinthine temporal bone and jugular foramen and is useful for the management of glomus jugulare tumours, neuromas, and meningiomas. The type B approach exposes the petrous apex and midclivus, including the horizontal ICA, which facilitates resection of chordomas and extensive cholesterol granulomas. The type C approach extends the exposure to the parasellar region, cavernous sinus, and foramen rotundum and permits resection of nasopharyngeal carcinomas and angiofibromas. All three variations lie within the domain of the neurootologist and involve mastoidectomy, facial nerve dissection and transposition, and obliteration of the Eustachian tube, middle ear, and external auditory canal with a resulting permanent conductive hearing loss.

To perform a type A IFT approach, a C-shaped retroauricular incision is performed and extended into the neck to the anterior border of the sternocleidomastoid (SCM) muscle. Dissection proceeds to expose the mastoid process, the parotid gland, and the digastric muscle. The SCM muscle is released from the mastoid process and retracted posteriorly, and then the mastoid tip is drilled away. The digastric muscle is divided and retracted anteriorly to drill the bone inferior to the sigmoid sinus. The lower cranial nerves, the carotid artery, and the jugular vein are identified and wrapped loosely with rubber slings.

A mastoidectomy with preservation of the ear canal wall is performed. The bone from the inferior portion of the sigmoid sinus is removed, and the facial nerve is followed down to the stylomastoid foramen to identify its main trunk. A facial recess approach extended inferiorly is performed, the chorda tympani nerve must be divided, and the ossicular chain should be kept intact. By skeletonizing the facial nerve, it is possible to gain access to the jugular bulb medially and open the hypotympanum to remove the tumour that has grown from the jugular foramen (Fig. 16.26). If a canal wall down mastoidectomy is performed, then the ear canal is transected and closed in a blind sac; the posterior wall is drilled away; the incudo-stapedial joint is separated; the tympanic membrane, malleus, and incus are removed; the Eustachian tube is plugged with muscle; and the anterior wall of the canal must be drilled to remove the epithelial remnants. Alternatively, to the fallopian bridge technique, rerouting of the facial nerve could be performed to gain more access to the jugular bulb.

The venous flow to the sigmoid sinus is blocked by packing Surgicel between the bone of the sinus. The internal jugular vein is divided and ligated in the neck (Fig. 16.27), then the sinus wall is opened to expose the jugular bulb, and

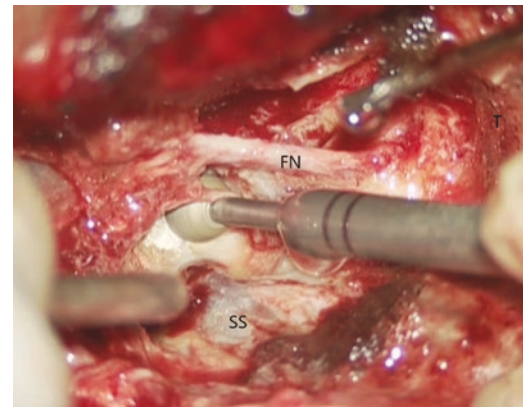


Fig. 16.26 Infratemporal fossa approach, type A, left mastoid. The facial nerve (*FN*) and the sigmoid sinus (*SS*) have been skeletonized, the surgeon is using a diamond burr to expose the jugular bulb

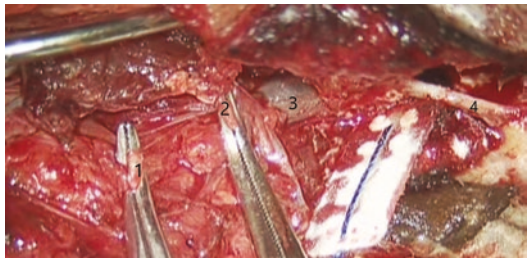


Fig. 16.27 Ligature of internal jugular vein: the internal jugular vein has been ligated in the left neck, and regurgitation of the jugular bulb is evident. Cottonoids have been placed to collapse the sigmoid sinus. Distal end of the internal jugular end (*1*), cephalic end of the internal jugular vein (*2*), jugular bulb (3), facial nerve (*4*)

bleeding is controlled with Surgicel, cottonoid pledges, and pressure to occlude the inferior petrosal sinus collaterals and the condylar emissary vein. Complete removal of the tumour within the bulb is achieved.

16.18 Surgery for Squamous Cell Carcinoma: Temporal Bone Resection

Depending on the extension of the disease, the SCC of the temporal bone should be treated with a lateral temporal bone resection (LTBR), a subtotal temporal bone resection (STBR), or a total temporal bone resection (TTBR). The LTBR is performed en bloc through an extended facial recess approach, which implies the sacrifice of the chorda tympani. The EAC, tympanic membrane, malleus, and incus are removed, while the facial nerve and inner ear are entirely preserved. Depending on tumour spread, additional procedures should be considered, such as parotidectomy, partial mandibulectomy, and a modified neck dissection.

When malignancy has extended to the middle ear, dissection is extended depending on tumour spread. Starting with an en bloc LTBR, drilling continues medially into the otic capsule and petrous temporal bone till negative margins are attained. If the facial nerve is involved, it should be resected until a negative frozen section is achieved. The internal carotid artery is preserved. Nevertheless, the internal jugular vein and the internal carotid artery should be identified and controlled in the neck.

Finally, in TTBR, resection extends to involve the petrous apex, the sigmoid sinus, and possibly the petrous segment of the internal carotid artery. Internal carotid artery resection should only be considered in patients who have shown tolerance to ischaemia after performing a balloon test occlusion. Since TTBR has significantly higher morbidity compared with STBR, and a survival benefit has yet to be proven, selection of therapy should be carefully discussed with the patient and a multidisciplinary team. Reconstruction with mastoid cavity obliteration is especially relevant in patients undergoing post-operative radiotherapy.

16.19 Endoscopic Ear Surgery

Endoscopic ear surgery (EES) is a novel technique used to address middle ear and tympanic membrane pathology, including cholesteatoma, tympanic membrane perforation, and ossicular pathology. Some surgeons have used it to treat lesions like paragangliomas, meningiomas, and schwannomas [80]. This technique allows for an excellent surgical exposition using a transcanal approach, avoiding mastoidectomies and external incisions altogether. Due to its recent introduction, the surgeon must acquire a unique perspective on the anatomy of the middle ear. The most important structures and landmarks for this endoscopic procedure are given below.

16.19.1 Protympanum

The protympanic space lies anteriorly to the mesotympanum and inferiorly to the anterior epitympanic space. The anterior limit consists of the cochleariform process, the tensor fold, and

the tensor tympani, while the posterior limit is marked by the promontory. The tympanic portion of the Eustachian tube is found in the protympanum and measures 11–12 mm in diameter. Above and medially to the Eustachian tube opening runs the internal carotid artery, which can be dehiscent in some cases. Knowledge of this area is important because cholesteatoma can hide in this region [81].

16.19.2 Epitympanum

The epitympanic space is a pneumatized portion of the temporal bone superior to the mesotympanum. It is divided from the latter by the epitympanic diaphragm. This last structure consists of three malleal ligamental folds (anterior, lateral, and posterior), the posterior incudal ligamental fold, and two membranous folds (the tensor fold and the lateral incudo-malleal fold) together with the malleus and incus [82]. From this anatomical point of view (using an angled 30° endoscope), it is possible to classify the epitympanum into two different compartments: a larger posterior compartment and a smaller anterior compartment. The posterior epitympanic space contains the incudo-malleolar joint, a crucial landmark during the transcanal endoscopic approach [81, 83].

16.19.3 Retrotympanum

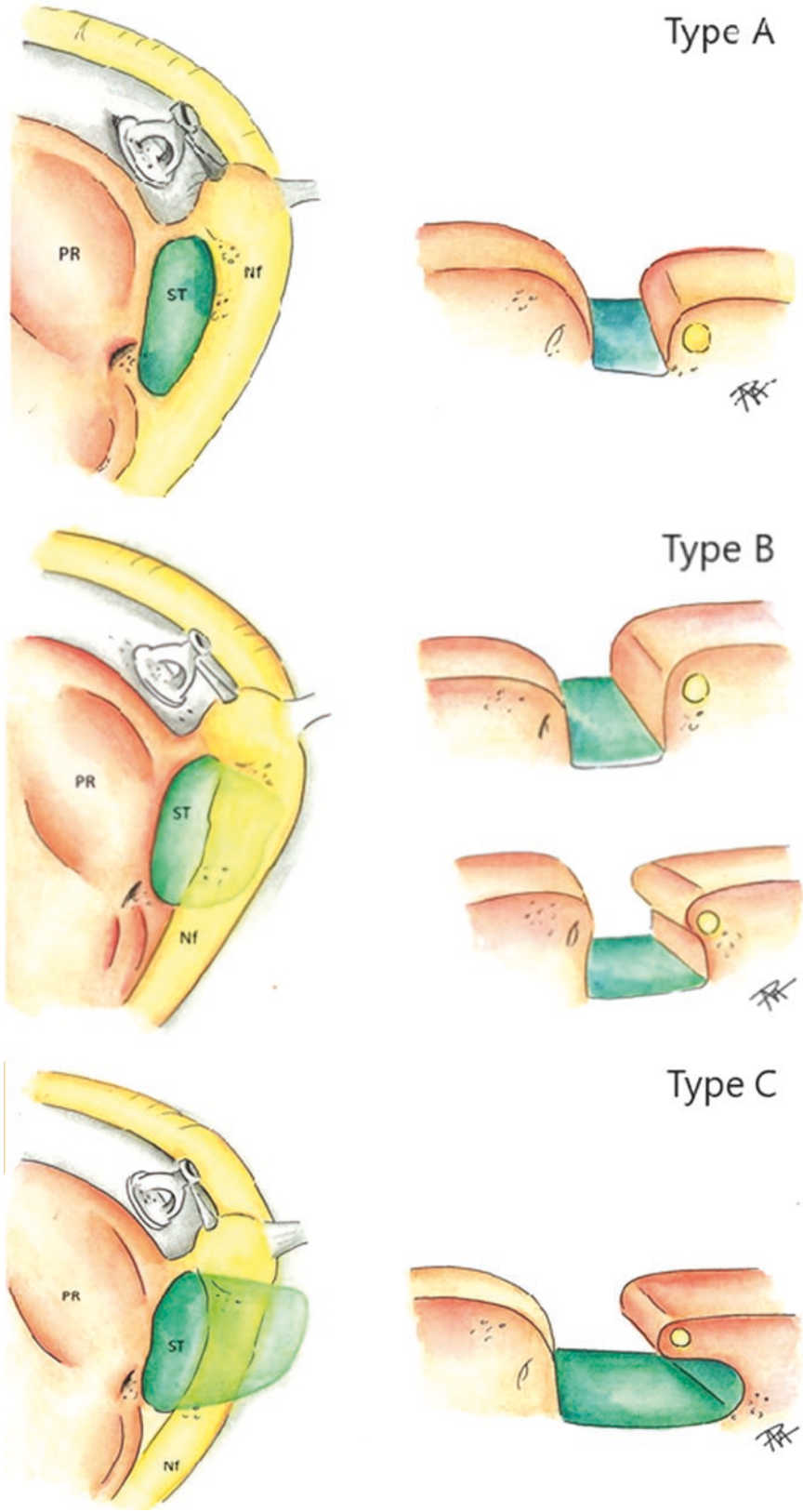
The spaces surrounding the mesotympanum are complex because of the dimensions and details of the air cells [82]. Nevertheless, Marchioni et al. described four regions in the retrotympanum: the posterior sinus, *sinus tympani*, *sinus subtympanicus*, and facial recess [81]. These spaces are limited by the pyramidal eminence and three bony ridges, the ponticulum, subiculum, and funiculum. The ponticulum connects the pyramidal process to the promontory. The subiculum extends from the posterior lip of the round window to the styloid eminence. The funiculum marks the end of the retrotympanum and connects the anterior lip of the round window to the hypotympanic air cells. The posterior recess is a small space between the pyramidal eminence and the posterior crus of the stapes. The *sinus tympani* are located between the ponticulum and subiculum. The *sinus subtympanicus* is located below the sinus tympani, between the subiculum and funiculum [84]. Finally, the facial recess is located lateral to the pyramidal eminence.

The depth of the *sinus tympani* is significant because the deeper it is, the more difficult it is to achieve complete removal of cholesteatoma. Abreu et al. have classified the depth of the sinus tympani into three types as follows: small (type A), deep (type B), and deep with a posterior extension (type C) (Fig. 16.28) [84].

16.19.4 Hypotympanum

It is the inferior compartment of the tympanic cavity, located anteriorly and inferiorly to the retrotympanum. Its inferior limit is formed by the floor of the tympanic cavity and jugular bulb; its upper limit is a virtual plane passing through the styloid eminence and continuing to the inferior margin of the EAC. The hypotympanum floor has an irregular surface due to osseous trabeculae and small irregular tympanic cells [82].

Fig. 16.28 Classification of sinus tympani, promontory (*PR*), sinus tympani (*ST*), facial nerve (*Nf*). (Adapted from Abreu et al. (2015) Endoscopic Ear Surgery: Principles Indications and Techniques [84])


Type A
PR
ST
Nf
Type B
PR
ST
Nf
Type C
PR
ST
Nf

16.20 Complications, Challenges, and Prognosis

Possible complications of transmastoid procedures include recurrent infection, wound dehiscence, dysgeusia, hearing loss, vestibular deficit, and facial palsy. Canal wall down procedures are more morbid. CFS leak and intracranial infection like meningitis could occur in those procedures when the internal ear is manipulated, or the dura is opened. Failure of the device is a relatively common complication of cochlear implant surgery. Due to the extent of the IFT approach, possible complications are hearing loss, facial palsy, lower CN (IX, X, XI, XII) palsy, internal carotid artery bleeding, and venous infarction with intracranial hypertension.

Due to the deleterious impact on the patient's quality of life, facial palsy is a highly feared complication by the surgeon and the patient. Fortunately, its incidence is low due to higher anatomical knowledge and neuromonitoring. Preservation of hearing, vestibular function, and patients' ability to perform aquatic activities after temporal bone surgery remain a challenge in different situations, mainly after surgery of chronic otitis media with cholesteatoma. Currently, not only the complete removal of disease but also the preservation of functional status and quality of life are of outermost relevance. Technology advances in imaging techniques and use of endoscopes have achieved excellent control of disease with appropriate functional preservation in selected patients. Indications for cochlear implantation surgery continue to expand, making the surgeon face special situations such as cochlear ossification, implantation after cholesteatoma, and other challenges. The prognosis of temporal bone diseases and tumours mainly depends on the aetiology, location, and size of the lesion.

16.21 Conclusion

The temporal bone is a complex anatomical area, affected by a large number of benign and sinister diseases. Strong anatomical knowledge is essential to reduce complications; technological advances and working with a multidisciplinary team are also appropriate measures for the management of patients with temporal bone diseases. Novice surgeons should properly identify surgical landmarks and eventually perform increasingly complex approaches.

References

1. Cosetti M, Roland JTJ. Cochlear implantation in the very young child: issues unique to the under-1 population. Trends Amplif. 2010;14(1):46–57. https://doi.org/10.1177/1084713810370039.
2. Castle JT. Cholesteatoma pearls: practical points and update. Head Neck Pathol. 2018;12(3):419–29. https://doi.org/10.1007/s12105-018-0915-5.
3. Gulati M, Gupta S, Prakash A, Garg A, Dixit R. HRCT imaging of acquired cholesteatoma: a pictorial review. Insights Imaging. 2019;10(1):92. https://doi.org/10.1186/s13244-019-0782-y.
4. Kalra VK. Aural polyp is not always due to chronic otitis media (COM): preoperative computed tomographic scan is good pointer for sinister lesions. Indian J Otolaryngol Head Neck Surg. 2018;70(4):505–9. https://doi.org/10.1007/s12070-018-1482-5.
5. Karamert R, Eravcı FC, Cebeci S, Düzlü M, Zorlu ME, Gülhan N, et al. Canal wall down versus canal wall up surgeries in the treatment of middle ear cholesteatoma. Turk J Med Sci. 2019;49(5):1426–32. https://doi.org/10.3906/sag-1904-109.
6. Bakaj T, Zbrozkova LB, Salzman R, Tedla M, Starek I. Recidivous cholesteatoma: DWI MR after canal wall up and canal wall down mastoidectomy. Bratislavske lekarske listy. 2016;117(9):515–20. https://doi.org/10.4149/BLL_2016.
7. Hu Y, Teh BM, Hurtado G, Yao X, Huang J, Shen Y. Can endoscopic ear surgery replace microscopic surgery in the treatment of acquired cholesteatoma? A contemporary review. Int J Pediatr Otorhinolaryngol. 2020;131:109872. https://doi.org/10.1016/j.ijporl.2020.109872.
8. Orhan KS, Çelik M, Polat B, Aydemir L, Aydoseli A, Sencer A, et al. Endoscope-assisted surgery for petrous bone cholesteatoma with hearing preservation. J Int Adv Otol. 2019;15(3):391–5. https://doi.org/10.5152/iao.2019.7212.
9. Gordin E, Lee TS, Ducic Y, Arnaoutakis D. Facial nerve trauma: evaluation and considerations in management. Craniomaxillofac Trauma Reconstr. 2015;8(1):1–13. https://doi.org/10.1055/s-0034-1372522.
10. Diaz RC, Cervenka B, Brodie HA. Treatment of temporal bone fractures. J Neurol Surg B Skull Base. 2016;77(5):419–29. https://doi.org/10.1055/s-0036-1584197.
11. Vajpayee D, Mallick A, Mishra AK. Post temporal bone fracture facial paralysis: strategies in

decision making and analysis of efficacy of surgical treatment. Indian J Otolaryngol Head Neck Surg. 2018;70(4):566–71. https://doi.org/10.1007/s12070-018-1371-y.
12. Xie S, Wu X, Zhang Y, Xu Z, Yang T, Sun H. The timing of surgical treatment of traumatic facial paralysis: a systematic review. Acta Otolaryngol. 2016;136(12):1197–200. https://doi.org/10.1080/00016489.2016.1201862.
13. Abbaszadeh-Kasbi A, Kouhi A, Ashtiani MTK, Anari MR, Yazdi AK, Emami H. Conservative versus surgical therapy in managing patients with facial nerve palsy due to the temporal bone fracture. Craniomaxillofac Trauma Reconstr. 2019;12(1):20–6. https://doi.org/10.1055/s-0038-1625966.
14. Johnson F, Semaan MT, Megerian CA. Temporal bone fracture: evaluation and management in the modern era. Otolaryngol Clin N Am. 2008;41(3):597–618. https://doi.org/10.1016/j.otc.2008.01.006.
15. Szyfter W, Karlik M, Sekula A, Harris S, Gawęcki W. Current indications for cochlear implantation in adults and children. Otolaryngologia polska (Pol Otolaryngol). 2019;73(3):1–5. https://doi.org/10.5604/01.3001.0013.1000.
16. Santa Maria PL, Gluth MB, Yuan Y, Atlas MD, Blevins NH. Hearing preservation surgery for cochlear implantation: a meta-analysis. Otol Neurotol. 2014;35(10):e256–69. https://doi.org/10.1097/MAO.0000000000000561.
17. Lesser JCC, de Brito Neto RV, de Souza Queiroz Martins G, Bento RF. Cochlear implantation through the middle fossa approach: a review of related temporal bone studies and reported cases. Int Arch Otorhinolaryngol. 2017;21(1):102–8. https://doi.org/10.1055/s-0036-1582266.
18. Lopez-Escamez JA, Carey J, Chung W-H, Goebel JA, Magnusson M, Mandalà M, et al. Diagnostic criteria for Menière's disease. J Vestib Res. 2015;25(1):1–7. https://doi.org/10.3233/VES-150549.
19. Perkins E, Rooth M, Dillon M, Brown K. Simultaneous labyrinthectomy and cochlear implantation in unilateral Meniere's disease. Laryngoscope Investig Otolaryngol. 2018;3(3):225–30. https://doi.org/10.1002/lio2.163.
20. Kitahara T. Evidence of surgical treatments for intractable Meniere's disease. Auris Nasus Larynx. 2018;45(3):393–8. https://doi.org/10.1016/j.anl.2017.07.016.
21. Thomsen J, Bonding P, Becker B, Stage J, Tos M. The non-specific effect of endolymphatic sac surgery in treatment of Meniere's disease: a prospective, randomized controlled study comparing "classic" endolymphatic sac surgery with the insertion of a ventilating tube in the tympanic membrane. Acta Otolaryngol. 1998;118(6):769–73.
22. Bretlau P, Thomsen J, Tos M, Johnsen NJ. Placebo effect in surgery for Menière's disease: nine-year follow-up. Am J Otol. 1989;10(4):259–61.
23. Pillsbury HC 3rd, Arenberg IK, Ferraro J, Ackley RS. Endolymphatic sac surgery. The Danish sham surgery study: an alternative analysis. Otolaryngol Clin N Am. 1983;16(1):123–7.
24. Sood AJ, Lambert PR, Nguyen SA, Meyer TA. Endolymphatic sac surgery for Ménière's disease: a systematic review and meta-analysis. Otol Neurotol. 2014;35(6):1033–45. https://doi.org/10.1097/MAO.0000000000000324.
25. Welling DB, Nagaraja HN. Endolymphatic mastoid shunt: a reevaluation of efficacy. Otolaryngol Head Neck Surg. 2000;122(3):340–5. https://doi.org/10.1067/mhn.2000.101575.
26. Devantier L, Schmidt JH, Djurhuus BD, Hougaard DD, Händel MN, Liviu-Adelin Guldfred F, et al. Current state of evidence for endolymphatic sac surgery in Menière's disease: a systematic review. Acta Otolaryngol. 2019;139(11):953–8. https://doi.org/10.1080/00016489.2019.1657240.
27. de Lourdes Flores García M, de la Llata Segura C, Lesser JCC, Pianese CP. Endolymphatic sac surgery for Ménière's disease—current opinion and literature review. Int Arch Otorhinolaryngol. 2017;21(2):179–83. https://doi.org/10.1055/s-0037-1599276.
28. Minor LB, Solomon D, Zinreich JS, Zee DS. Sound- and/or pressure-induced vertigo due to bone dehiscence of the superior semicircular canal. Arch Otolaryngol Head Neck Surg. 1998;124(3):249–58. https://doi.org/10.1001/archotol.124.3.249.
29. Welgampola MS, Myrie OA, Minor LB, Carey JP. Vestibular-evoked myogenic potential thresholds normalize on plugging superior canal dehiscence. Neurology. 2008;70(6):464–72. https://doi.org/10.1212/01.wnl.0000299084.76250.4a.
30. Zan E, Limb CJ, Koehler JF, Yousem DM. Middle ear adenoma: a challenging diagnosis. AJNR Am J Neuroradiol. 2009;30(8):1602–3. https://doi.org/10.3174/ajnr.A1534.
31. Touska P, Juliano AF-Y. Temporal bone tumors: an imaging update. Neuroimaging Clin N Am. 2019;29(1):145–72. https://doi.org/10.1016/j.nic.2018.09.007.
32. Saliba I, Evrard AS. Middle ear glandular neoplasms: adenoma, carcinoma or adenoma with neuroendocrine differentiation: a case series. Cases J. 2009;2(3):1–8. https://doi.org/10.1186/1757-1626-2-6508.
33. Leong K, Haber MM, Divi V, Sataloff RT. Neuroendocrine adenoma of the middle ear (NAME). Ear Nose Throat J. 2009;88(4):874–9.
34. Mundada P, Purohit BS, Kumar TS, Tan TY. Imaging of facial nerve schwannomas: diagnostic pearls and potential pitfalls. Diagn Intervent Radiol (Ankara, Turkey). 2016;22(1):40–6.
35. Lin EP, Crane BT. The management and imaging of vestibular schwannomas. Am J Neuroradiol. 2017;38(11):2034–43.
36. Düzlü M, Tutar H, Karamert R, Karaloğlu F, Şahin MM, Göcek M, et al. Temporal bone paragangliomas: 15 years' experience. Braz J Otorhinolaryngol. 2016;84:58–65. https://doi.org/10.1016/j.bjorl.2016.11.001.
37. Jackson CG, Glasscock ME 3rd, Harris PF. Glomus tumors. Diagnosis, classification, and management of

large lesions. Arch Otolaryngol (Chicago, Ill: 1960). 1982;108(7):401–10. https://doi.org/10.1001/archotol.1982.00790550005002.
38. Oldring D, Fisch U. Glomus tumors of the temporal region: surgical therapy. Am J Otol. 1979;1(1):7–18.
39. Moe KS, Li D, Linder TE, Schmid S, Fisch U. An update on the surgical treatment of temporal bone paraganglioma. Skull Base Surg. 1999;9(3):185–94. https://doi.org/10.1055/s-2008-1058145.
40. Jansen TTG, Kaanders JHAM, Beute GN, Timmers HJLM, Marres HAM, Kunst HPM. Surgery, radiotherapy or a combined modality for jugulotympanic paraganglioma of Fisch class C and D. Clin Otolaryngol. 2018;43(6):1566–72. https://doi.org/10.1111/coa.13216.
41. Al-Mefty O, Teixeira A. Complex tumors of the glomus jugulare: criteria, treatment, and outcome. J Neurosurg. 2002;97(6):1356–66. https://doi.org/10.3171/jns.2002.97.6.1356.
42. de Brito R, Cisneros Lesser JC, Lopes PT, Bento RF. Preservation of the facial and lower cranial nerves in glomus jugulare tumor surgery: modifying our surgical technique for improved outcomes. Eur Arch Otorhinolaryngol. 2018;275(8):1963–9. https://doi.org/10.1007/s00405-018-5026-0.
43. Lionello M, Stritoni P, Facciolo MC, Staffieri A, Martini A, Mazzoni A, et al. Temporal bone carcinoma. Current diagnostic, therapeutic, and prognostic concepts. J Surg Oncol. 2014;110(4):383–92. https://doi.org/10.1002/jso.23660.
44. Gidley PW, DeMonte F. Temporal bone malignancies. Neurosurg Clin N Am. 2013;24(1):97–110. https://doi.org/10.1016/j.nec.2012.08.009.
45. Franciszek B. Benign and malignant tumours of the ear and temporal bone. In: Rozylo-Kalinowska I, Orhan K, editors. Imaging of the temporomandibular joint. Cham: Springer; 2019. https://doi.org/10.1007/978-3-319-99468-0_18.
46. da Silva AP, Breda E, Monteiro E. Malignant tumors of the temporal bone—our experience. Braz J Otorhinolaryngol. 2016;82(4):479–83. https://doi.org/10.1016/j.bjorl.2015.09.010.
47. Beyea JA, Moberly AC. Squamous cell carcinoma of the temporal bone. Otolaryngol Clin N Am. 2015;48(2):281–92. https://doi.org/10.1016/j.otc.2014.12.003.
48. Arriaga M, Curtin H, Takahashi H, Hirsch BE, Kamerer DB. Staging proposal for external auditory meatus carcinoma based on preoperative clinical examination and computed tomography findings. Ann Otol Rhinol Laryngol. 1990;99(9 Pt 1):714–21. https://doi.org/10.1177/000348949009900909.
49. Moody SA, Hirsch BE, Myers EN. Squamous cell carcinoma of the external auditory canal: an evaluation of a staging system. Am J Otol. 2000;21(4):582–8.
50. Nabuurs CH, Kievit W, Labbé N, Leemans CR, Smit CFGM, van den Brekel MWM, et al. Evaluation of the modified Pittsburgh classification for predicting the disease-free survival outcome of squamous cell carcinoma of the external auditory canal. Head Neck. 2020;42(12):3609–22. https://doi.org/10.1002/hed.26424.
51. Morita S, Mizumachi T, Nakamaru Y, Sakashita T, Kano S, Hoshino K, et al. Comparison of the University of Pittsburgh staging system and the eighth edition of the American Joint Committee on Cancer TNM classification for the prognostic evaluation of external auditory canal cancer. Int J Clin Oncol. 2018;23(6):1029–37. https://doi.org/10.1007/s10147-018-1314-3.
52. Halmagyi GM, Chen L, MacDougall HG, Weber KP, McGarvie LA, Curthoys IS. The video head impulse test. Front Neurol. 2017;8:258. https://doi.org/10.3389/fneur.2017.00258.
53. Venhovens J, Meulstee J, Verhagen WIM. Vestibular evoked myogenic potentials (VEMPs) in central neurological disorders. Clin Neurophysiol. 2016;127(1):40–9. https://doi.org/10.1016/j.clinph.2014.12.021.
54. Ng JH, Zhang EZ, Soon SR, Tan VYJ, Tan TY, Mok PKH, et al. Pre-operative high resolution computed tomography scans for cholesteatoma: has anything changed? Am J Otolaryngol. 2014;35(4):508–13. https://doi.org/10.1016/j.amjoto.2014.02.015.
55. Marquet JFE. Surgery and pathology of the middle ear. In: Marquet JFE, editor. Proceedings of the international conference on 'The Postoperative Evaluation in Middle Ear Surgery' held in Antwerp on June 14–16, 1984. 1st ed. Dordrecht: Springer; 1985. p. 424.
56. Shekhar C, Bhavana K. Aesthetics in ear surgery: a comparative study of different post auricular incisions and their cosmetic relevance. Indian J Otolaryngol Head Neck Surg. 2007;59(2):187–90. https://doi.org/10.1007/s12070-007-0057-7.
57. Barrett G, Koecher S, Ronan N, Whinney D. Patient satisfaction with postaural incision site. Int J Otolaryngol. 2014;2014:851980. https://doi.org/10.1155/2014/851980.
58. Brackmann DE, Shelton C, Arriaga MA. Otologic surgery. 3rd ed. Philadelphia: Saunders/Elsevier; 2010.
59. Lempert J. Endaural, antauricular surgical approach to the temporal bone: principles involved in this new approach; summary report of 1,780 cases. Arch Otolaryngol. 1938;27(5):555–87. https://doi.org/10.1001/archotol.1938.00650030568004.
60. Pennings RJE, Cremers CWRJ. Postauricular approach atticotomy: a modified closed technique with reconstruction of the scutum with cymbal cartilage. Ann Otol Rhinol Laryngol. 2009;118(3):199–204. https://doi.org/10.1177/000348940911800307.
61. Isaacson B. Anatomy and surgical approach of the ear and temporal bone. Head Neck Pathol. 2018;12(3):321–7. https://doi.org/10.1007/s12105-018-0926-2.
62. Schwartze E. Ueber die künstliche Eröffnung des Warzenfortsatzes. Archiv für Ohrenheilkunde. 2005;7:157–62.
63. Bento RF, de Oliveira Fonseca AC. A brief history of mastoidectomy. Int Arch Otorhinolaryngol.

2013;17(2):168–78. https://doi.org/10.7162/S1809-97772013000200009.
64. Aslan A, Mutlu C, Celik O, Govsa F, Ozgur T, Egrilmez M. Surgical implications of anatomical landmarks on the lateral surface of the mastoid bone. Surg Radiol Anat. 2004;26(4):263–7. https://doi.org/10.1007/s00276-004-0235-1.
65. Yilmazer R, Baskadem Yilmazer A, Hoffer ME, Eshraghi AA, Telischi FF, Angeli SI. A new technique to find the facial nerve and recess by using the short process of the incus and the spine of Henle as landmarks: incus-spine angle. Acta Otolaryngol. 2018;138(11):1051–6. https://doi.org/10.1080/00016489.2018.1504168.
66. Comrie JD. Section of the history of medicine. Br Med J. 1927;2(3474):205–10. https://doi.org/10.1136/bmj.2.3474.205.
67. Goycoolea MV. Mastoid and tympanomastoid procedures in otitis media: classic mastoidectomy (simple, modified, and radical) and current adaptations; open-cavity, closed-cavity, and intact-bridge tympanomastoidectomy. Otolaryngol Clin N Am. 1999;32(3):513–23. https://doi.org/10.1016/S0030-6665(05)70149-3.
68. Luers JC, Hüttenbrink K-B. Surgical anatomy and pathology of the middle ear. J Anat. 2016;228(2):338–53. https://doi.org/10.1111/joa.12389.
69. Irugu DVK, Singh A, Kumar R. Morphometry of the digastric ridge and its significance for mastoid surgeries—a cadaveric study. Ear Nose Throat J. 2021;100(6):NP296–8. https://doi.org/10.1177/0145561319870491.
70. Toros SZ, Karaca CT, Habeşoğlu TE, Noşeri H, Ertugay CK, Naiboğlu B, et al. Is there a relation between mastoid aeration and Körner's septum? Eur Arch Otorhinolaryngol. 2010;267(10):1523–6. https://pubmed.ncbi.nlm.nih.gov/20480369/
71. Przewoźny TT, Kosiński A, Markiet K, Sierszeń W, Kuczkowski J, Kuryłowicz J, et al. Körner's septum (petrosquamosal lamina): the anatomical variant or clinical problem? Folia Morphol. 2020;79(2):205–10. https://doi.org/10.5603/FM.a2019.0079.
72. Williamson SL, Rini DA. In: Francis HW, Niparko JK, editors. Temporal bone dissection guide. 2011th-1st ed. Stuttgart: Georg Thieme Verlag; 2011. Available from: http://www.thieme-connect.de/products/ebooks/book/10.1055/b-002-74277.
73. Bittencourt AG, Burke PR, de Souza Jardim I, de Brito R, Tsuji RK, de Oliveira Fonseca AC, et al. Implantable and semi-implantable hearing AIDS: a review of history, indications, and surgery. Int Arch Otorhinolaryngol. 2014;18(3):303–10. https://doi.org/10.1055/s-0033-1363463.
74. Arnoldner C, Lin VYW, Chen JM. Cortical mastoidectomy. In: Manual of otologic surgery. Vienna: Springer; 2015. p. 5–13. https://doi.org/10.1007/978-3-7091-1490-2_2.
75. Prasad SC, Roustan V, Piras G, Caruso A, Lauda L, Sanna M. Subtotal petrosectomy: surgical technique, indications, outcomes, and comprehensive review of literature. Laryngoscope. 2017;127(12):2833–42. https://doi.org/10.1002/lary.26533.
76. Cruz OLM, Tedeschi H, Rhoton AL Jr. In: Flint PW, Haughey BH, Robbins KT, Thomas JR, Niparko JK, Lund VJ, et al., editors. Cummings otolaryngology—head and neck surgery. Philadelphia: Elsevier Health Sciences; 2014. p. 2662–70. https://doi.org/10.1016/B978-1-4557-4696-5.00173-1.
77. Angeli S. Middle fossa approach: indications, technique, and results. Otolaryngol Clin N Am. 2012;45(2):417–38. https://doi.org/10.1016/j.otc.2011.12.010.
78. Schick B, Dlugaiczyk J. Surgery of the ear and the lateral skull base: pitfalls and complications. GMS Curr Top Otorhinolaryngol Head Neck Surg. 2013;12:Doc05. https://doi.org/10.3205/cto000097.
79. Fisch U. Infratemporal fossa approach to tumours of the temporal bone and base of the skull. J Laryngol Otol. 1978;92(11):949–67.
80. Marchioni D, Rubini A, Nogueira JF, Isaacson B, Presutti L. Transcanal endoscopic approach to lesions of the suprageniculate ganglion fossa. Auris Nasus Larynx. 2018;45(1):57–65. https://doi.org/10.1016/j.anl.2017.03.006.
81. Marchioni D, Molteni G, Presutti L. Endoscopic anatomy of the middle ear. Indian J Otolaryngol Head Neck Surg. 2011;63(2):101–13. https://doi.org/10.1007/s12070-011-0159-0.
82. Isaacson G. Endoscopic anatomy of the pediatric middle ear. Otolaryngol Head Neck Surg. 2014;150(1):6–15. https://doi.org/10.1177/0194599813509589.
83. Marchioni D, Alicandri-Ciufelli M, Mattioli F, Nogeira JF, Tarabichi M, Villari D, et al. From external to internal auditory canal: surgical anatomy by an exclusive endoscopic approach. Eur Arch Otorhinolaryngol. 2013;270(4):1267–75. https://doi.org/10.1007/s00405-012-2137-x.
84. Abreu JPS, Alicandri-Ciufelli M, Artioli FL, Ayache S, Badr-El-Dine MMK, Cunsolo EM, et al. Endoscopic ear surgery. In: Presutti L, Marchioni D, editors. Principles, indications, and techniques. Stuttgart: Georg Thieme Verlag; 2015. Available from: http://www.thieme-connect.de/products/ebooks/book/10.1055/b-003-121086.

17 Paediatric Head and Neck Pathology and Surgery

Jeyasakthy Saniasiaya and Norhafiza Mat Lazim

17.1 Introduction

Paediatric patients represent a special group of patients who require different management and therapeutic approaches. Numerous critical factors should be meticulously considered prior to determining the perfect management options in paediatric patients. Importantly, the human anatomy is significantly different between the paediatric and the adult head and neck anatomy. This alters surgical landmarks that are used during any surgical procedures. In particular, the airway diseases pose life-threatening sequelae if it is poorly managed. Other diseases and tumours of the paediatric patients also show some significant variations. This can be in the aetiopathogenesis, clinical presentation, required treatment and complications. This should be meticulously addressed by in-charge clinicians to ensure that the best treatment outcomes can be achieved (Table 17.1).

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17.2 Common Tumours in Paediatric Patients

17.2.1 Vascular Lesions

Vascular lesions which comprise vascular malformation and vascular neoplasms are commonly encountered in children, especially in the newborns [1]. Despite benign in nature and being mostly self-limiting, these vascular lesions can be a part of syndromes, systemic disorders or secondary complications. Vascular anomalies have been classified according to the International Society for the Study of Vascular Anomalies (ISSVA), 2018, into the following [2] (Table 17.2).

17.2.2 Infantile Haemangioma

17.2.2.1 Introduction

Infantile haemangioma (IH) is considered to be the most prevalent vascular neoplasm, which is characterised by the presence of aberrant proliferation of endothelial cells as well as blood vessels. Other examples of vascular tumour include congenital haemangioma, pyogenic granuloma, tufted angioma and haemangioendothelioma.

17.2.2.2 Epidemiology

Approximately 5% of infants are affected by IH [1, 3], of which IH amongst newborns has been

N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_17

Table 17.1 Variation amid paediatric and adult head and neck anatomy

Head and neck anatomy	Adult	Paediatric
1. Neck and larynx	Wide neck with low larynx	Short neck with high larynx
2. Airway	Narrowest airway is in the glottic region	Narrowest airway is subglottic
3. Bony	Mature and well-ossified bones	Underdeveloped face and mandible
4. Skin and surface area	Variation in skin thickness and surface area	Thin skin with greater body surface area
5. Subcutaneous tissues	Variation in subcutaneous tissue and skin thickness	Variable subcutaneous fat
6. Neural and vascular structures	Variations in neural and vascular structure	Superficial neural and vascular structures
7. Morphology of neurovascular structures	Neurovascular structures are well formed	Different colour, consistency and location of the nerves

Table 17.2 Classification of vascular tumours

Categories of vascular lesions	Examples
1. Vascular tumours	• Benign, borderline and malignant tumours
2. Simple malformation	• Capillary malformations, lymphatic malformations, venous malformations and arteriovenous fistula
3. Combined vascular malformations	• Two or more vascular malformations found in a single lesion
4. Anomalies of major vessels	• Congenital aneurysm
5. Vascular malformations associated with other syndromes	• Sturge-Weber syndrome, Klippel-Trenaunay syndrome, Proteus syndrome, CLOVES syndrome, macrocephaly-capillary malformation

reported to be almost 1–3% [4]. Female preponderance has been noted over the years [5] with female-to-male ratio of 1.4:1 to 3:1 [6, 7]. It is noteworthy that gender disparity is higher amongst paediatric patients with PHACE syndrome (posterior fossa malformation, haemangiomas, cerebrovascular arterial anomalies, cardiovascular anomalies and eye anomalies), whereby the female predominance is reported with a proportion of 9 females to 1 male [8].

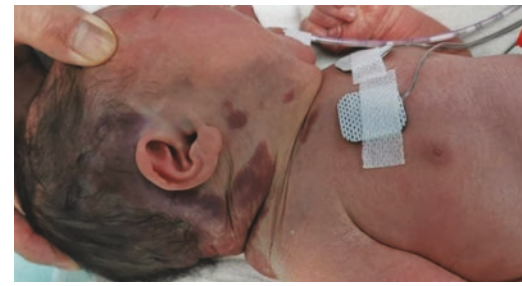

Fig. 17.1 Vascular malformation in a newborn with visible multiple patches of hyperpigmentation areas on the neck and upper chest

IH has been found to be higher among preterm infants, especially infants weighing under 1 kg [6]. Interestingly, it has been reported that for every 55 g reduction of birth weight, the chance of IH occurring amongst infants is 25% [9]. Besides low birth weight, other notable risk factors are advanced maternal age, multiple gestation, placenta previa, pre-eclampsia [6], retroplacental haematoma, infarction and dilated vascular communications [10] (Fig. 17.1).

17.2.2.3 Pathogenesis

Despite the countless theories on pathogenesis of IH, cellular origin from either intrinsic progenitor cells or angioblasts of placental origin has been the most plausible theory [11]. Apart from that, intrinsic causes include angiogenic and vasculogenic components, whereas external causes include hypoxia and growth disturbance [5].

17.2.2.4 Phases

IH has two evolutionary phases:

(a) Proliferative phase
(b) Involution phase

Proliferative phase begins upon early infancy, which later progresses spontaneously into involution phase by 1 year of age [12]. It is noteworthy that intermediate phase occurs between proliferation and involution phase, which is normally dur-

ing the near-late infancy period termed as 'plateau' phase. The 'plateau' or intermediate phase represents a phase when there is equality between individual proliferating cells and cells going through involution and apoptosis [13]. The involution phase takes several years.

17.2.2.4.1 Proliferative Phase

Early findings include blanching or localised erythema. As IH enlarges, it obtains elevated, rubbery nature. Following the rapid growth period, ulceration and pain followed by scarring may occur. IH traditionally occurs prior to 4 weeks of age [13]. Yet, IH grows between 1 and 2 months of age [13].

17.2.2.4.2 Involution Phase

Involution phase occurs when the infant's age is from 6 to 12 months. Although this phase may prolong longer, IH regresses before 4 years of life [14, 15]. IH lesions usually flatten from the centre towards periphery. It is noteworthy that as IH lesions resolve, myriad dermatological conditions such as telangiectasia, fibrofatty tissue, excessive skin, anetoderma as well as scar remain [16].

IH may appear as superficial or deep lesion. Superficial lesion appears and involutes earlier as compared to the deeper lesion.

17.2.2.5 Diagnosis

IH can be diagnosed clinically ensuing classical appearance of 'raspberry-red' cutaneous lesions, which increases in size along with the presence of sharp margin. Biopsy or imaging is not required for cutaneous haemangiomas.

Yet, presence of IH especially in difficult locations, requirement to identify the extension of lesion, inconclusive diagnosis and associated complications warrant imaging. Ultrasonography is the best initial imaging modality as it is cost effective and rapid and the child does not require sedation. Ultrasonography of IH usually demonstrates well-delineated high-flow parenchymal tumour with shunting occasionally. Ultrasonography also enables IH to be differentiated from other deeper dermal or subcutaneous lesions. Yet, its limitation is its inability to evaluate deeper regions of the haemangioma. High vessel density of more than 5 vessels/cm^2 along with increased peak arterial Doppler shift of more than 2 kHz has exhibited high sensitivity and specificity of IH [17]. It is noteworthy that ultrasonography can screen patients with multifocal IH to identify visceral involvement, notably liver involvement [18].

Magnetic resonance imaging (MRI) is favoured as it outlines the entire lesion as well as the surrounding anatomy with no risk of radiation. Proliferating type of IH appears as well-demarcated mass with high flow as well as intermediate in T1 and high intensity in T2 images [19]. Flow voids may be noted in T2 images. Gadolinium administration will enhance the lesion with intense and uniform enhancement, whilst non-enhancing areas denote the presence of thrombosis or necrosis. On contrast, increased signal is noted in T1 images upon the involution phase as fat replaces the lesion and contrast administration demonstrates low enhancement.

As for computed tomography (CT), it is usually avoided due to risk of exposing the child to ionising radiation. CT findings are similar to MRI as upon the proliferating phase of IH, CT depicts well-delineated, enhancing lesion, whilst the involution phase of IH demonstrates less avid lesion.

17.2.2.6 Treatment

Although IH is benign and has the potential to involute spontaneously, it is prudent to identify the necessity for intervention. Close observation may be carried out in cases of uncomplicated and stable IH. Yet, regular follow-ups are vital as many uncomplicated IH can transform into complicated stage during the early infancy period [20].

Indication of intervention includes [5]:

1. Life-threatening complications such as airway obstruction or liver IH causing high-output congestive heart failure
2. Functional impairment such as failure to thrive, pain and bleeding
3. To evaluate structural anomalies causing IH
4. To reduce potential long-term or permanent disfigurement

Factors which influence the choice of appropriate therapeutic modality include age, underlying comorbidity, growth phase, location of IH, size of lesion, extension of lesion, being single or multiple, severity, urgency of intervention, potential of psycho-emotional effects, side effects of treatment as well as complications, parental preference and finally physicians' experience.

17.2.2.7 Medical Therapy

Medical therapy includes both topical and systemic therapy. Topical agents are preferred for smaller, localised and superficial lesions or in patients with systemic drug contraindications. Systemic route of therapy is prescribed in larger, extensive, multiple lesions or in patients with risk of functional deficit or disfigurement.

Popular medical therapies which are widely used today include steroids, alpha-interferon [21, 22] and propranolol [23]. Besides that, novel antiangiogenic agents are being used including rapamycin [24], a macrolide with immunosuppressant and antiangiogenic potential, and bevacizumab [25].

17.2.2.8 Laser Therapy

Pulsed dye laser is a popular mode of therapeutic choice for superficial IH. Yet, its limitation is owing to its limited depth of penetration (<2 mm). Laser therapy can still be utilised in cases whereby IH lesions are refractory to other treatments, in ulcerative IH or as a part of multimodal therapy.

17.2.2.9 Surgical Therapy

Surgical indications include [26–28]:

1. Medical therapy contraindications
2. Failure of medical therapy
3. Focal, diffuse lesion in a favourable anatomical area
4. IH lesion which definitely needs surgical resection

As a presurgical procedure, embolisation can be carried out to facilitate removal as well as to reduce preoperative bleeding. Embolisation is preformed prior to surgery as a precaution to reduce intraoperative blood loss as well as to facilitate removal of the mass (Fig. 17.2).

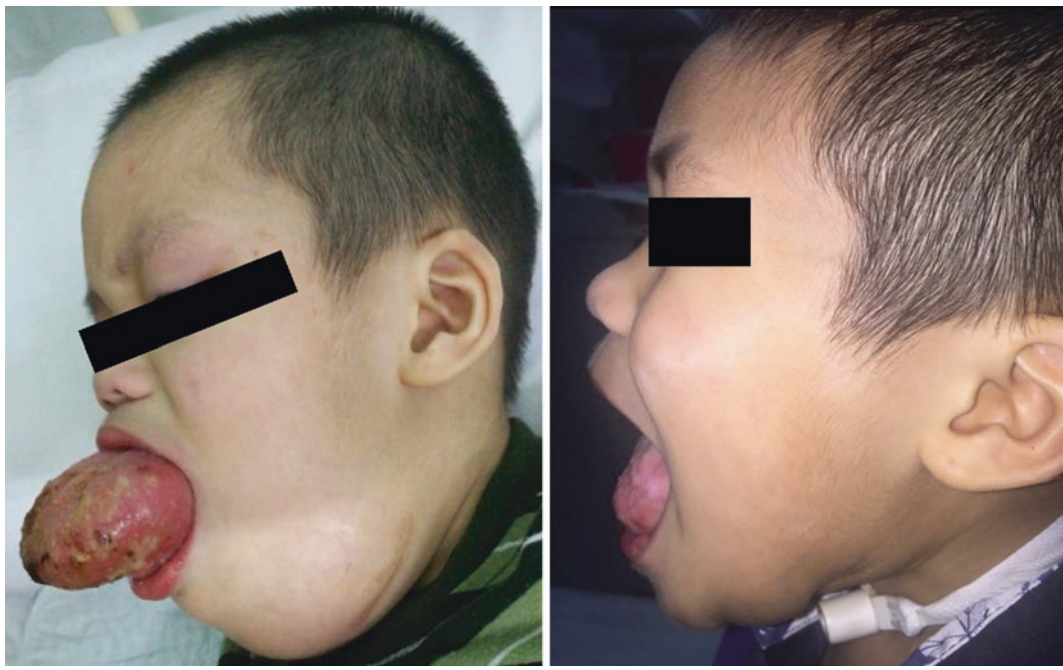

Fig. 17.2 Tongue haemangioma pre-resection and post-resection

17.2.3 Dermoid Cyst

17.2.3.1 Introduction

Dermoid cyst (DC) is an uncommon cyst of childhood, which may be either congenital or acquired. DC is a benign cyst, which originates from ectoderm and mesoderm. It comprises stratified squamous epithelium along dermal structures including hair follicles, smooth muscle, sweat glands, sebaceous glands as well as adipose tissue [29]. Nearly 7% of all DC is found in the head and neck region whereby it is predominately found in the periorbital, nasal, submental and suprasternal region [30]. DC has no gender predilection. Most DCs are evident before the child is 5 years old.

17.2.3.2 Classification of Aetiology

DC has been classified into three pathologic types [31]:

(a) Acquired implantation
(b) Congenital teratoma
(c) Congenital inclusion

The acquired type of DC occurs after traumatically implanted portion of skin occurs in deeper parts of the skin. Congenital teratoma forms from all three types of embryonic germinal epithelium as well as elements of epithelium, bone and cartilage. Congenital inclusion DC occurs resulting from embryonic fusion and contains dermal as well as epidermal structures. DC is the congenital inclusion type.

17.2.3.3 Clinical Presentation

Head and neck DC appears as a traditionally asymptomatic cystic mass. The cystic mass may enlarge or become inflamed following infection or trauma. Additionally, it is worth noting that if the DC is ruptured, the contact between the cyst content and surrounding structures may cause inflammatory reaction. This most commonly occurs amongst the periorbital DC.

DC is traditionally associated with a midline or near-midline lesion with the exception of orbital DC. Yet, lateral dermoid cyst has been postulated to be midline cyst, which has migrated laterally [32].

17.2.3.4 Imaging

Ultrasound is able to differentiate with other masses such as lymph node and schwannoma. MRI aids to diagnose especially intracranial DC and for surgical planning as well as to assess treatment outcome. In case of a nasal DC with intracranial connection, three-dimensional reconstructed MRI is helpful. MRI reveals hyperintensity in T2-weighted images [33].

17.2.3.5 Treatment

17.2.3.5.1 Surgery

Excision of DC is the gold standard treatment [34]. The range of age can vary from 1 month to 63 years [35]. It is prudent when performing the excision as the content of DC may lead to foreign-body reactions and other complications when it comes in contact with the surrounding structures. The recent advent of instrumentations has aided surgical outcome as well as morbidity, especially minimally invasive endoscopic procedures.

17.3 Thyroglossal Duct Cyst

17.3.1 Introduction

Thyroglossal duct cyst (TGDC) is the most prevalent congenital mass amongst paediatric patients. Traditionally, TGDC is encountered as a cystic lesion in the midline of the neck of children. The TGDS forms from the epithelial remnant of thyroglossal tract [36]. TGDC is present in 7% of population [37, 38]. No gender predominance has been reported. It is worth noting that, albeit a benign lesion, the risk of malignant transformation has been reported to be approximately 1% [39].

17.3.2 Embryology

Thyroglossal duct is an epithelial connection between thyroid gland and foramen caecum. The thyroglossal duct tract commonly disappears at the end of eighth week. However, the tract can remain as a fibrous cord or epithelial tube [40]. TGDC does not have an exter-

nal orifice since the course of the tract does not extend to the neck surface [41].

17.3.3 Clinical Presentation

Patients traditionally present with cystic mass in the midline, which moves upon tongue protrusion. Mass is oftentimes asymptomatic although slight tenderness may occasionally be present. Mass may enlarge suddenly following trauma or following upper respiratory tract infection. Apart from that, dysphagia, odynophagia, choking or foreign-body sensation may ensue TGDC. Albeit uncommon, TGDC causing sudden death from respiratory distress has been reported [42].

Most of the TGDCs are located close to the hyoid bone. Infrahyoid is the commonest location (85%), followed by suprahyoid (8%) and base of tongue (1–2%), and finally in 5% of children, the cyst was detected low in neck [43, 44]. It is noteworthy that TGDCs are located 2 cm from midline although it can be found at a more lateral position. TGDC is also associated with ectopic thyroid. Ectopic thyroid tissue can be found within the walls of TGDS [45]. Interestingly, ectopic thyroid tissue was found in up to 65% of TGDC when examined histologically [46]. Parallel to that, nearly 1–2% of patients suspected with TGDC turned out to be having ectopic thyroid gland [47].

17.3.4 Diagnosis

17.3.4.1 Blood Investigation

Thyroid function test needs to be carried out in cases suspected of ectopic thyroid or clinically suspicious for hyperthyroid or hypothyroid.

17.3.4.2 Fine Needle Aspiration Cytology (FNAC)

FNAC enables TGDC to be determined histologically as well as to exclude other neck lesions.

17.3.4.3 Histology

TGDCs are lined by stratified squamous epithelium or pseudostratified ciliated columnar epithelium [36].

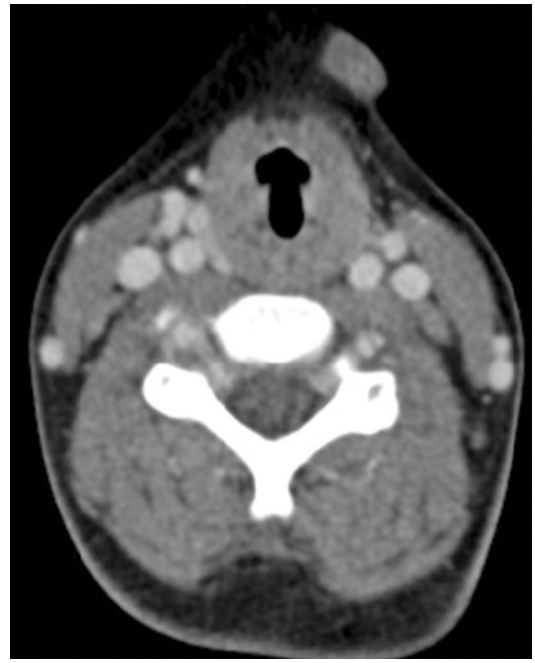

Fig. 17.3 CT neck revealing enhancing cystic lesion anterior to neck

17.3.4.4 Imaging

Ultrasonography is able to reveal the cystic nature of TGDC so as to look for any abnormality of thyroid gland. However, the relationship between the cyst and surrounding structures' notable hyoid bone is difficult to be established. Ultrasonography features include well-defined, thin-walled, hypoechoic or anechoic mass.

Contrasted CT is the ideal tool. CT imaging is able to delineate the cyst as well as to outline the relation between the cyst and surrounding structures. TGDC normally appears homogenous with thin enhancing rim, whilst extra enhancement indicates infection [48]. MRI demonstrates hyperintensity on T2-weighted images. It enables delineation between the cyst as well as structures in the vicinity (Fig. 17.3).

17.3.5 Treatment

17.3.5.1 Surgery

Surgery remains the gold standard treatment using Sistrunk method, which comprises cyst excision in addition to excision of the proximal part of the

tract and body of hyoid bone. Recurrence rate following Sistrunk procedure is 3% [49]. Simple excision of the cyst has demonstrated recurrence in more than 50% of cases. It is noteworthy that suture-guided transhyoid pharyngotomy, a modification of Sistrunk operation, has been postulated to enable better visibility of the normal structures as well as to provide the route of entry to tissue between hyoid bone and foramen caecum [50].

17.3.5.2 Sclerotherapy

Alternative approach especially in children who are not fit for surgery is percutaneous ethanol injection, although its effectiveness is still debatable.

17.4 Rhabdomyosarcoma

17.4.1 Introduction

Rhabdomyosarcoma is a malignant neoplasm which entails primitive mesenchymal tissue origin that expresses myogenic differentiation. Soft-tissue sarcoma is found in approximately 60% of the paediatric age group [51, 52] to be RMS, whilst the numbers are lower in adults with approximately 2–5% [53]. Following neuroblastoma and Wilms' tumour, RMS is the most prevalent extracranial solid neoplasm amongst paediatric patients [54, 55].

17.4.2 Epidemiology and Aetiology

RMS expresses dual-age distribution as the first peak presents in the first decade and the second during the teenage group [56]. Age distribution for RMS has been reported to be 1% for children under 1 year of age, 35% amongst children within 1–4 years of age, 25% in children within 5–9 years of age, 20% in children from 10 to 14 years of age and 13% amongst children above 15 years of age [57]. Only a slight male predilection has been reported [56, 58].

Interestingly, RMS is found to be higher in children of mothers with a history of breast tumour, though its pathogenesis has not been confirmed. Other notable risk factors include genetic factor ensuing RMS correlation with Recklinghausen disease [59], Li-Fraumeni syndrome [60], Costello syndrome, Noonan syndrome [61], Beckwith-Wiedemann [62] as well as mothers' history of narcotic abuse [63].

17.4.3 General Characteristics

Head and neck RMS accounts for approximately 35% [51, 52] and can be classified into three subtypes [64]:

(a) Parameningeal
(b) Orbital
(c) Non-orbital non-parameningeal

Parameningeal RMS includes tumours located in the nasal cavity, nasopharynx, paranasal sinus, middle ear and skull base and comprises 25% of RMS [65]. This group of tumours are oftentimes difficult to achieve complete resection. Upon early stage, patients remain asymptomatic and have subtle presentation such as haemo-purulent discharge or blockage of aural and sino-nasal cavity, or dysphagia [66] which oftentimes mimics chronic mucosal inflammation leading to delay in diagnosis.

Orbital RMS comprises 9% of RMS [65]. This group of RMS carries good prognosis ensuing its early presentation, which includes exophthalmos, strabismus and periorbital ecchymosis. Other subgroups of RMS are located within the soft tissue of the neck, salivary glands, oral cavity, laryngopharyngeal region as well as thyroid glands. Due to its rapid proliferating nature, vital structures in the vicinity as well as lymph node involvement have been reported. It is noteworthy that metastasis to distant organs is more likely in this group of tumours rather than lymph node involvement. Involvement of distant organs such as lungs, bones, bone marrow, central nervous system, liver and retroperitoneal region has been reported [67].

17.4.4 Histology

RMS comprises small round blue cell tumours that encompass small cells along large, round, hyperchromatic nucleus, which stains dark blue by haematoxylin and eosin.

Histologically, RMS can be further subdivided into [68, 69]:

(a) Embryonal
(b) Alveolar
(c) Pleomorphic or undifferentiated

Embryonal which comprises 60% of RMS is reported to be the most prevalent type within the head and neck [64] which carries best prognosis. Alveolar type of RMS, comprises 20% of RMS and is localized within the extremities, trunk, perineum and paranasal sinus, whereas the pleomorphic RMS is normally located in the extremities and oftentimes involves adults. Histological subtypes are prudent so as to decide the outcome of treatment. Other additional histochemical testing includes desmin, myoglobin, actin and vimentin (Fig. 17.4).

17.4.5 Diagnosis

RMS is diagnosed ensuing meticulous history taking, physical examination, imaging, histological, laboratory as well as occasionally molecular test.

Presentation of mass, especially when it is fixed and hard in consistency which has presented for longer than several weeks, requires through investigation as malignancy should be ruled out. Examination should include general inspection, palpation, cranial nerve examination, lymph node examination as well as nasoendoscopic, otoscopic as well as 70° rigid endoscopy. Additionally, general systemic examination including lung auscultation, abdomen, extremities and genitalia examination should be carried out to detect distant metastasis.

Imaging is an important diagnostic modality. MRI is favoured as it depicts tumour size, its precise location, extension, presence of metastasis to lymph node and distant involvement. Additionally, presence of residual mass following treatment or recurrence can be visualised via MRI. It is noteworthy that, however, MRI requires the child to be sedated without risk of radiation.

Other imaging modalities include computed tomography (CT), ultrasound and positron emission tomography (PET). CT enables evaluation of bone infiltration and skull base infiltration. It is noteworthy that PET scan is an excellent modality to diagnose residual tumours [70]. Yet, PET/CT has been recently deemed superior in detecting bone metastasis as well as lymph node metastasis [71, 72], which is crucial as 15% of patients were reported to have distant metastasis upon presentation (Fig. 17.5).

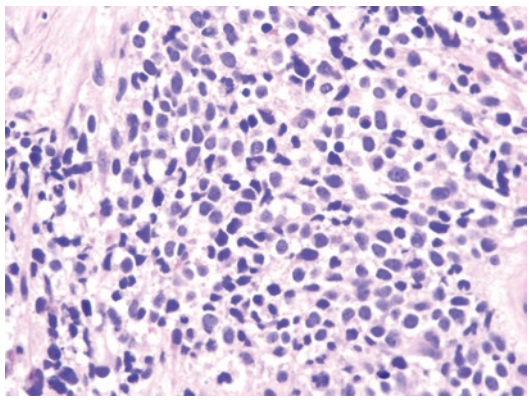

Fig. 17.4 HPE revealing small round blue cells in a child with temporal bone embryonal rhabdomyosarcoma

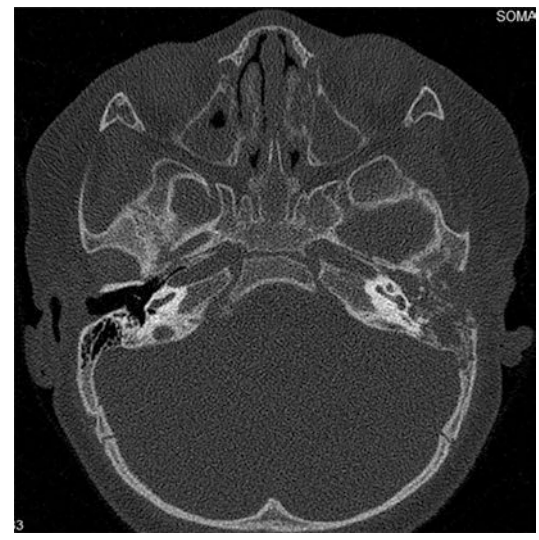

Fig. 17.5 RMS of left temporal bone in a 5-year-old revealing extensive erosion of the left mastoid cortex, ossicles and facial canal

Table 17.3 Disease staging dependant on tumour site, size and presence or absence of metastasis

Stage	Sites	T	Size	N	M
I	Orbit, head and neck (except parameningeal)	T1 or T2	a or b	N0 or N1 or Nx	M0
II	Parameningeal	T1 or T2	a	N0 or Nx	M0
III	Parameningeal	T1 or T2	a	N1	M0
			b	N0 or N1 or Nx	M0
IV	All	T1 or T2	a or b	N0 or N1	M1

17.4.5.1 Biopsy

Biopsy is required to obtain the definitive diagnosis. Sampling can be obtained via open or needle biopsy. Fine needle aspiration as well as tru-cut biopsy can be carried out for inaccessible regions under imaging guidance and can be a less invasive mode of obtaining diagnosis.

17.4.6 Staging

Staging is according to the size and presence of metastasis (Table 17.3). It is noteworthy that, upon presentation, most children present at stage III of disease. 3-Year failure-free survival rate is 86% for stage I, 80% for stage II, 68% for stage III and 25% for stage IV.

Tumour
- T1: confined to anatomic site of location
- T2: extension and/or fixation to the surrounding tissues

Size
- a: <5 cm in diameter
- b: >5 cm in diameter

Regional Nodes
- N0: regional nodes not clinically involved
- N1: regional nodes clinically involved by neoplasm
- Nx: clinical status of regional nodes unknown

Metastases
- M0: no distant metastases
- M1: metastases present

17.4.7 Treatment

Multidisciplinary team should be involved in managing RMS in children including paediatric oncology team, otorhinolaryngologists, reconstructive surgeons, neurosurgeons, nutritionists, psychologists, physiotherapists and counsellors. The treatment focuses to achieve local control and prevent metastasis whilst maintaining functional and cosmetic appearance. Myriad protocols have been developed, which have evolved throughout the years. Treatment mainly involves chemotherapy with or without surgery as well as radiotherapy.

17.4.7.1 Chemotherapy

Chemotherapy has been regarded as the main modality in treatment despite surgical resection following the presence of micrometastasis upon diagnosis. Utilisation of combined chemotherapeutic agents has revealed success by increasing the overall survival rate [65, 73]. Yet, combination of drugs as well as its dosage depends on risk group, histology type, surgical resection, age as well as general condition of patient [74].

Gold standard multi-agent chemotherapy has been vincristine, actinomycin D, cyclophosphamide (VAC) or ifosfamide (VAI). It is noteworthy that, in low-risk group, VAC has shown a success rate of 90%. In intermediate-risk group, either VAC or VAI can be utilised with survival rate reaching 70% [75]. A more intensive treatment is deemed necessary in children with metastasis as it has poor prognosis. Children within group IV category are recommended to undergo aggressive chemotherapy followed by autologous myogenic stem cell transplantation [76, 77].

17.4.7.2 Radiation Therapy

Radiation is a crucial part of therapy besides amongst children within the low-risk tumour category. It is noteworthy that radiation therapy is a favoured modality as only 15% of RMS patients

(group I) achieve total recuperation. Radiation therapy is administered in RMS children, especially with residual disease. The total radiation dosage is individualised according to protocol regime.

Delay in radiation therapy leads to local tumour relapse. The recommended dose of radiation is between 36 and 50.4 Gy. Lesser dosage is given in patients in group II following microscopically incomplete surgical resection. In case of residual or unresected tumour, greater radiation dosage is required. The challenge in radiation therapy is owing to the numerous vital structures which are located in the vicinity, which may lead to delayed radiation adverse effects.

17.4.7.3 Surgical Therapy

Many authors advocate surgery to be the primary mode of treatment. 10% of new identified cases are surgically resectable [65, 73]. Additionally, non-parameningeal RMS enables complete surgical resection, notably ear, zygoma, soft palate, tongue as well as supraglottis, whereas the parameningeal RMS poses a challenge for complete tumour resection [64].

Complete surgical resection with negative margin is ideal as survival rate is increased and avoids radiation therapy [78, 79]. Having said that, if unacceptable morbidity is postulated, surgical resection should be avoided.

17.4.8 Prognosis

Outcome of treatment depends largely on the anatomic site of involvement, child's age, stage as well as histology type. Poor prognostic factors include older age child, presence of metastasis, large tumour size, alveolar type of RMS and parameningeal RMS [80].

17.4.9 Recurrence

Local or metastatic recurrence is demonstrated in nearly one-third of children albeit after aggressive treatment. Patients who underwent surgery have been reported to demonstrate better outcome, notably those who had complete surgical resection [81].

17.5 Juvenile Nasopharyngeal Angiofibroma

17.5.1 Introduction

Juvenile nasopharyngeal angiofibroma (JNA) is a rare, aggressive non-cancerous, vascular tumour which occurs predominately amongst adolescent boys [82]. JNA is deemed aggressive owing to its tendency to spread locally and its possibility to extend into the skull base and intracranial region.

17.5.2 Epidemiology

JNA is reported in 0.5% of all head and neck tumours whilst affecting 1 in every 150,000 individuals. It affects adolescent males aged between 11 and 25 years [83], although average age is 15 years in most studies [82]. Presentation in older patients, notably beyond 25 years, is uncommon. JNA has been reported to be more common in the East, especially Indian continent, as compared to the West [84]. As this tumour occurs exclusively amongst males, occurrence in females requires genetic testing.

17.5.3 Aetiology

JNA originates predominately at the superior lip of the sphenopalatine foramen, formed by pterygoid process of the sphenoid bone and sphenoidal process of the palatine bone. Apart from sphenopalatine foramen, other possible sites of origin include pterygopalatine fossa, base of sphenoid bone, sphenoid sinus, paranasal sinus region and lacrimal sac. Tumour spreads submucosally into the adjacent structures.

17.5.4 Pathogenesis

Close relation between these tumours as well as androgen receptor expression postulates that this tumour is androgen dependant, hence its predominance amongst males [83, 85]. Apart from androgen theory, other postulated theories include [86] undifferentiated epithelioid nest

cells, desmoplastic response of the nasopharyngeal periosteum, embryonic fibrocartilage and nonchromaffin paraganglionic cells of the terminal branches of the maxillary artery. JNA is noted to demonstrate superior level of hormone receptors and vascular endothelial growth receptor (VEGF), which indicates possible interaction between receptors and VEGF [87].

It is noteworthy that the tumour's blood supply is mainly derived from ipsilateral sphenopalatine branch of maxillary artery, a branch of external carotid artery [88]. Other contributing vessels are ascending pharyngeal artery, vidian artery and contralateral vessels. It is noteworthy that bilateral vascular supply, albeit rare, has been reported [89].

17.5.5 Presentation

JNA involves adolescent males with the mean age of 15 years upon presentation [82]. Nasal obstruction, epistaxis and nasopharyngeal mass have been reiterated as the three most common presentations for years [90]. Nasal obstruction is usually progressive and painless, whereas epistaxis is spontaneous, painless and usually severe requiring attention. Other clinical manifestations include headache, facial swelling, cheek numbness and deformity, unilateral rhinorrhea, olfactory disturbances, otalgia, aural fullness and reduced hearing. It is noteworthy that clinical manifestations result from mass effect of the tumour. It is noteworthy that patients with JNA seek treatment after 6–12 months of having symptoms [91]. If delayed, the tumour will progressively grow causing devastating clinical manifestations such as ptosis, cranial nerve palsies, blurring of vision, diplopia and even blindness [91, 92], which denotes advanced stage of disease.

17.5.6 Diagnosis

A meticulous history taking along with complete physical examination would lead to the suspicion of JNA. Thorough physical examination complemented by cranial nerve examination is deemed necessary. Nasoendoscopic examination is essential in all patients suspected with JNA. Presence of vascular mass at the nasopharynx, particularly the posterolateral wall, should raise suspicion. It is of utmost importance that biopsy is not performed as torrential bleed will ensue if proceeded. Additionally, otoscopic examination, ocular examination as well as flexible nasopharyngolaryngoscopy need to be carried out to appraise the extension of the tumour.

17.5.7 Imaging

CT and MRI are both favoured imaging tools. CT enables tumour delineation along with this extension and detects bony erosion particularly the skull base. Classical findings include Holman-Miller sign which encompasses the anterior bowing of the posterior wall of maxilla, dumb-bell-shaped or bilobed tumour, erosion of sphenoid bone particularly the greater wing of sphenoid as well as hyperintensity owing to the extensive vascular supply of the tumour. CT angiography is able to detect the specific feeding vessel and to look for tumour blush, as well as is used for preoperative embolisation.

MRI has superior soft-tissue tumour delineation, along with tumour extension, intracranial extension, perineural invasion as well as orbital extension. Avid enhancement is seen in a contacted T1-weighted image, whilst multiple signal voids are seen in T2-weighted images.

17.5.8 Histology

JNA is an encapsulated mass, which comprises vascular tissue and fibrous stroma and collagen fibres. The afflicted vessels are commonly thin walled and lack elastic fibres with absence of smooth muscles. Plump cells within the stromal cells radiate around the vessels.

17.5.9 Staging

Fisch staging and Radkowski staging are the most prevalent staging systems used in myriad studies.

17.5.9.1 Fisch Staging

I: Tumours limited to nasal cavity and nasopharynx with no bony destruction
II: Tumours invading the pterygomaxillary fossa and paranasal sinuses with bony destruction
III: Tumours invading the infratemporal fossa, orbit and parasellar region, remaining lateral to the cavernous sinus
IV: Tumours with invasion to the cavernous sinus, optic chiasmal region and pituitary fossa

17.5.9.2 Radkowski Staging

Stage

IA: Limited to nose and nasopharyngeal area
IB: Extension into one or more sinuses
IIA: Minimal extension into pterygopalatine fossa
IIB: Occupies pterygopalatine fossa with or without orbital region
IIC: Infratemporal fossa extension with or without cheek or pterygoid plate involvement
IIIA: Erosion of the skull base (middle cranial fossa or pterygoids)
IIIB: Erosion of the skull base with intracranial extension with or without cavernous sinus involvement

17.5.10 Treatment

Surgery is the primary mode of treatment. However, amongst patients not fit for surgery, other modalities including radiotherapy, chemotherapy as well as medical therapy exist.

17.5.10.1 Surgery

Surgery has been reiterated as the first-line treatment. Despite the myriad surgical armamentarium which exists to date, best surgical approach does not exist. It is noteworthy that surgical approach relies chiefly on tumour extension. Surgical approaches have evolved over the last decade, whereby surgical approach can mainly be divided into open, endoscopic or a combined approach. Open approaches include transpalatal, transpharyngeal, transfacial via lateral rhinotomy, midfacial degloving, LeFort I osteotomy, and infratemporal and subtemporal lateral approaches [93, 94]. It is noteworthy that advances in imaging as well as preoperative embolisation have enabled better preoperative management as well as aided in tumour resection. Intraoperative bleeding has been the most devastating complication feared by most surgeons. Availability of cell savage machine as well as haemostat materials such as absorbable gelatine, powder, sponge oxidised regenerated cellulose, microfibrillar collagen, fibrin and synthetic sealant aids to control bleeding [95].

With the advent of endoscope, endoscopic tumour resection has enabled surgeons to resect tumour with reduced morbidity. Mass involving nasopharynx, nasal cavity, paranasal sinuses and pterygopalatine fossa could be removed through endoscopic approach successfully [96]. Endoscopic resection is feasible for tumours involving Radkowski I–IIIA [97], as well as extension into orbit, parasellar region and infratemporal region by experienced surgeons [93, 97, 98].

17.5.10.2 Outcome

Nearly 18% recurrence rate is demonstrated with long-term disease-free survival rate of 87% [91, 92]. Yet, recurrence rate of up to 50% has been reported [99]. Notable risk factors contributing to recurrence include advanced stage at presentation, extensive tumour especially tumour in pterygoid fossa and basisphenoid, clival erosion, intracranial extension and younger age at diagnosis.

17.5.10.3 Complications

Complications can occur from surgery or from tumour extension. Most common complications are from the sinonasal and neurologic concerns. Prominent complications include bleeding, nasopharyngeal stenosis, epiphora, impaired facial growth, facial deformity, scar and blindness. Trismus may ensue from infratemporal approach whilst paraesthesia on the cheek from Weber-Ferguson incision or midfacial degloving approach. Albeit rare, meningitis and blindness following JNA surgery have been reported. It is noteworthy that transient blindness may ensue embolisation.

17.5.10.4 Radiotherapy

Radiotherapy is not the first line in view of the strings of complications which follow notable radiation-induced malignancy. Yet, radiotherapy is recommended in patients with unresectable tumours or incomplete tumour removal. Residual lesions in vital regions which are progressively increasing in size warrant radiotherapy [98]. Recurrence rate following primary radiotherapy with 30–55 Gy revealed recurrence rate of 15% [100]. Intensity-modulated radiotherapy revealed favourable outcome in patients with extensive or persistent JNA with no recurrence noted [101].

17.5.10.5 Chemotherapy

Chemotherapy has revealed successful outcome in numerous patients [102, 103]. Goepfert et al. advocated the usage of two chemotherapy protocols: doxorubicin and dacarbazine or vincristine, and dactinomycin and cyclophosphamide with successful outcome [102].

17.5.10.6 Hormonal Therapy

Hormonal therapy has revealed promising results especially with oestrogen and androgen receptor blocker [104]. Flutamide, a non-steroidal androgen receptor blocker, revealed tumour regression of 44% in four cases [105]. Parallel to that, flutamide revealed regression of tumour in 20 advanced-stage post-pubertal patients [106].

17.5.10.7 Spontaneous Regression

Spontaneous regression was demonstrated amongst young adults aged between 20 and 25, especially in patients with post-resection residual tumour [107].

17.6 Lymphatic Malformation

17.6.1 Introduction

Lymphatic malformation (LM) is characterised by low-flow vascular tumour of the lymphatic system, which affects 1 patient among 2000–4000 live births [108]. LM is classified into macrocystic with a diameter measuring more than 1 cm and microcystic with a diameter of less than 1 cm or mixed [109]. LM presents at birth in almost 60% of infants and in 90% of children within 2 years. Macrocystic LM within the cervical region is termed as cystic hygroma [109].

17.6.2 Genetics

Albeit the genetic causes of LM are unknown, in a small number of children, LM is linked with numerous syndromic disorders such as Turner syndrome, Proteus syndrome, Klippel-Trenaunay-Weber and congenital lipomatous overgrowth, vascular malformations and CLOVES syndrome [110].

17.6.3 Clinical Presentation

Clinical manifestation relies on the anatomical location. LM may present as small swelling to a diffusely large area compromising adjacent area [111]. Approximately 75% of LM can be discovered in the cervicofacial region [112]. In any case, if the LM is present within the aerodigestive tract, airway compromise, swallowing as well as speech disturbance may occur [113–115]. LM presenting in orbital area may lead to visual disturbance, ptosis, diplopia and dystopia. Besides that, LM had been reported within the chest, axilla, mediastinum, retroperitoneum, buttocks as well as anogenital region [116] and extremities. As LM expands, it can cause severe functional impairment as well as cosmetic deformity, pain and bleeding. It is noteworthy that children with LM may develop lymphopenia resulting in high risk of developing infection [114, 117].

17.6.4 Diagnosis

LM can be identified at early stage during prenatal follow-up through ultrasound within the second or third trimester. Foetal MRI is a superior diagnostic modality to outline the mass as well as its extension and to look for any associated anomaly [118]. It is also noteworthy that foetal MRI enables decision of treatment or mode of delivery such as the need for ex utero intrapar-

tum treatment (EXIT) procedure. If not diagnosed prenatally, LM can be diagnosed at birth or early infancy period with appearance of ballotable mass. LM usually enlarges slowly as the child grows; occasionally, sudden or rapid increase in mass size may occur following infection, haemorrhage or trauma. Additionally, usage of lymphoscintigraphy to diagnose LM has been reported.

17.6.5 Treatment

Aims of treatment in LM include to maintain function, control symptoms as well as preserve cosmesis [119, 120]. Prior to deciding on the mode of treatment, a multi-unit team discussion including otorhinolaryngologists, paediatricians, dieticians, reconstructive surgeons, speech therapists, audiologists and psychologists together with parents is deemed necessary.

17.6.5.1 Observation

Albeit surgical approach is considered the gold standard, some authors have advocated observation in uncomplicated cases whereby the LM does not cause functional deficit. Gilony et al. found that 45% of patients who were observed demonstrated spontaneous regression [121]. Additionally, Gilony discovered that most patients can be observed initially prior to intervention [121].

17.6.5.2 Sclerotherapy

Sclerotherapy has demonstrated promising results in treating macrocystic LM [111, 122]. Popular sclerosants include picibanil (OK-432), doxycycline, bleomycin, ethanol, acetic acid, sodium tetradecyl sulfate and hypertonic saline [119, 120]. Sclerosants are administered intralesionally after aspirating cystic fluid. Side effects include soft-tissue oedema, skin necrosis and neuropathy [111]. It is noteworthy that aspirating the cystic fluid is carried out to aid in diagnosis, to create space for sclerosants as well as to increase surface area between the sclerosants and LM wall.

17.6.5.3 Surgery

Surgical choice relies mainly on anatomical location as well as extension of the LM. Additionally, surgery can be performed in conjunction with sclerotherapy. Both open and endoscopic approaches have been performed. In cases of abdominal LM, laparoscopic approach has been utilised. Complications of surgery include cranial nerve injury, incomplete resection, scar and recurrence.

17.6.5.4 Other Modalities

Microcystic LM usually is difficult to manage as compared to macrocystic. Radiofrequency ablation (RFA) has shown promising results over the recent years in managing microcystic LM [114, 123]. RFA can be delivered via high-frequency or low-frequency mode. RFA has proved to reduce LM within the oral cavity and improve pain, bleeding and infection [124].

Apart from RFA, other modalities such as carbon dioxide laser and pulsed dye laser can be utilised especially for cutaneous LM.

17.6.5.4.1 Novel Agents

With the advancement of technologies, newer therapies are resurfacing with promising results. Recent data has demonstrated that novel oral medications including propranolol, sildenafil and sirolimus have been proven to be effective [125–127].

17.7 Cystic Hygroma

Cystic lymphangioma is a congenital malformation which most commonly occurs in infants and young children. These abnormalities usually occur in the neck and axillary region, but may occur in other parts of the body, such as the mediastinum, pelvis, retroperitoneum and solid organs [128]. It is histologically benign, but it infiltrates deep into the tissue and tends to recur.

These lesions are classified into capillary lymphangioma, cavernous lymphangioma and cystic lymphangioma. It appears as a cavernous lymphangioma when a lymphangioma is confined to fairly dense tissue, such as the tongue. A

cystic lesion occurs when it develops in the relatively loose fascia of the neck. The cystic hygromas account for around 90% of the lymphangiomas in the region of the head and neck [129]. Current literature has revealed that there is an association between cystic hygroma and hereditary lymphoedema. The cystic hygroma can be inherited in autosomal recessive as well as autosomal dominant similar to lymphoedema, with the latter most likely associated with a better prognosis [130].

Lymphangiomas are seen as large, cystic masses on imaging studies. As the first diagnostic workup, ultrasound is preferable and can classify the subtype of lymphangioma and it can assess the size of the cysts. The characteristics of the mass, the involvement of critical and vital structures and the extent of the tumour can be evaluated by CT and MRI. These two imaging modalities can yield an accurate preoperative evaluation of lymphangiomas and other vascular lesions [131].

At this juncture, there is no consensus on the best treatment options for cystic hygroma. Depending on the size of the lesion, anatomical localisation and complications, the treatment should be individualised. Some of the treatment options include observation, aspiration, injection, cryotherapy, electrocautery, radiation, laser, ligation and excision. In addition, surgical excision is reserved for recurrent tumours that persist despite conservative therapy and the tumour that is symptomatic.

OK-432 sclerotherapy has become the first-line therapy for cystic lymphangioma in recent years, and many reports have highlighted about its usage and therapeutic benefit. In polycystic cases and cases with small cystic areas, however, it is difficult to achieve a complete response with OK-432 and it can be occasionally ineffective [132]. Other proponents have reported that in properly selected patients affected by lymphangiomas, OK-432 therapy is a safe and effective option [133].

Of all vascular malformations, the most difficult pathology to eradicate is lymphatic malformations. Their infiltrating nature, coupled with the difficulty in distinguishing important head and neck structures from adjacent normal tissues, makes it even harder to achieve a complete surgical extirpation [134]. Therefore, the probability of postsurgical recurrence and complications is greater than that of other vascular lesions. The selection of treatment modalities should depend on the status of patients and the available techniques. In order to obtain the best treatment outcomes, the treatment protocol should be individualised and comprehensive as well as sequential [134].

Other treatment options, such as sclerotherapy, have been proposed as an alternative to reduce the impact and complications of surgery, and surgical resection remains the best treatment for lymphangiomas. As sclerotherapy agents, various products have been used, such as sodium morrhuate, dextrose, tetracycline, doxycycline, bleomycin, ethibloc and OK-432. The other agents were reported to cause perilesional fibrosis in addition to OK-432 and thus to complicate eventual surgical excision [129]. In addition, cervicofacial macrocystic lesions can be treated with sclerotherapy, whilst laser therapy is used for superficial mucosal microcystic lesions [135].

17.7.1 Surgical Treatment for a Recurrent Cystic Hygroma: Illustration of a Case

A 9-year-old Malay girl has been diagnosed with cystic hygroma since birth. The tumoural mass has grown in size over the years, where it necessitates tracheostomy to relieve airway obstruction. The patient had multiple sclerotherapies for her tumour but with limited response. In addition, the patient had a history of surgical resection of residual mass post sclerotherapy, with evident right marginal mandibular nerve paresis. On follow-up, there was recurrent tumour on the same side, and after multiteam discussion, it was decided for a re-surgery (Figs. 17.6, 17.7, 17.8, 17.9, 17.10, 17.11, 17.12, 17.13, 17.14, and 17.15).

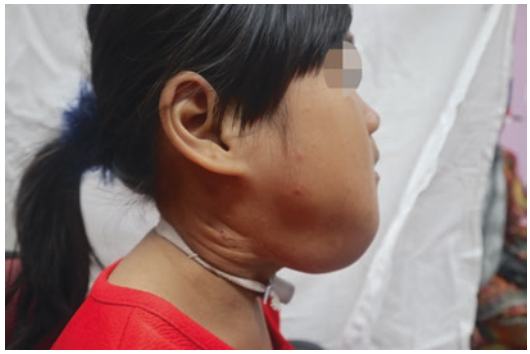

Fig. 17.6 On clinical examination, there was a surgical scar at the lateral neck due to previous surgery with the evidence of marginal mandibular nerve paralysis. There was a submandibular mass at level Ib, firm in consistency, and measuring 4.0 cm × 5.0 cm. The tracheostomy tube was in situ and patent. There was no granulation tissue around the stoma

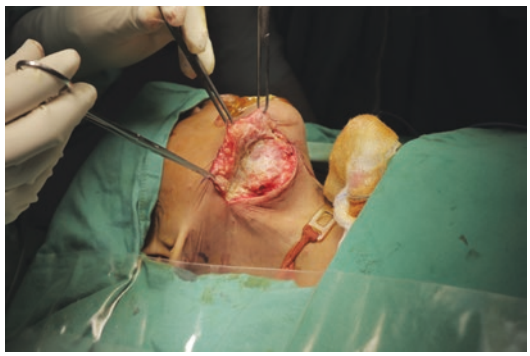

Fig. 17.7 Intraoperatively, the same skin incision for submandibulectomy is used. A subplatysmal skin flap is raised with caution to preserve the residual marginal mandibular nerve function. There was thick granulation tissue overlying the mass due to previous surgery

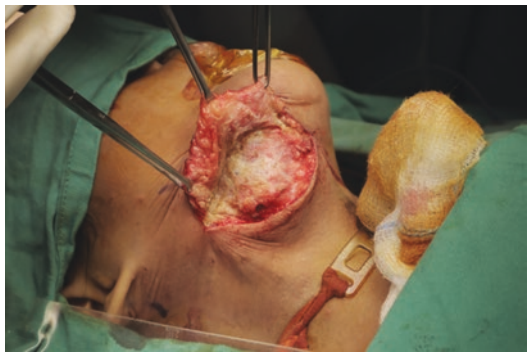

Fig. 17.8 The dissection is deepened. The tissue was fibrotic and difficult to dissect. The marginal mandibular nerve cannot be identified since tissues were all whitish and thickened

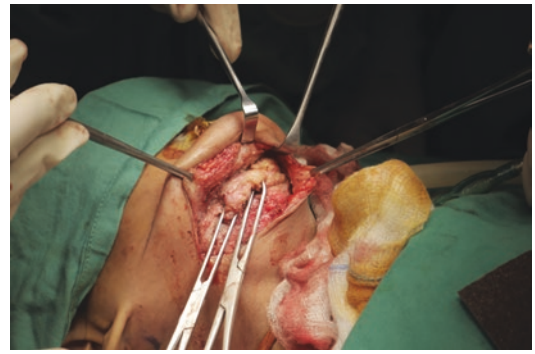

Fig. 17.9 The dissection deepened around the mass, exposing the mass. The mass is retracted with Allis forceps to facilitate the ligation of the facial artery and vein

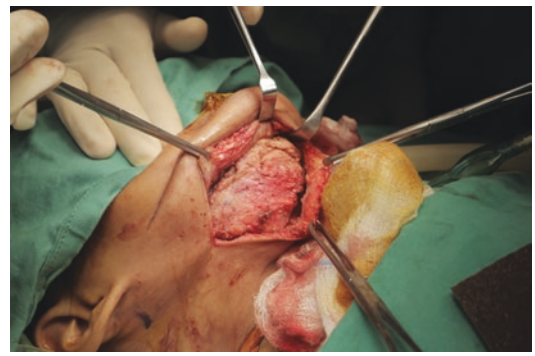

Fig. 17.10 Superiorly, the mass extends to the floor of mouth level, where only small thin mucosa is felt during dissection deep to the mass, medial to the mandible. The dissection continues supero-inferiorly and medial-laterally of the mass

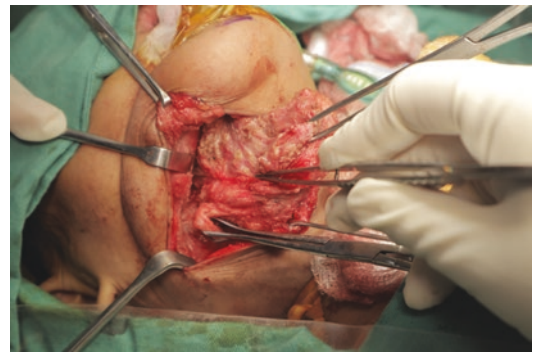

Fig. 17.11 The hypoglossal and lingual nerves cannot be identified due to dense fibrotic tissues. Anteriorly, the mylohyoid muscle is adherent and blended to the mass

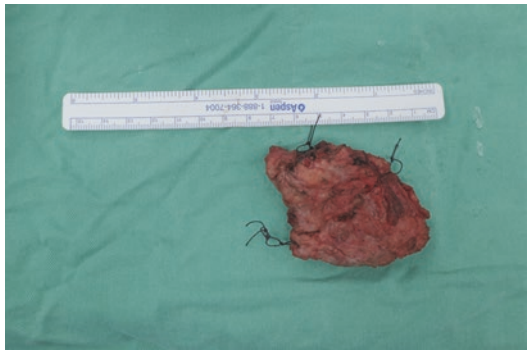

Fig. 17.12 The mass is removed in total which measures 7.0 cm × 5.0 cm. The mass is sutured to orientate the histopathology examination by the pathologist

Fig. 17.13 The wound is closed in two layers; the size 10 drain is secured. The tracheostomy tube is kept in situ

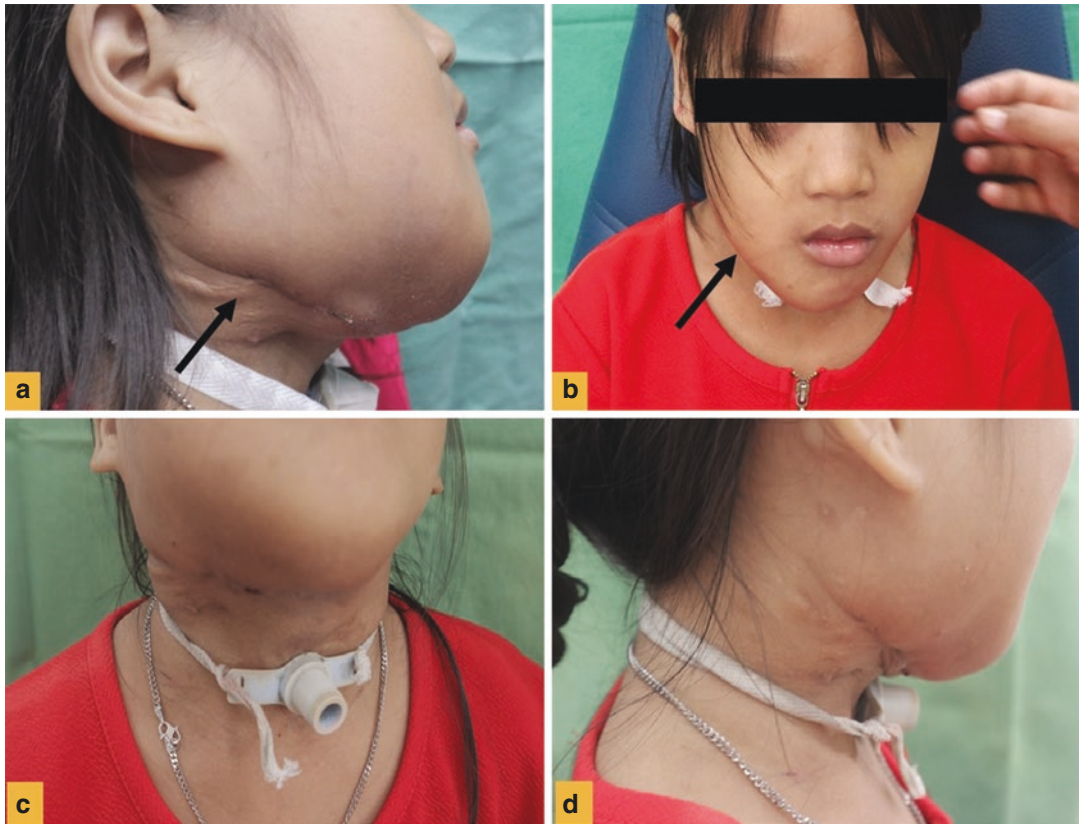

Fig. 17.14 (**a**–**d**) Post-operatively at 4 months, the appearance of scar is lessened

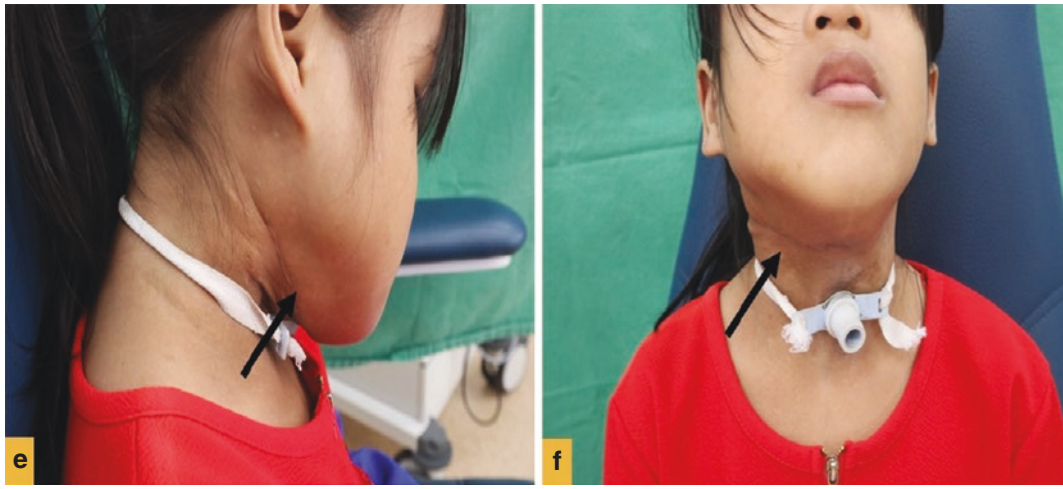

Fig. 17.15 (**e**, **f**) Post-operatively at 8 months, the submandibular swelling has reduced significantly, the scar follows the previous old scar and the marginal mandibular nerve remains similar. The patient was happy with surgical treatment outcomes

17.8 Lymphoma

Lymphoma constitutes 10–15% of all malignancy in childhood. Lymphoma can be divided into Hodgkin's lymphoma and non-Hodgkin's lymphoma. It is noteworthy that the most common presentation of HL and NHL in children is cervical lymphadenopathy.

17.8.1 Hodgkin's Lymphoma

Hodgkin's lymphoma (HL) is one of the most common malignancies accounting for 4% in children aged between 0 and 14 years and 12% amongst children aged between 15 and 30 years [136]. Male predominance is noted amongst children under 10 years of age, whereas amongst adolescence there is no gender predilection [137]. To date, the exact aetiology of HL is still unknown. Epstein-Barr virus (EBV) has long been associated with HL. Approximately 40–50% of HL in developed countries has been linked to EBV. Additionally, HL incidences are seen amongst certain immunodeficiency disorders such as ataxia telangiectasia, Wiskott-Aldrich syndrome as well as Bloom syndrome [138].

Histologically, classical HL feature is the presence of large, multinucleated Reed-Sternberg cells which are B cell in origin. Additionally, lymphocytes are present in HL. Histological classification of HL is based on Rye classification: lymphocytic predominance, mixed cellularity, lymphocytic depletion and nodular sclerosis [139].

17.8.2 Non-Hodgkin's Lymphoma

Non-Hodgkin's lymphoma (NHL) can be divided into mature B cell lymphoma (Burkitt lymphoma, diffuse large B cell lymphoma and primary mediastinal large B cell lymphoma), lymphoblastic lymphoma of precursor B or T cell and anaplastic large-cell lymphoma. It is noteworthy that the incidence of NHL varies according to different geographic regions [140].

17.8.3 Clinical Presentation of HL and NHL

Most common presentation for both HL and NHL amongst children is cervical lymphadenopathy. It is important that the presentation of lymph node is

not taken lightly as persistent adenopathy beyond 2 weeks should raise suspicion. In a study by Oguz et al., 98.2% of chronic adenopathy turned out to be lymphoma [141]. Head and neck involvement of lymphoma is between 42% and 60% [142].

Cervical lymph node is affected by lymphoma almost 66% [142]. As for extranodal involvement, initial manifestation may involve tonsils, base of tongue and nasopharynx. According to a study by Roh et al., extranodal involvement of lymphoma affects 40.5% [142]. Extralymphatic involvement mainly affects NHL. Weisberger et al., in their series, found that 4 out of 15 children presented with extralymphatic involvement of lymphoma, which includes maxillary and ethmoid sinus, mandible, thyroid gland, parotid and pharynx [143].

Besides that, mediastinal lymphadenopathy causing lymphoma may lead to superior vena cava syndrome causing dyspnoea, headache, and facial and arm swelling. Other symptoms such as fever, bleeding symptoms and bone pain may ensue. Adenopathy can be fixed and nontender, and it can involve any lymph node. Additionally, cutaneous lesion secondary to lymphoma may occur [144].

17.8.4 Diagnosis

17.8.4.1 Haematology

Blood investigations including full blood picture, erythrocyte sedimentation rate, lactate dehydrogenase, ferritin and C-reactive protein are suggestive of lymphoma. Bone marrow aspirate, biopsy as well as cerebrospinal fluid analysis can determine lymphoma.

17.8.4.2 Imaging

Ultrasonography is the first line in diagnostic approach as it is non-invasive and rapid and does not require sedation. Suspicious lymph node can be detected via ultrasonography as it detects vascularisation, number, size and anatomical relation. Computed tomography (CT), magnetic resonance imaging and positron emission tomography (PET) enable staging and treatment plan as well as follow-up.

17.8.4.3 Surgery

Tissue biopsy is deemed superior as histological typing is required for diagnosis as well as treatment plan. In a large mass, excision biopsy can be performed.

17.8.5 Classification

HL is classified based on Ann Arbor classification system, whilst St. Jude Children's Research Hospital staging classification is used for NHL (Tables 17.4 and 17.5).

17.8.6 Treatment of HL

HL in children has been associated with excellent prognosis with a 5-year disease-free survival rate from 80% to 95%. Poor prognosis indicator includes presence of B symptoms and bulky mediastinal lymph node, extranodal extension and advanced stage of disease (III–IV). Gold standard treatment is combination of chemoradiotherapy. Various regime protocols have been developed, which have evolved over the years. COPP (cyclophosphamide, vincristine (VCR), procarbazine, prednisone) was initially used for HL. Then, ABVD (adriamycin, bleomycin, vin-

Table 17.4 Ann Arbor staging classification of Hodgkin's lymphoma

Stage I	Involvement of a single lymph node region (I) or of a single extralymphatic organ or site (IE)
Stage II	Involvement of two or more lymph node regions on the same side of the diaphragm (II) or localised involvement of an extralymphatic organ or site and of one or more lymph node regions on the same side of the diaphragm (IIE)
Stage III	Involvement of lymph node regions on both sides of the diaphragm (III), which may also be accompanied by localised involvement of an extralymphatic organ or site (IIIE) or by involvement of the spleen (HIS) or both (HISE)
Stage IV	Diffuse or disseminated involvement of one or more extralymphatic organs or tissues with or without associated lymph node enlargement

Table 17.5 St. Jude staging classification system

Stage I	A single tumour (extranodal) or single anatomical area (nodal) with the exclusion of the mediastinum or abdomen
Stage II	A single tumour (extranodal) with regional node involvement Two or more nodal areas on the same side of the diaphragm Two single (extranodal) tumours with or without regional node involvement on the same side of the diaphragm A primary gastrointestinal tract tumour, usually in the ileocecal area with or without involvement of associated mesenteric nodes only, grossly completely resected
Stage III	Two single tumours (extranodal) on opposite sides of the diaphragm Two or more nodal areas above and below the diaphragm All the primary intrathoracic tumours (mediastinal, pleural, thymic) All extensive primary intra-abdominal disease, unresectable All paraspinal or epidural tumours, regardless of other tumour site(s)
Stage IV	Any of the above with initial central nervous system and/or bone marrow involvement

blastine and dacarbazine) became popular amongst children with localised, early-stage disease. COPP-ABV protocol along with low-dose radiotherapy was developed to treat children with advanced stage of disease [145, 146].

17.8.7 Treatment of NHL

Treatment in children with NHL depends on the subtypes as the clinical features and molecular and cellular biology vary [147]. For example, treatment in children with B-NHL is usually of short duration and comprises intensive chemotherapy with CPM, high-dose (HD) methotrexate (MTX), cytarabine (ARA-C), doxorubicin, VCR, etoposide, ifosfamide and corticosteroids (CTS).

17.8.7.1 Radiation Therapy

Although chemotherapy is the main treatment modality, radiation therapy plays an important role in certain subtypes of lymphoma.

17.9 Langerhans Cell Histiocytosis

Langerhans cell histiocytosis (LCH) is regarded as an uncommon condition that incorporates the dendritic Langerhans cell [148]. The hallmark of the disease is the polyclonal proliferation of Langerhans cells, which are macrophages located within the dermis [149]. Owing to its aggressive nature, osteolysis, recalcitrance and propensity to produce synchronous lesion, it is often confused with malignancy. Historically, LCH was termed as eosinophilic granuloma, Hand-Christian-Schuller disease and Letterer-Siwe disease. However, in a workshop in Philadelphia in 1985, the term LCH was coined ensuing the histologic as well as pathologic features of the entity.

17.9.1 Epidemiology

LCH has been reported to affect approximately 5.4 cases per 1 million [149]. This entity has shown male predilection with peak incidence affecting children with age ranging from 1 to 4 years [150]. Although LCH is regarded as a disease of childhood, cases involving adult patients have been reported [151]. Approximately 80% of LCH consists of the head and neck region, whereby temporal bone involvement is reported to be between 15% and 60%. Additionally, nearly 4–25% of patients with temporal bone LCH present with otoneurological symptoms [152]. Risk stratification is classified into three systems: single-system LCH, low-risk multisystem LCH and high-risk multisystem.

17.9.2 Pathogenesis

The pathogenesis of LCH is still a conundrum to date. Over the past decade, myriad hypothesis regarding the pathogenesis of LCH has emerged including the most prominent theory: that is, either a reactive disease or a neoplastic entity [153]. Spontaneous remission, vast multiple cytokines by dendritic cells and T cells in LCH

mass and good prognosis along with favourable survival rate point towards the reactive process of LCH [154], whereas features pointing towards neoplastic process include infiltration of organs by a monoclonal population of aberrant cells, lethal evolution ability and promising results following cancer-based treatment [155]. The presence of clonal proliferation and disseminated cells that express CD1a and CD207 is regarded as a key feature of the epidermal Langerhans cell. Parallel to that, 55% of cases were reported to reveal a somatic mutation in BRAF, and almost all the LCH cases demonstrated RAS-RAF-MEK-ERK pathway activation [156], supporting the neoplastic theory.

On the other hand, there is emerging evidence advocating the role of immune dysfunction via a permissive immunosurveillance system. Besides that, viral attribution has been suggested ensuing Epstein-Barr virus DNA expression discovered in the LCH lesions [157].

17.9.3 Clinical Feature

The clinical presentation depends on the degree of dissemination of LCH, which can range from a solitary to a multifocal lesion. Solitary or single-system involvement is the most common and has a relatively favourable outcome as compared to multisystem involvement. Solitary involvement includes lymph nodes, lungs and bones. Pulmonary LCH is regarded as a separate entity as it exclusively involves smokers and has been demonstrated to resolve upon cessation of smoking [158]. The multisystem disease includes liver, spleen and bone marrow, which are regarded as 'risk organs' ensuing its high risk of mortality.

The head and neck are regarded as the prevalent sites of involvement; notably, base of skull is affected in 60% of cases [159]. In one of the series, authors report a calvarium to be the predominant site of LCH [160]. Temporal bone is affected in nearly 50% of cases with bilateral involvement reported in one-third of all cases. The petrous ridge of the temporal bone is regarded as the most prevalent site of involvement [161]. Patients with temporal bone LCH commonly present with otorrhea, otalgia, aural polyp (Fig. 17.16) and swelling over the mastoid or any temporal region. The vague ontological presentation which mimics common conditions such as external otitis externa delays the diagnosis of LCH [162]. Traditionally, the nature of the LCH entity is interesting due to its ability to resolve spontaneously as the child grows.

17.9.4 Investigations

LCH is diagnosed based on the histopathological examination of the biopsy of the lesion. The histological pathognomonic feature of LCH is proliferation of Langerhans cells with inflammatory cells such as eosinophils in addition to Birbeck granule. The Langerhans cell proliferation is demonstrated to be monoclonal [155]. Nuclei of the LCH cells are irregular with prominent folds and grooves, fine chromatin with indistinct nucleoli with the presence of scattered eosinophils, lymphocytes, histiocytes and neutrophils. Additionally, sinusoidal involvement is demonstrated when LCH involves lymph nodes.

The presence of positive CD1a, S100 and langerin (CD207) demonstrated by immunohisto-

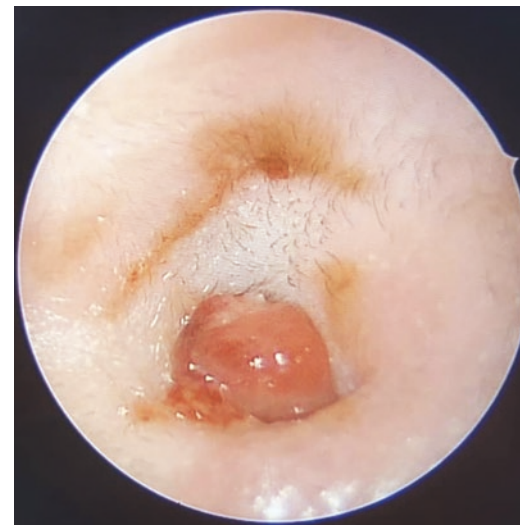

Fig. 17.16 Aural endoscopic view showing polyp occupying the entire external auditory canal which turns out to be temporal bone LCH

chemical staining is the hallmark of LCH. Parallel to that, the expression of CD68 has been reported variably. Birbeck granules and elongated, zipper-like cytoplasmic structures measuring 200–400 nm × 33 nm are characteristics (Figs. 17.17, 17.18, 17.19, 17.20, and 17.21).

Imaging can reveal nature, extension as well as relationship with the adjacent structures and, importantly, multisystem involvement. Traditionally, radiographs, skeletal surveys and technetium-99m methylene diphosphate (MDP) bone scans were used. Over the past decade, both CT and MRI have revealed its effectiveness to detect bone lesions, notably in the skull, vertebrae and pelvis. Additionally, ultrasonography,

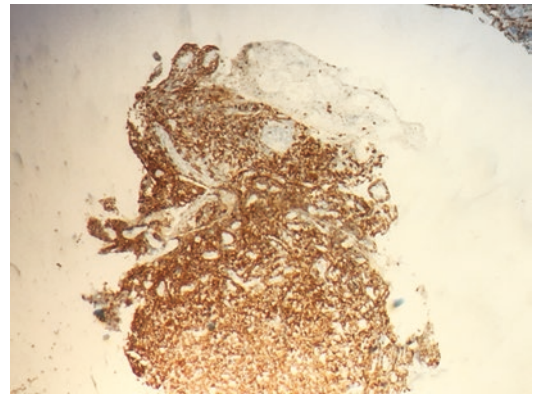

Fig. 17.19 The Langerhans cells are strongly positive for CD1a

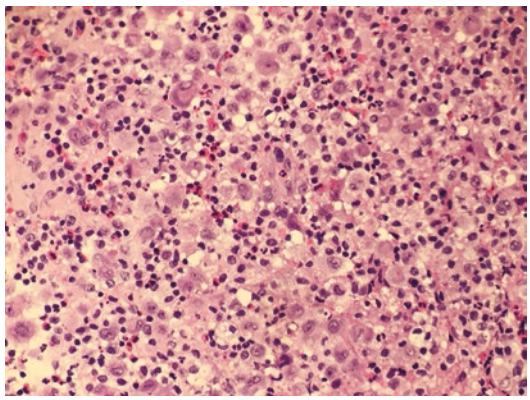

Fig. 17.17 Langerhans cells showing kidney-shaped nuclei, occasional nuclear groove, fine granular chromatin and abundant eosinophilic cytoplasm

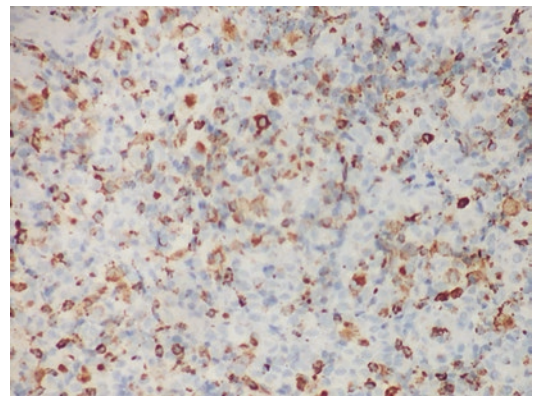

Fig. 17.20 The Langerhans cells positive for CD68

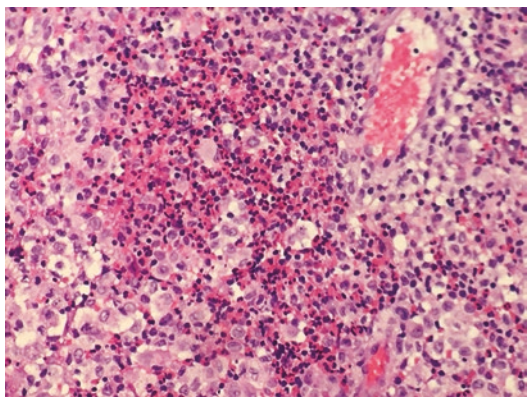

Fig. 17.18 Dense sub-epithelial infiltrates of Langerhans cell histiocytes in clusters, associated with prominent eosinophils and neutrophil infiltrates

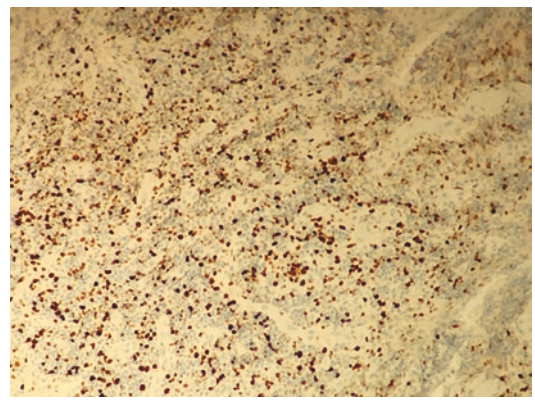

Fig. 17.21 Langerhans cell with Ki67 is about 30–40%, including background inflammatory cells

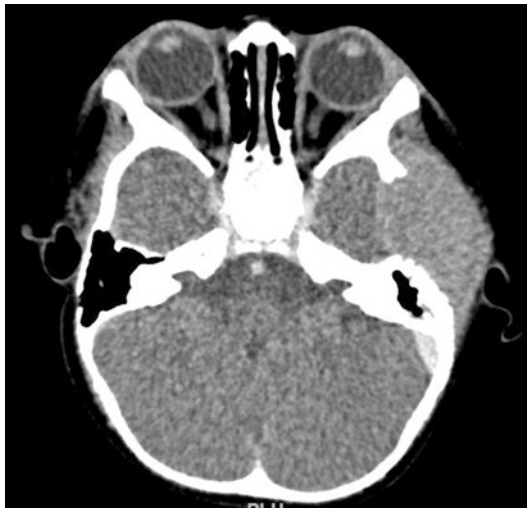

Fig. 17.22 Axial view contrast-enhanced computed tomography showing an extensive irregular soft-tissue lesion involving the left temporal bone and left mastoid air cells

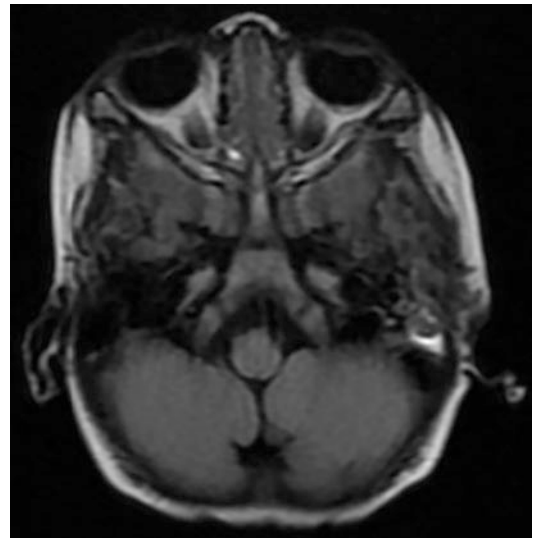

Fig. 17.23 Coronal cut contrasted magnetic resonance imaging showing the same soft-tissue lesion involving the left temporal bone, left temporalis muscle and left mastoid air cells

particularly the abdominal ultrasound, can be used to assess multisystem involvement. No pathognomonic imaging features have been reported to date. The lesions appear iso- to hypointense on T1-weighted images with marked enhancement following contrast, and in T2-weighted images, hyperintensity with no peripheral oedema is noted (Figs. 17.22 and 17.23).

PET/CT has been advocated to evaluate LCH lesions. The 18-fluorodeoxyglucose (FDG) isotope detects the metabolically active histiocytes, which may not be detected by skeletal surveys or bone scans [163]. Owing to its high sensitivity and specificity, it is useful for whole-body evaluation of osseous and extraosseous disease activity as well as to evaluate treatment response [164]. A study comparing PET scan with MRI and CT revealed that PET scan detected more lesions at diagnosis in children with osseous LCH lesions [165]. Parallel to that, PET scan was reported to be superior at detecting new disease, recurrence and monitoring response of disease [163].

Other additional investigations that can be performed are based on the location of the mass. Temporal bone LCH requires an audiological assessment as baseline and follow-up evaluation. Hearing loss can be attributed to ossicular or inner ear destruction.

17.9.5 Treatment

Treatment modality ranges from observation to multimodality depending on location, extension and whether it is solitary or multisystem involvement.

17.9.5.1 Solitary or Single-System Involvement

To date, data involving optimal treatment of unifocal or multifocal involvement is still debated. Choice of therapy depends on the site of involvement. Single-system or solitary LCH does not have systemic symptoms such as weight loss or fever. Treatment modality includes single agent with prednisolone, or combined agents with vinblastine and prednisolone, curettage of bone lesions and topical therapy. Additionally, close observations may have opted in certain groups of patients. Localised skin lesions notable in younger patients traditionally regressed spontaneously. Other treatment options for cutaneous lesions include topical nitrogen mustard, topical cortico-

steroid and oral methotrexate. Patients with solitary involvement have demonstrated an excellent prognosis, with recovery reported in more than 80% of patients following initial treatment [166].

17.9.5.2 Multisystem Involvement

Patients with multisystem are further classified into low risk and high risk based on the involvement of 'risk organs' such as liver, spleen and bone marrow. Initial 6-week induction or intensive chemotherapy is initiated. Response at 6 weeks is assessed, and the continuation phase is advocated until a total of 12 months of treatment is completed. Patients with unsatisfactory responses will undergo a second induction phase or second-line chemotherapy regimens.

Low-risk multisystem patients are treated with systemic chemotherapy using vinblastine and prednisolone [167]. In refractory and recurrence cases, clofarabine, cytarabine and cladribine are used as salvage therapy [167].

17.9.5.3 Induction Chemotherapy

Induction, also called intensive chemotherapy, aims to achieve complete resolution of signs and symptoms. 66% of patients with high-risk organ involvement demonstrate favourable response by 6 weeks. In the combination therapy, prednisolone (40 mg/m^2/day) is prescribed orally for 4 weeks and then tapered down over 2 weeks, whereas vinblastine (6 mg/m^2) is given weekly for 6 weeks. The response to induction therapy is assessed after 6 weeks through history, physical examination and imaging. Post-treatment imaging used is MRI and PET.

17.9.5.4 Continuation Chemotherapy

The continuation phase is a vital part of the treatment of LCH. Chemotherapy using vinblastine and prednisolone is given over a total duration of 12 months. Patients with high-risk organ involvement have mercaptopurine added. Vinblastine and prednisolone are administered in 3-week cycles for a total of 12 months. Prednisolone (40 mg/m^2/day) is given orally on days 1–5 and repeated every 3 weeks, whereas vinblastine (6 mg/m^2) is given intravenously on day 1 and repeated every 3 weeks. In the high-risk group, daily mercaptopurine (50 mg/m^2/day) is given until the completion of the continuation phase.

17.9.5.5 Post-treatment Follow-Up

Upon completion of treatment, the patient is followed up regularly to assess the possibility of relapse. The initial assessment of response is at the end of 6 weeks of therapy. The response is regarded as good when there is no evidence of active disease, or continuous regression is noted. This is then followed by assessment at 12, 18 and 24 weeks, followed by every 3 months, every 2 years, every 6 months for 2 years and then yearly. Patients who failed to have regression of the disease or have active disease are subjected to second-line chemotherapy.

17.9.5.6 Relapsed or Refractory Disease

Low-risk patients who relapsed less than 12 months can be treated with single-agent cladribine for a six-month duration of therapy. Low-risk LCH patients who relapsed more than 12 months can be treated with vinblastine and prednisolone in combination with oral methotrexate and mercaptopurine. 85% of patients have been reported to show a second remission. High-risk LCH patients who relapsed are treated with clofarabine, which has demonstrated 90% survival rate.

References

1. Kanada KN, Merin MR, Munden A, Friedlander SF. A prospective study of cutaneous findings in newborns in the United States: correlation with race, ethnicity, and gestational status using updated classification and nomenclature. J Pediatr. 2012;161(2):240–5.
2. Martinez-Lopez A, Salvador-Rodriguez L, Montero-Vilchez T, et al. Vascular malformations syndromes: an update. Curr Opin Pediatr. 2019;31:747–53.
3. Kilcline C, Frieden IJ. Infantile hemangiomas: how common are they? A systematic review of the medical literature. Pediatr Dermatol. 2008;25(2):168–73.
4. Jacobs AH, Walton RG. The incidence of birthmarks in the neonate. Pediatrics. 1976;58(2):218–22.

5. Darrow DH, Greene AK, Mancini AJ, Nopper AJ. Diagnosis and management of infantile hemangioma. Paediatrics. 2015;136(4):1060–104.
6. Haggstrom AN, Drolet BA, Baselga E, et al., Hemangioma Investor Group. Prospective study of infantile hemangiomas, demographic, prenatal, and perinatal characteristics. J Pediatr. 2007;150(3): 291–294.
7. Hoornweg MJ, Smeulders MJ, Ubbink DT, van der Horst CM. The prevalence and risk factors of infantile hemangiomas: a case-control study in the Dutch population. Pediatr Perinat Epideniol. 2012;26(2):156–62.
8. Metry D, Heyer G, Hess C, et al., PHACE Syndrome Research Conference. Consensus statement on diagnostic criteria for PHACE syndrome. Pediatrics. 2009;124(5):1447–56.
9. Drollet BA, Swanson EA, Frieden IJ. Hemangioma Investigator Group. Infantile hemangiomas: an emerging health issue linked to an increased rate of low birth weight infants. J Pediatr. 2008;154(5):712–5.
10. Colonna V, Resta L, Napoli A, Bonifazi E. Placental hypoxia and neonatal hemangioma: clinical and histological observations. Br J Dermatol. 2010;162(1):208–9.
11. Greenberger S, Adini I, Boscolo E, Mulliken JB, Bischoff J. Targeting NF-kB in infantile hemangioma-derived stem cell reduces VEGF-A expression. Angiogenesis. 2010;13(4):327–35.
12. Li Q, Yu Y, Bischoff J, Mulliken JB, Olsen BR. Differential expression of CD146 in tissues and endothelial cells derived from infantile hemangioma and normal human skin. J Pathol. 2003;210(2):296–302.
13. Chang LC, Haggstrom AN, Drolet BA, et al., Hemangioma Investigator Group. Growth characteristics of infantile hemangioma: implications for management. Pediatrics. 2008;122(2):360–7.
14. Couto RA, Maclellan RA, Zurakowski D, Greene AK. Infantile hemangioma: clinical assessment of the involuting phase and implications for management. Plast Reconstr Surg. 2012;130(3):619–24.
15. Tollefson MM, Frieden IJ. Early growth of infantile hemangiomas: what parents photographs tell us. Pediatrics. 2012;130(2):e314–20.
16. Bauland CG, Luning TH, Smith JM, Zeebregts CJ, Spauwen PH. Untreated hemangiomas: growth pattern and residual lesions. Plast Reconstr Surg. 2011;127(4):1643–8.
17. Dubois J, Patriquin HB, Garel L, et al. Soft-tissue hemangiomas in infants and children: diagnosis using Doppler sonography. AJR Am J Roentgenol. 1998;171(1):247–52.
18. Kasarjian A, Zurakowski D, Dubois J, Paltiel HJ, Fishman SJ, Burrows PE. Infantile hepatic hemangiomas: clinical and imaging findings and their correlation with therapy. AJR Am J Roentgenol. 2004;182(3):785–95.
19. Flors L, Leiva-Salinas C, Maged IM, et al. MR imaging of soft-tissue vascular malformations: diagnosis, classification and therapy follow-up. Radiographics. 2011;31(5):1321–40.
20. Maguiness SM, Frieden IJ. Current management of infantile hemangiomas. Semin Cutan Med Surg. 2010;29(2):106–14.
21. Ezekowitz RA, Mulliken JB, Folkman J. Interferon alfa-2a therapy for life-threatening hemangiomas of infancy. N Engl J Med. 1992;326(22):1456–63.
22. White CW, Sondheimer HM, Crouch EC, Wilson H, Fan LL. Treatment of pulmonary hemangiomatosis with recombinant interferon alfa-2a. N Engl J Med. 1989;320(18):1197–200.
23. Leaute-Labrezel C, Dumas de la Roque E, Hubiche T, Boralevi F, et al. Propanolo for severe hemangiomas of infancy. N Engl J Med. 2008;358(24):2649–51.
24. Greenberger S, Yuan S, Walsh LA, et al. Rapamycin suppresses self-renewal and vasculogenic potential of stem cells isolated from infantile hemangioma. J Invest Dermatol. 2011;131(12):2467–76.
25. Mahajan D, Miller C, Hirose K, McCullough A, Yerian L. Incidental reduction in the size of liver hemangioma following use of VEGF inhibitor bevacizumab. J Hepatol. 2008;49(5):867–70.
26. Arneia JS, Mulliken JB. Resection of amblyogenic periocular hemangiomas: indications and outcomes. Plast Reconstr Surg. 2010;125(1):274–81.
27. Greene AK. Management of hemangiomas and other vascular tumours. Clin Plast Surg. 2011;38(1):45–63.
28. Mulliken JB, Fishman SJ, Burrows PE. Vascular anomalies. Curr Probl Surg. 2000;37(8):517–84.
29. Pryor SG, Lewis JE, Weaver AL, et al. Pediatric dermoid cysts of the head and neck. Otolaryngol Head Neck Surg. 2005;132:938–42.
30. McAvoy JM, Zuckerbraun L. Dermoid cysts of the head and neck in children. Arch Otolaryngol. 1976;102:529–31.
31. New GB, Erich JB. Dermoid cysts of the head and neck. Surg Gynecol Obstet. 1937;65:48–55.
32. Leveque H, Saraceno CA, Tang CK, et al. Dermoids cysts of the floor of mouth. Laryngoscope. 1979;89:296–305.
33. Min HJ, Hong SC, Kim KS. The usefulness of three-dimensional reconstruction computed tomography in the nasal dermoid cyst. J Craniofac Surg. 2016;27(3):819–20.
34. Cao L, Wang Y, Zhao L, Hu X, Cai C. Congenital dermoid inclusion cyst over the anterior fontanel in Chinese children. Clin Dysmorphol. 2020;29(2):81–5.
35. Khalid S, Ruge J. Considerations in the management of congenital cranial dermoid cysts. J Neurosurg Pediatr. 2017;21:1–5.
36. Moorthy NS, Arcot R. Thyroglossal duct cystmore than just an embryological remnant. Indian J Surg. 2011;73(1):28–31. https://doi.org/10.1007/s12262-010-0171-8.

37. Abuabara A, Baratto Filho F, Fuzza RF. Thyroglossal duct cyst. South Braz Dent J. 2010;7(2):244–6.
38. Jackie C, Andrew W, Robert H, Anna Z, Maciej Michalak R, Shane T, Marios L. Thyroglossal duct cysts: anatomy, embryology and treatment. Surg Radiol Anat. 2013;35:875–81.
39. Mondin V, Ferlito A, Muzzi E, Silver CE, Fagan JJ, Devaney KO, Rinaldo A. Thyroglossal duct cyst: personal experience and literature review. Auris Nasus Larynx. 2008;35(1):11–25.
40. David S, Fallat ME. Thyroglossal duct and other congenital midline cervical anomalies. Semin Pediatr Surg. 2006;15:70–5.
41. Ostlie DJ, Burjonrappa SC, Snyder CL, Watts J, Murphy JP, Gittes GK, Andrews WA, Sharp RJ, Goerge W. Thyroglossal duct infections and surgical outcomes. J Pediatr Surg. 2004;39:396–9.
42. Byard RW, Bourne AJ, Silver MM. The association of lingual thyroglossal duct remnants with sudden death in infancy. Int J Pediatr Otorhinolaryngol. 1990;20(2):107–12.
43. Brousseau VJ, Solares CA, Xu M, Krakovitz P, Koltai PJ. Thyroglossal duct cysts: presentation and managements in children versus adults. Int J Pediatr Otorhinolaryngol. 2003;67:1285–90.
44. Montgomery WW, Varvares MA, editors. Surgery of the neck, surgery of the larynx, trachea, esophagus and neck. Philadelphia: WB Saunders; 2002. p. 72–7.
45. Lilley JS, Lomenick JP. Delayed diagnosis of hypothyroidism following excision of a thyroglossal duct cyst. J Pediatr. 2013;162:427.
46. LiVolsi VA, Perzin KH, Savetsky L. Carcinoma arising in median ectopic thyroid (including thyroglossal duct tissue). Cancer. 1974;34:1303.
47. Radkowski D, Arnold J, Healy GB, et al. Thyroglossal duct remnants. Preoperative evaluation and management. Arch Otolaryngol Head Neck Surg. 1991;117:1378.
48. Brown RE, Harave S. Diagnostic imaging of benign and malignant neck masses in children-a pictorial review. Quant Imaging Med Surg. 2016;6:591.
49. Pelausa ME, Forte V. Sistrunk revisited: a 10-year review of revision thyroglossal duct surgery at Toronto's Hospital for Sick Children. J Otolaryngol. 1989;18(7):325–33.
50. Perkins JA, Inglis AF, Sie KC, Manning SC. Recurrent thyroglossal duct cysts: a 23-year experience and a new method for management. Ann Otol Rhinol Laryngol. 2006;115:850.
51. Blatt J, Snyderman C, Wollman MR, Mirro J Jr, Janecka IP, Albo VC, et al. Delayed resection in the management of nonorbital rhabdomyosarcoma of the head and neck in childhood. Med Pediatr Oncol. 1997;29:294–8.
52. Womer RB, Pressey JG. Rhabdomyosarcoma and soft tissue sarcoma in childhood. Current Opin Oncol. 2000;12:337–44.
53. Hawkins WG, Hoos A, Antonescu CR, Urist MJ, Leung DHY, Gold JS, et al. Clinicopathologic analysis of patients with adult rhabdomyosarcoma. Cancer. 2001;91(4):794–803.
54. Parham DM. Pathologic classification of rhabdomyosarcomas and correlation with molecular studies. Mod Pathol. 2001;14(5):506–14.
55. Raney RB, Anderson JR, Barr FG, Donaldson SS, Pappo AS, Qualman SJ, et al. Rhabdomyosarcoma and undifferentiated sarcoma in the first two decades of life: a selective review of the intergroup rhabdomyosarcoma study group experience and rationale for intergroup rhabdomyosarcoma study V. J Pediatr Hematol Oncol. 2001;23(4):215–20.
56. Hicks J, Flaitz C. Rhabdomyosarcoma of the head and neck in children. Oral Oncol. 2002;38:450–9.
57. Qualman SJ, Coffin CM, Newton WA, Hojo H, Triche TJ, Parham DM, et al. Intergroup rhabdomyosarcoma study: update for pathologists. Pediatr Dev Pathol. 1998;1:550–61.
58. Turner JH, Richmon JD. Head and neck rhabdomyosarcoma: a critical analysis of population-based incidence and survival data. Otolaryngol Head Neck Surg. 2011;145:967–73.
59. Sung L, Anderson JR, Arndt C, Raney RB, Meyer WH, Pappo AS. Neurofibromatosis in children with rhabdomyosarcoma: a report from the Intergroup Rhabdomyosarcoma study IV. J Pediatr. 2004;144:666–8.
60. Carnevale A, Lieberman E, Cárdenas R. Li-Fraumeni syndrome in pediatric patients with soft tissue sarcoma or osteosarcoma. Arch Med Res. 1997;28:383–6.
61. Jung A, Bechthold S, Pfluger T, Renner C, Ehrt O. Orbital rhabdomyosarcoma in Noonan syndrome. J Pediatr Hematol Oncol. 2003;25:330–2.
62. Smith AC, Squire JA, Thorner P, et al. Association of alveolar rhabdomyosarcoma with the Beckwith-Wiedemann syndrome. Pediatr Dev Pathol. 2001;4:550–8.
63. Grufferman S, Schwartz AG, Ruymann FB, Maurer HM. Parents' use of cocaine and marijuana and increased risk of rhabdomyosarcoma in their children. Cancer Causes Control. 1993;4:217–24.
64. O'Neill A, Watters K, Rahbar R, et al. Chapter: Sarcoma: rhabdomyosarcoma. In: Paediatric head and neck tumor. New York: Springer; 2014.
65. Crist WM, Anderson JR, Meza JL, et al. Intergroup rhabdomyosarcoma study-IV: results for patients with nonmetastatic disease. J Clin Oncol. 2001;19:3091–102.
66. Pietniczka-Załęska M. Rhabdomyosarcoma głowy i szyi u dzieci. Magazyn Otorynolaryngologiczny. 2006;(Suppl X):30–6.
67. Radzikowska J, Kukwa W, Kukwa A, et al. Rhabdomyosarcoma of the head and neck in children. Contemp Oncol (Pozn). 2015;19(2):98–107. https://doi.org/10.5114/wo.2015.49158.
68. Agamanopolis DP, Dasu S, Krill CE, et al. Tumours of the skeletal muscle. Hum Pathol. 1986;17:778–95.
69. Newton WA Jr, Soule EH, Hamoudi AB, et al. Histopathology of childhood sarcomas, intergroup

rhabdomyosarcoma studies I and II: clinicopathologic correlation. J Clin Oncol. 1988;6:67–75.
70. Breitfeld PP, Meyer WH. Rhabdomyosarcoma: new windows of opportunity. Oncologist. 2005;10:518–27.
71. Evangelista L, Panunzio A, Polverosi R, Ferretti A, Chondrogiannis S, Pomerri F, Rubello D, Muzzio PC. Early bone marrow metastasis detection: the additional value of FDG-PET/CT vs. CT imaging. Biomed Pharmacother. 2012;66:448–53.
72. Dasgupta R, Rodeberg DA. Update on rhabdomyosarcoma. Semin Pediatr Surg. 2012;21:68–78.
73. Crist W, Gehan EA, Ragab AH, et al. The third intergroup rhabdomyosarcoma study. J Clin Oncol. 1995;13:610–30.
74. Kazanowska B, Chybicka A. Postępowanie diagnostyczno-terapeutyczne w nowotworach tkanek miękkich u dzieci. Onkologia w Praktyce Klinicznej. 2007;3:680–98.
75. Arndt CA, Stoner JA, Hawkins DS, et al. Vincristine, actinomycin, and cyclophosphamide compared with vincristine, actinomycin, and cyclophosphamide alternating with vincristine, topotecan, and cyclophosphamide for intermediate-risk rhabdomyosarcoma: children's oncology group study D9803. J Clin Oncol. 2009;27:5182–8.
76. Admiraal R, van der Paardt M, Kobes J, Kremer LC, Bisogno G, Merks JH. High-dose chemotherapy for children and young adults with stage IV rhabdomyosarcoma. Cochrane Database Syst Rev. 2010:CD006669.
77. Peinemann F, Kröger N, Bartel C, Grouven U, Pittler M, Erttmann R, Kulig M. High-dose chemotherapy followed by autologous stem cell transplantation for metastatic rhabdomyosarcoma—a systematic review. PLoS One. 2011;6:e17127.
78. Daya H, Chan HS, Sirkin W, Forte V. Pediatric rhabdomyosarcoma of the head and neck: is there a place for surgical management? Arch Otolaryngol Head Neck Surg. 2000;126:468–72.
79. Stevens MC. Treatment for childhood rhabdomyosarcoma: the cost of cure. Lancet Oncol. 2005;6:77–84.
80. Mazzoleni S, Bisogno G, Garaventa A, et al. Outcomes and prognostic factors after recurrence in children and adolescents with nonmetastatic rhabdomyosarcoma. Cancer. 2005;104:183–90.
81. Raney RB Jr, Crist WM, Maurer HM, Foulkes MA. Prognosis of children with soft tissue sarcoma who relapse after achieving a complete response. A report from the Intergroup Rhabdomyosarcoma Study I. Cancer. 1983;52:44–50.
82. Saniasiaya J, Abdullah B, Ramli RR. Surgical management and outcome of juvenile nasopharyngeal angiofibroma in a single centre: a fifteen-year experience. Egypt J Ear Nose Throat Allied Sci. 2017;18:39–41.
83. Coutinho-Camillo CM, Brentani MM, Nagai MA. Genetic alterations in juvenile nasopharyngeal angiofibromas. Head Neck. 2008;30:390–400.
84. Biswas D, Saha S, Bera SP. Relative distribution of the tumours of ear, nose and throat in the paediatric patients. Int J Pediatr Otorhinolaryngol. 2007;71:801–5.
85. Schick B, Rippel C, Brunner C, et al. Numerical sex chromosome aberrations in juvenile angiofibromas: genetic evidence for an androgen-dependant tumour? Oncol Rep. 2003;10:1251–5.
86. Tewfil TL, Tan AK, Chowdhury K, et al. Juvenile nasopharyngeal angiofibroma. J Otolaryngol. 1999;38:145–51.
87. Liu Z, Wang J, Wang H, et al. Hormonal receptors and vascular endothelial growth factor in juvenile nasopharyngeal angiofibroma: immunohistochemical and tissue microarray analysis. Acta Otolaryngol. 2015;135(1):51–7.
88. Marshall AH, Bradley PJ. Management dilemmas in the treatment and follow-up of advanced juvenile nasopharyngeal angiofibroma. ORL. 2006;28:273–8.
89. Wu AW, Mowry SE, Vinuela F, Abemayor E, Wang MB. Bilateral vascular supply in juvenile nasopharyngeal angiofibromas. Laryngoscope. 2011;121(3):639–43.
90. Tang IP, Sashinder S, Gopala KG, Narayanan P. Juvenile nasopharyngeal angiofibroma in a tertiary centre: a ten-year experience. Singap Med J. 2009;50:261–4.
91. Leong SC. A systematic review of surgical outcomes for advanced juvenile nasopharyngeal angiofibroma with intracranial involvement. Laryngoscope. 2013;123(5):1125–31.
92. Boghani Z, Husain Q, Kanumuri VV, Khan MN, Sangvhi S, Liu JK, Eloy JA. Juvenile nasopharyngeal angiofibroma: a systematic review and comparison of endoscopic, endoscopic-assisted, and open resection in 1047 cases. Laryngoscope. 2013;123(4):859–69.
93. Midhilli R, Karci B, Akyildiz S. Juvenile nasopharyngeal angiofibroma: analysis of 42 cases and important aspects of endoscopic approach. Int J Paediatr Otorhinolaryngol. 2009;73(3):401–8.
94. Scholtz AW, Appenroth E, Kammen-Jolly K, et al. Juvenile nasopharyngeal angiofibroma: management and therapy. Laryngoscope. 2001;111(4):681–7.
95. Solares CA, Ong YK, Snyderman CH. Transnasal endoscopic skull base surgery: what are the limits? Curr Opin Otolaryngol Head Neck Surg. 2010;18(1):1–7.
96. Nicolai P, Berlucchi M, Tomenzoli D, et al. Endoscopic surgery for juvenile nasopharyngeal angiofibroma: when and how. Laryngoscope. 2003;113(5):775–82.
97. Ardehali MM, Samimi Ardestani SH, Yazdani N, et al. Endoscopic approach for excision of juvenile nasopharyngeal angiofibroma: complications and outcomes. Am J Otolaryngol. 2010;31(5):343–9.
98. Nicolai P, Villaret AB, Farina D, et al. Endoscopic surgery for juvenile nasopharyngeal angiofibroma: a critical review of indications after 46 cases. Am J Rhinol Allerg. 2010;24(2):e67–72.

99. Fagan JJ, Synderman CH, Carrau RL, Janecka IP. Nasopharyngeal angiofibromas: selecting a surgical approach. Head Neck. 1997;19(5):391–9.
100. Lee JT, Chen P, Safa A, et al. The role of radiation in the treatment of advanced juvenile angiofibroma. Laryngoscope. 2002;112(7):1213–20.
101. Kuppersmith RB, Teh BS, Donovan DT, et al. The use of intensity modulated radiotherapy for the treatment of extensive and recurrent juvenile nasopharyngeal angiofibroma. Int J Peadiatr Otorhinolaryngol. 2000;52(3):261–8.
102. Goepfert H, Cangir A, Ayala G, Eftekhari F. Chemotherapy of locally aggressive head and neck tumours in the paediatrics age group. Desmoid fibromatosis and nasopharyngeal angiofibroma. Am J Surg. 1982;144(4):437–44.
103. Schick B, Kahle G, Habler R, Draf W. Chemotherapy of juvenile nasopharyngeal angiofibroma-an alternative course for treatment? HNO. 1996;44(3):148–52.
104. Hwang HC, Mills SE, Patterson K, et al. Expression of androgen receptors in nasopharyngeal angiofibroma: an immunohistochemical study of 24 cases. Mod Pathol. 1998;11(11):1122–6.
105. Gates GA, Rice DH, Koopmann CF, Schuller DE. Flutamide-induced regression of angiofibroma. Laryngoscope. 1992;102(6):641–4.
106. Thakar A, Gupta G, Bhalla AS. Adjuvant therapy with flutamide for presurgical volume reduction in juvenile nasopharyngeal angiofibroma. Head Neck. 2011;33(11):1747–53.
107. Tosum F, Onerci M, Durmaz A, Ugurel S. Spontaneous involution of nasopharyngeal angiofibroma. J Craniofac Surg. 2008;19(6):796–9.
108. Kennedy TL, Whitaker M, Pellitteri P, Wood WE. Cystic hygroma/lymphangioma: a rational approach to management. Laryngoscope. 2001;111:1929–37.
109. Bagrodia N, Defnet AM, Kandel JJ. Management of lymphatic malformations in children. Curr Opin Pediatr. 2015;27:356–63.
110. Brouillard P, Boon L, Vikkula M. Genetics of lymphatic anomalies. J Clin Invest. 2014;124:898–904.
111. Colletti G, Valassina D, Bertossi D, et al. Contemporary management of vascular malformations. J Oral Maxillofac Surg. 2014;72:510–28.
112. Schoinohoriti OK, Theologie-Lygidakis N, Tzerbos F, Iatrou I. Lymphatic malformations in children and adolescents. J Craniofac Surg. 2012;23:1744–7.
113. Bajaj Y, Hewitt R, Ifeacho S, Hartley BE. Surgical excision as primary treatment modality for extensive cervicofacial lymphatic malformations in children. Int J Pediatr Otorhinolaryngol. 2011;75:673–7.
114. Balakrishnan K, Edwards TC, Perkins JA. Functional and symptom impacts of pediatric head and neck lymphatic malformations: developing a patient-derived instrument. Otolaryngol Head Neck Surg. 2012;147:925–31.
115. Berg EE, Sobol SE, Jacobs I. Laryngeal obstruction by cervical and endolaryngeal lymphatic malformations in children: proposed staging system and review of treatment. Ann Otol Rhinol Laryngol. 2013;122:575–81.
116. Puig S, Casati B, Staudenherz A, Paya K. Vascular low-flow malformations in children: current concepts for classification, diagnosis and therapy. Eur J Radiol. 2005;53:35–45.
117. Tempero RM, Hannibal M, Finn LS, et al. Lymphocytopenia in children with lymphatic malformation. Arch Otolaryngol Head Neck Surg. 2006;132:93–7.
118. Koelblinger C, Herold C, Nemec S, et al. Fetal magnetic resonance imaging of lymphangiomas. J Perinat Med. 2013;41:437–43.
119. Jamal N, Ahmed S, Miller T, et al. Doxycycline sclerotherapy for pediatric head and neck macrocystic lymphatic malformations: a case series and review of the literature. Int J Pediatr Otorhinolaryngol. 2012;76:1127–31.
120. Perkins JA, Manning SC, Tempero RM, et al. Lymphatic malformations: review of current treatment. Otolaryngol Head Neck Surg. 2010;142:795–803.
121. Gilony D, Schwartz M, Shpitzer T, et al. Treatment of lymphatic malformations: a more conservative approach. J Pediatr Surg. 2012;47:1837–42.
122. Adams MT, Saltzman B, Perkins JA. Head and neck lymphatic malformation treatment: a systematic review. Otolaryngol Head Neck Surg. 2012;147:627–39.
123. Thottam PJ, Al-Barazi R, Madgy DN, Rozzelle A. Submucosal resection of a microcystic oropharyngeal lymphatic malformation using radiofrequency ablation. Int J Pediatr Otorhinolaryngol. 2013;77:1589–92.
124. Kim SW, Kavanagh K, Orbach DB, et al. Long-term outcome of radiofrequency ablation for intraoral microcystic lymphatic malformation. Arch Otolaryngol Head Neck Surg. 2011;137:1247–50.
125. Akyuz C, Atas E, Varan A. Treatment of a tongue lymphangioma with sirolimus after failure of surgical resection and propranolol. Pediatr Blood Cancer. 2014;61:931–2.
126. Danial C, Tichy AL, Tariq U, et al. An open-label study to evaluate sildenafil for the treatment of lymphatic malformations. J Am Acad Dermatol. 2014;70:1050–7.
127. Ozeki M, Kanda K, Kawamoto N, et al. Propranolol as an alternative treatment option for pediatric lymphatic malformation. Tohoku J Exp Med. 2013;229:61–6.
128. Damaskos C, Garmpis N, Manousi M, et al. Cystic hygroma of the neck: single center experience and literature review. Eur Rev Med Pharmacol Sci. 2017;21(21):4918–23.
129. Grasso DL, Pelizzo G, Zocconi E, Schleef J. Lymphangiomas of the head and neck in children. Acta Otorhinolaryngol Ital. 2008;28(1):17–20.
130. Noia G, Maltese PE, Zampino G, et al. Cystic hygroma: a preliminary genetic study and a short review from the literature. Lymphat Res Biol. 2019;17(1):30–9. https://doi.org/10.1089/lrb.2017.0084.

131. García Carretero R, Rodriguez-Maya B, Vazquez-Gomez O. Non-surgical treatment of a relapsed cystic hygroma in an adult. BMJ Case Rep. 2017;2017:bcr2016218783. Published 2017 May 22. https://doi.org/10.1136/bcr-2016-218783.
132. Mitsukawa N, Satoh K. New treatment for cystic lymphangiomas of the face and neck: cyst wall rupture and cyst aspiration combined with sclerotherapy. J Craniofac Surg. 2012;23(4):1117–9. https://doi.org/10.1097/SCS.0b013e31824e6d20.
133. Aluffi Valletti P, Brucoli M, Boffano P, et al. A single-center experience in the management of head and neck lymphangiomas. Oral Maxillofac Surg. 2020;24(1):109–15.
134. Zheng JW, Qin ZP, Zhang ZY. [Management of lymphatic malformations in oral and maxillofacial regions: the rationale according to the new classification]. Shanghai Kou Qiang Yi Xue. 2005;14(6):553.
135. Wang Y, Li X. Lin Chung Er Bi Yan Hou Tou Jing Wai Ke Za Zhi. 2015;29(11):1049–52.
136. Bleyer A, Viny A, Barr R. Cancer in 15- to 29-year-olds by primary site. Oncologist. 2006;11:590–601.
137. Spitz MR, Sider JG, Johnson CC, Butler JJ, Pollack ES, et al. Ethnic patterns of Hodgkin's disease incidence among children and adolescents in the United States, 1973-82. J Natl Cancer Inst. 1986;2:235–9.
138. Gaini RM, Romagnoli M, Sala A, et al. Lymphomas of head and neck in pediatric patients. Int J Pediatr Otorhinolaryngol. 2009;73:65–70.
139. Lukes RJ, Butler JJ. The pathology and nomenclature of Hodgkin's disease. Cancer Res. 1966;26:1063–83.
140. Reiter A. Diagnosis and treatment of childhood non-Hodgkin lymphoma. Hematol Am Soc Hematol Educ Prog. 2007;2007:285–96.
141. Oguz A, Karadeniz C, Temel EA, Citak EC, Okur FV. Evaluation of peripheral lymphadenopathy in children. Pediatr Hematol Oncol. 2006;23:549–61.
142. Roh JL, Huh J, Moon HN. Lymphomas of the head and neck in the pediatric population. Int J Pediatr Otorhinolaryngol. 2007;71:1471–7.
143. Weisberger EC, Davidson DD. Unusual presentations of lymphoma of the head and neck in childhood. Laryngoscope. 1990;100:337–42.
144. Millot F, Robert A, Bertrand Y, Mechinaud F, et al. Cutaneous involvement in children with acute lymphoblastic leukemia or lymphoblastic lymphoma. The Children's Leukemia Cooperative Group of the European Organization of Research and Treatment of Cancer (EORTC). Pediatrics. 1997;100:60–4.
145. Hamilton VM, Norris C, Bunin N, Goldwein JW, Bunin GR, Lange B, et al. Cyclophosphamide-base, seven-drug hybrid and low-dose involved field radiation for the treatment of childhood and adolescent Hodgkin disease. J Pediatr Hematol Oncol. 2001;23:84–8.
146. Sagar TG, Chandra A, Raman SG. Childhood Hodgkin disease treated with COPP/ABV hybrid chemotherapy: a progress report. Med Pediatr Oncol. 2003;40:66–9.
147. Reiter A, Schrappe M, Parwaresch R, Henze G, Muller-Weihrich S, Sauter S, et al. Non-Hodgkin lymphoma in childhood and adolescence: results of a treatment stratified for biologic subtypes and stage—a report of the Berlin-Frankfurt-Munster group. J Clin Oncol. 1995;13:359–72.
148. Buchmann L, Emami A, Wei JL. Primary head and neck Langerhans cell histiocytosis in children. Otolaryngol Head Neck Surg. 2006;135(2):312–7.
149. Martini A, Aimoni C, Trevisani M, et al. Langerhans cell histiocytosis: report of a case with temporal localization. Int J Pediatr Otorhinolaryngol. 2000;55:51–6.
150. Boston M, Derkay CS. Langerhans cell histiocytosis of the temporal bone and skull base. Am J Otolaryngol. 2002;23(4):46–248.
151. Malpas JS. Langerhans cell histiocytosis in adults. Hematol Oncol Clin North Am. 1998;12(2):259–68.
152. De Brito Macedo Ferreira LM, de Carvalho JD, Pereira ST, et al. Histiocytosis X of the temporal bone. Rev Bras Otorrinolaringol. 2006;72:575.
153. Egeler RM, Annels NE, Hogendoorn PC. Langerhans cell histiocytosis: a pathologic combination of oncogenesis and immune dysregulation. Pediatr Blood Cancer. 2004;42(5):401–3.
154. Egeler RM, Favara BE, van Meurs M, Laman JD, Claassen E. Differential in situ cytokine profiles of Langerhans-like cells and T cells in Langerhans cell histiocytosis: abundant expression of cytokines relevant to disease and treatment. Blood. 1999;94(12):4195–201.
155. Willman CL, Busque L, Griffith BB, et al. Langerhans'-cell histiocytosis (histiocytosis X)—a clonal proliferative disease. N Engl J Med. 1994;331(3):154–60.
156. Egeler RM, Katewa S, Leenen PJ, Beverley P, Collin M, Ginhoux F, Arceci RJ, Rollins BJ. Langerhans cell histiocytosis is a neoplasm and consequently its recurrence is a relapse: in memory of bob Arceci. Pediatr Blood Cancer. 2016;63:1704–12.
157. Shimakage M, Sasagawa T, Kimura M, et al. Expression of Epstein-Barr virus in Langerhans' cell histiocytosis. Hum Pathol. 2004;35:862–8.
158. Roden AC, Hu X, Kip S, et al. BRAF V600E expression in Langerhans cell histiocytosis clinical and immunohistochemical study on 25 pulmonary and 54 extrapulmonary cases. Am J Surg Pathol. 2014;38(4):548–51.
159. Bayazit A, Sirikci A, Bayaram M, Kanlikama M, Demir A, et al. Eosinophilic granuloma of the temporal bone. Auris Nasus Larynx. 2001;28:99–102.
160. Cochrane LA, Prince M, Clarke K. Langerhans' cell histiocytosis in the pediatric population: presentation and treatment of head and neck manifestations. J Otolaryngol. 2003;32(1):33–7.
161. Azouz EM, Saigal G, Rodriguez MM, Podda A. Langerhans' cell histiocytosis: pathology, imaging and treatment of skeletal involvement. Pediatr Radiol. 2005;35:103–15.

162. Modest MC, Garcia JJ, Arndt CS, Carlson ML. Langerhans cell histiocytosis of the temporal bone: a review of 29 cases at a single center. Laryngoscope. 2016;126:1899–904.
163. Phillips M, Allen C, Gerson P, McClain K. Comparison of FDG-PET scans to conventional radiography and bone scans in management of Langerhans cell histiocytosis. Pediatr Blood Cancer. 2009;52:97–101.
164. Agarwal K, Seth R, Behra A, Jana M, Kumar R. 18F-Fluorodeoxyglucose PET/CT in Langerhans cell histiocytosis: spectrum of manifestations. Jpn J Radiol. 2016;34:267–76.
165. Daldrup H, Franzius C, Link T, Laukamp D, et al. Whole-body MR imaging for detection of bone metastases in children and young adults: comparison with skeletal scintigraphy and FDG PET. Am J Roentgenol. 2001;177(1):229–36.
166. Titgemeyer C, Grois N, Minkov M, et al. Pattern and course of single-system disease in Langerhans cell Histiocytosis data from the DAL-HX-83 abd 90-study. Med Pediatr Oncol. 2001;37(2): 108–14.
167. Degar BA, Fleming MD, Rollins BJ, et al. Histiocytoses. In: Orkin SH, Fisher DE, Ginsburg D, Look AT, Lux SE, Nathan DG, editors. Nathan and Oski's hematology and oncology of infancy and childhood. 8th ed. Philadelphia, PA: Elsevier Saunders; 2015. p. 2100–22.

18 Miscellaneous Head and Neck Surgery and the Surgical Steps

Norhafiza Mat Lazim

18.1 Excision of the Brachial Cyst

Brachial cyst is a common ENT presentation in young and middle-aged patients. Typically, a patient presents with a lateral neck mass, which slowly increases in size. It rarely causes symptoms, but infection and enlarging mass can cause some discomfort, pain and cosmesis concern especially in female patients' group. Clinical examination shows the mass that is located anterior to the anterior border of sternocleidomastoid muscle and occupies levels II and III of the neck regions. It is mostly soft and fluctuant in nature, and the transillumination test is positive. In some cases where it has been a long-standing presentation, the mass may feel firm on palpation.

The main treatment of a branchial cyst is surgical excision. In selected cases of a long-standing branchial cyst, especially in elderly patients, suspicion of coexisting malignancy should be considered. A study suggests that in patients older than 35 years, a cystic lateral neck mass should be considered potentially malignant [1]. The author reported that of the total 135 patients preoperatively diagnosed with lateral neck mass, a malignant post-operative histopathological diagnosis was revealed in 15% of cases. Thus, the clinician should be alert that the branchial cyst is a great mimicker of malignancy.

Initial diagnosis of a cervical branchial cleft cyst on the basis of the clinical examination should always be confirmed by means of ultrasonography. The ultrasonography gives detailed assessment of the mass in relation to major vessels of the neck, i.e. carotid artery and internal jugular vein. This information can also be used to guide the dissection during the surgery. In a huge cyst with a long-standing history, a CT scan of the neck would be ideal to assess the detailed nature of the mass, the border and the relationship to critical neurovascular structures of the neck.

In case of suspicion of a coexisting infection, or in cases of highly cystic lesion, fine needle aspiration cytology (FNAC) under ultrasound control is recommended [2]. Generally, a FNAC is recommended in all cystic neck lumps to rule out malignancy [3]. Complete excision of the branchial cyst under general anaesthesia is the treatment of choice for symptomatic cases [4]. The surgery of a branchial cyst may cause complications to structures like last four cranial nerves, IJV and carotid artery as the cyst is commonly located at levels II and III of the neck.

18.1.1 Case Illustration 1

This is a 35-year-old Malay male presented with a history of left neck mass for 3-year dura-

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N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_18

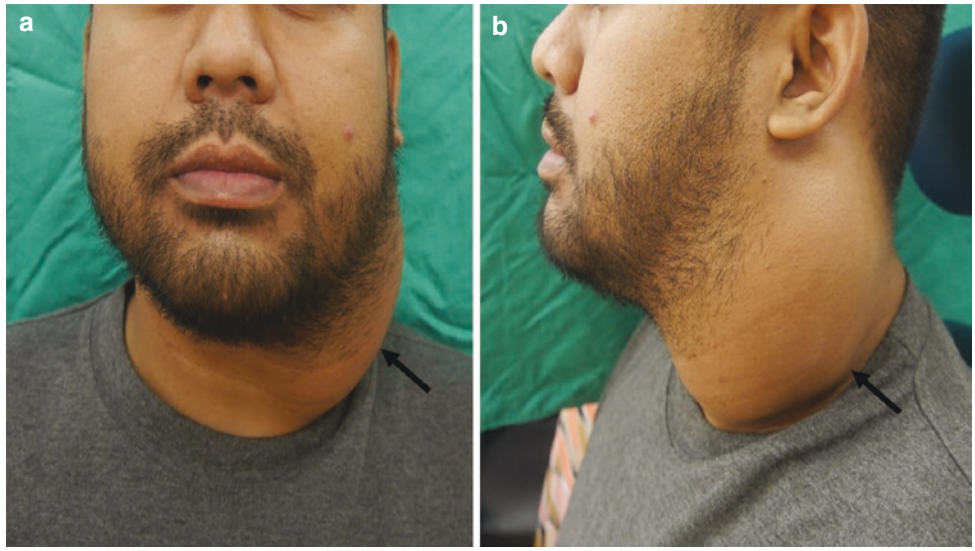

Fig. 18.1 The neck mass measures 10.0 cm × 6.0 cm and is positive for transillumination: (**a**) anterior view and (**b**) lateral view

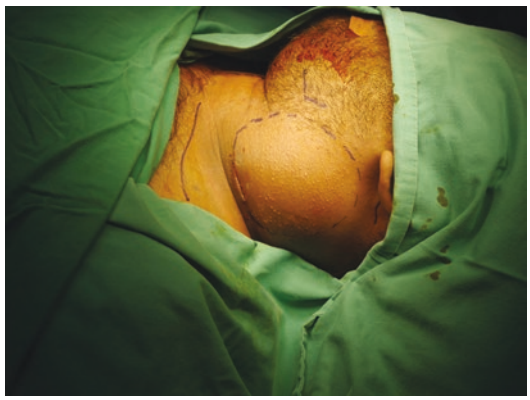

Fig. 18.2 The border of the mass is drawn in dotted lines. The angle of mandible and clavicle are also outlined

tion. The mass slowly increases in size and causes him discomfort and mild difficulty in swallowing. There was no other significant symptom. Clinical examination revealed a 10.0 cm × 6.0 cm in size, soft to firm in consistency (Fig. 18.1), and the transillumination test is positive. The imaging showed a heterogenous mass, well encapsulated medial to the sternocleidomastoid muscle. The mass has displaced the carotid sheath medially.

The FNAC confirmed that it was a branchial cyst. He was planned for excision of the branchial cyst under general anaesthesia.

18.1.2 Surgical Steps

Step 1: Patient positioning

Patient lies supine with neck hyperextended and turned contralaterally. The area is cleaned with diluted chlorhexidine or povidone. The draping is done with sterile towel.

Step 2: Skin incision and landmark marking

A pen marker is used to draw the landmarks. This includes mandible, border of mass, sternocleidomastoid muscle and clavicle (Fig. 18.2).

Step 3: Skin flap

A subplatysmal skin flap is raised using a blade size 11. An assistant assists in retracting the flap and skin laterally together with SCM. A retractor is used to retract the SCM and lateral tissue (Fig. 18.3).

Step 4: Mass dissection

The dissection continues at around the border of the mass. The mass is meticulously dissected while lifting the mass (Fig. 18.3).

Step 5: Deep dissection

The dissection continues to the deep and medial aspect of the mass. The sternomastoid muscle is retracted laterally (Figs. 18.4 and 18.5). The carotid artery, IJV and vagus nerve are identified and retracted away from the mass to avoid inadvertent injury like transection or puncture on these structures.

Step 6: Carotid sheath isolation

The carotid artery wall is a thicker wall in contrast to the IJV wall, which can be easily punctured and results in bleeding. The IJV also has many small branches that can be easily transected during the dissection. Thus, a meticulous dissection is necessary when delineating the tissue and fascia layers on the IJV (Figs. 18.6 and 18.7).

The mass is retracted superiorly during the dissection so as to facilitate the tissue medial and deep to the cyst (Fig. 18.5). The capsule of the cyst is thick, and the Allis forceps can be applied to hold the tissue capsule nicely.

Step 7: Vagus nerve

Vagus nerve resides in between the IJV and carotid artery. Together they are enveloped by a thin carotid sheath. These structures are deep and medial to the branchial cyst and need to be identified and preserved during dissection (Figs. 18.6 and 18.7).

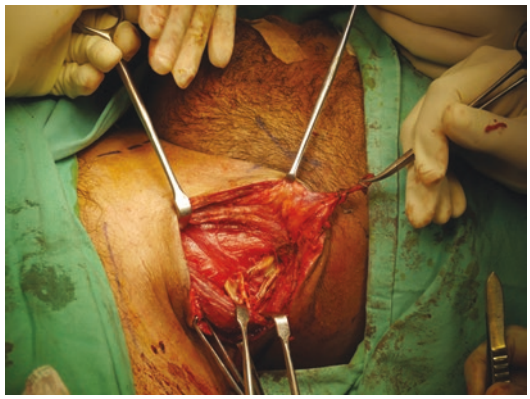

Fig. 18.3 The skin flap is raised, and sternocleidomastoid muscle is visible. The skin flap is retracted superiorly and laterally

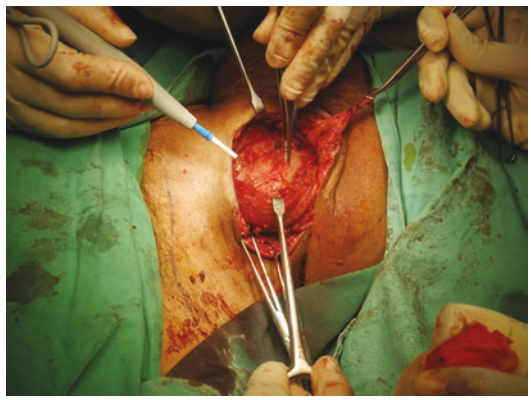

Fig. 18.4 The sternomastoid muscle is retracted laterally exposing the mass capsule

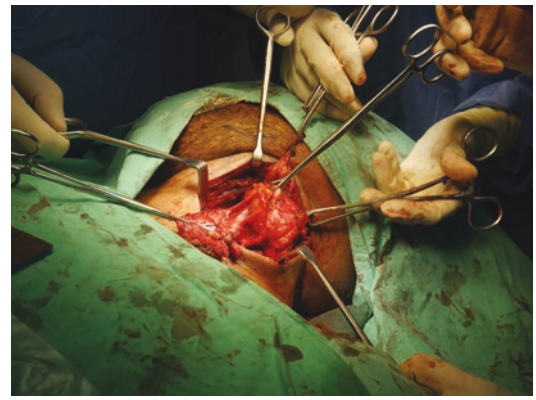

Fig. 18.5 The mass with its capsule is dissected and retracted superiorly

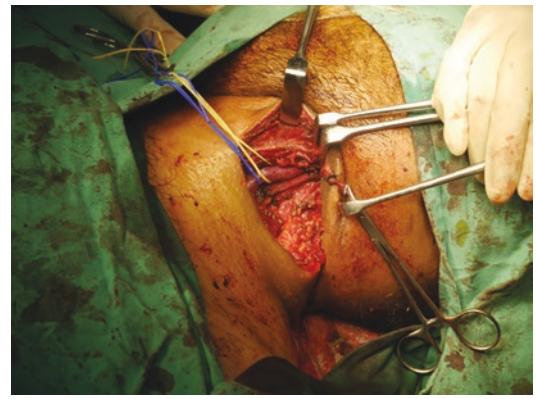

Fig. 18.6 The mass is out, leaving the surgical bed with the IJV and carotid artery in situ

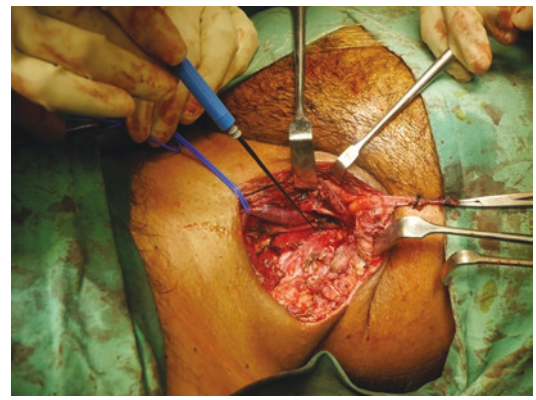

Fig. 18.7 The vagus nerve is located in between the IJV and carotid artery. The nerve functionality is tested with a nerve stimulator probe

Step 8: Homeostasis

Once the mass is removed, the surgical bed is inspected for any active bleeding. If any bleeder is identified, either ligaclip or bipolar cautery is used to stop the bleeding. The wound mass is irrigated with warm saline to reinspect for residual bleeding, before the wound closure.

Step 9: Drain and skin closure

A size 10 Redivac drain is secured. The drain is anchored to the skin with a 2.0 silk non-absorbable suture. The wound is closed in two layers with a 3.0 silk absorbable suture. The skin is sutured subcuticularly with a 3.0 white Vicryl or Prolene.

Another case of left branchial cyst (Fig. 18.8) is presented who had surgical excision. The scar is inline with the neck skin crease (Fig. 18.9). This improves the aesthetic post-operatively.

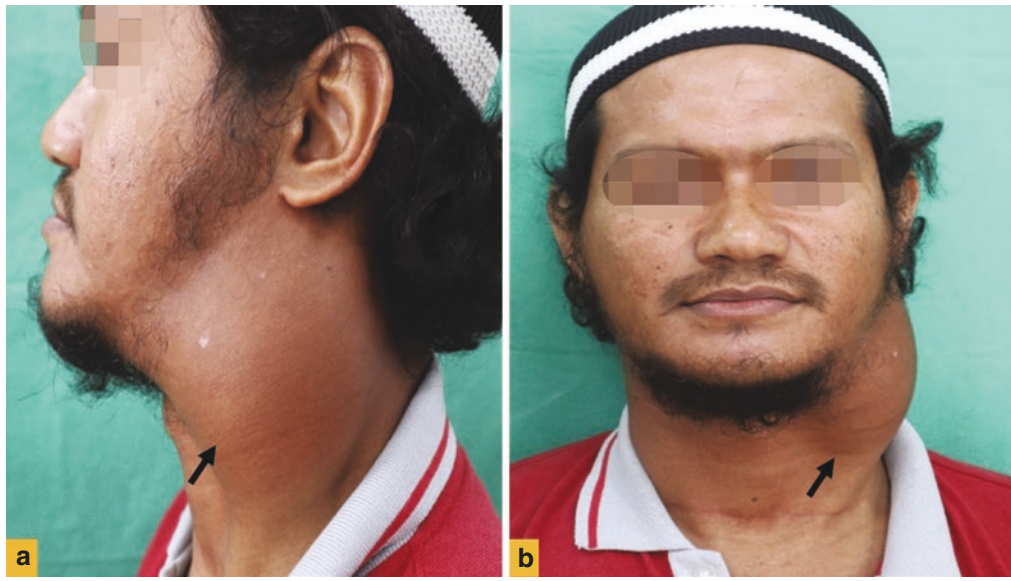

Fig. 18.8 The left branchial cyst in a young Malay male: (**a**) lateral view and (**b**) anterior view

Fig. 18.9 Post-surgical excision of left branchial cyst: (**c**) at 1-week follow-up and (**d**, **e**) at 3-month follow-up

18.2 Case Illustration 2

18.2.1 Voice Prosthesis Insertion During Total Laryngectomy Case

Total laryngectomy results in loss of voice, dysphagia and impairment of olfaction. Vocal rehabilitation plays an important role in the management of laryngectomized patients. Generally, voice prosthesis can be placed in the patient during the initial total laryngectomy surgery or as a second surgery. This primary TEP versus secondary TEP has its own merits and demerits. At a centre where the prosthesis is available, the primary TEP is preferable as it gives immediate post-operative vocalization. This is highly desired by the patients. The primary TEP and voice prosthesis insertion are preferable as it can give immediate and reliable voice, and there is no need for second general anaesthesia which will add more risks and complications.

This is a case of a 53-year-old Malay gentleman with diagnosed carcinoma larynx and T3 staging and who underwent total laryngectomy with bilateral anterolateral neck dissection. Intraoperatively, after removal of larynx and neck dissection, voice prosthesis is inserted. This is primary puncture of the prosthesis. For secondary puncture, the prosthesis is inserted at a later date of surgery.

The prosthesis is prepared on the sterile table near the patient and checked for its functioning. The accessories are a loading tube, an inserter, pharyngeal protector, guide wire with trocar and the prosthesis itself (Fig. 18.10).

The pharyngeal protector is placed at the cut end of pharynx (Figs. 18.11, 18.12, 18.13 and 18.14) to guide the wire insertion from the trachea side. The tube in the stoma is secured, and preoxygenation is done to allow manipulation. Trocar will be placed 1.0 cm below the mucocutaneous junction at the tracheal mucosa. The wire is placed into the trocar and pushed through so that it will come off through the pharyngeal protector on proximal side.

The closure of neopharynx is performed in three layers (Fig. 18.15). The first layer is the mucosal approximation via a Connell stitch suturing (Fig. 18.16). Secondly, the submucosal layer closure is performed. Lastly, the tissue and muscles are approximated (Fig. 18.17).

Post-operatively, the patient is allowed to use the prosthesis as early as day 1. This is to

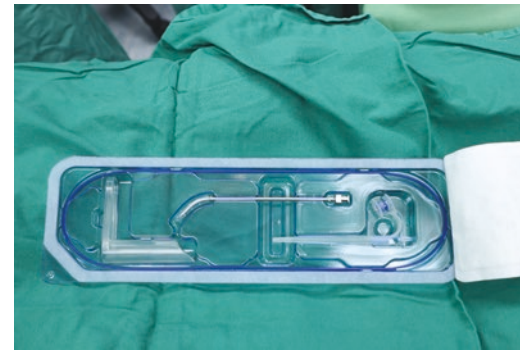

Fig. 18.10 Provox voice prosthesis set with a pharyngeal protector, a guide wire and a trocar

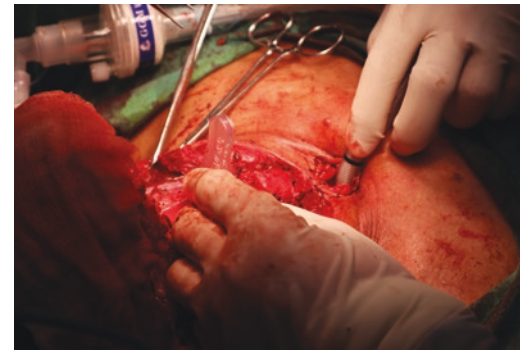

Fig. 18.11 Pharyngeal protector is placed at the pharyngeal site before the creation of neopharynx. The intubation tube is stabilized

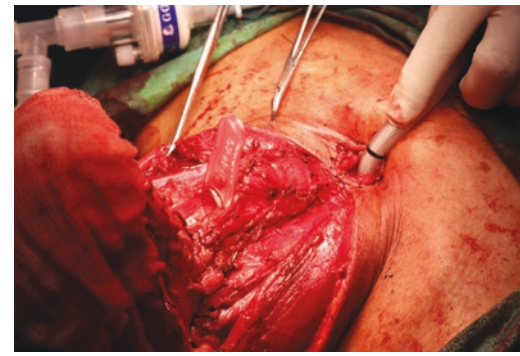

Fig. 18.12 Pharyngeal protector is placed at the pharyngeal site before the creation of neopharynx. The intubation tube is stabilized

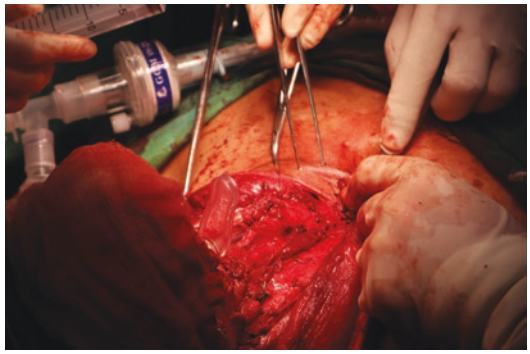

Fig. 18.13 Pharyngeal protector is placed at the proximal part of the open pharyngeal area

Fig. 18.14 Pharyngeal protector is inserted at the proximal end where the pharynx is open to safe guide the insertion of the trocar and prosthesis

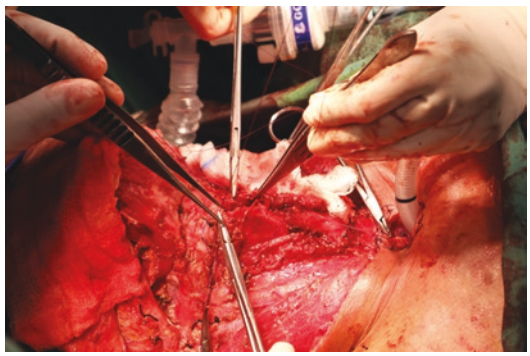

Fig. 18.15 The pharyngeal closure is performed by using three-layer closure. This is done after the prosthesis has been stabilized. The mucosa, submucosa and subcutaneous tissue are sutured by Connell stitching technique

encourage an early correct technique and better vocalization. Once the wound has dried and healed, the patient can use the prosthesis over the 24-h period.

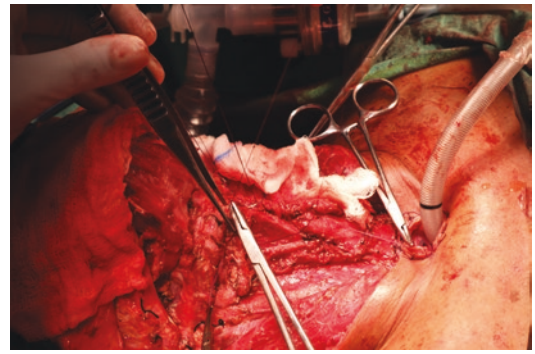

Fig. 18.16 Pharyngeal closure for neopharynx creation by performing a continuous Connell suturing technique

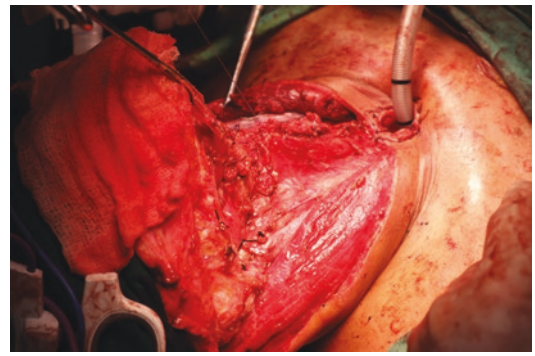

Fig. 18.17 Formation of neopharynx; the last layer of muscle is sutured to secure the neopharynx

18.3 Stomatoplasty

Stomal stenosis is a dreadful complication of total laryngectomy. It compromises the patient's breathing as well as complicates the cleaning of voice prosthesis. Risk factors of stoma stenosis include persistent infection post TL, patient who had previous chemoradiation, higher stage tumour or patient with multiple comorbidities such as diabetes. Medical treatment such as use of dilator or stenting can be used at night-time to avoid voicing interruption during daytime. If treatment fails at 4–6 weeks, the surgical revision, i.e. stomatoplasty, can be performed.

There are a few techniques of stomatoplasty that can be practised by the treating clinician. These include anterior advancement flap, V-Y flap, etc. Here, we describe a technique using anterior V-Y advancement flap.

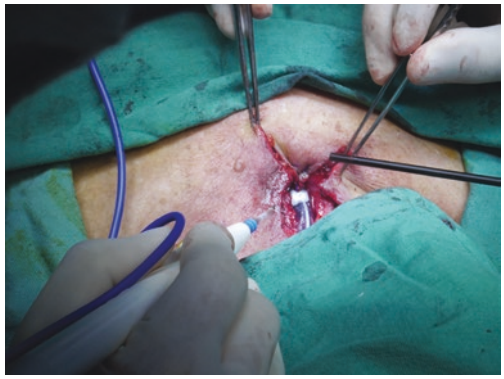

Fig. 18.18 The monopolar is used to undermine the tissue underneath the skin flap. The tracheal end and skin have been refreshened

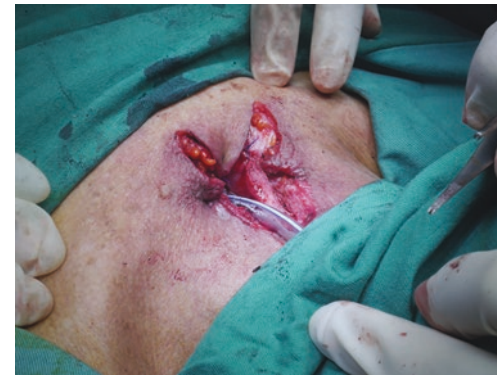

Fig. 18.19 The V cut has been made on the inferior skin part, and the edge of the stoma has been refreshened

Step 1: Patient lies supine with smaller intubation tube used for GA. This will allow ample surgical access for dissection and manipulation.

Step 2: The edges of trachea and skin are refreshened using a blade size 11, a monopolar cautery or a small tissue scissors. We prefer to use a monopolar cautery (Fig. 18.18).

Step 3: The trachea wall is undermined, and tissue is dissected away from the wall, exposing two tracheal rings. If the voice prosthesis is in situ, the posterior skin and trachea wall at posterior part overlying the prosthesis is leaving intact. This is to facilitate the tracheal cut.

Step 4: The V incision on the anterior skin is done with a blade. The flap is elevated anteroinferiorly (Fig. 18.19).

The cautery is used to dissect the tissue. The Colorado tip is preferable as it allows fine dissection and easy control and handling. The subcutaneous tissue dissection is performed under the 'V' skin incision and elevated.

The trachea edge is refreshened. The tracheal cut is made inferiorly at 6 o'clock. The trachea will splay open. The skin apex is retracted superiorly and attached and sutured to the apices of splayed tracheal wall. By doing this, the tracheal wall diameter is widened.

The suturing of the new stoma edge is carried out using a Dafilon 3.0 by interrupted sutures (Fig. 18.20). During suturing, the assistant needs to adjust the intubation tube to provide space for suturing. A meticulous suturing is performed to avoid excessive tractions and tissue damage that can cause significant scarring.

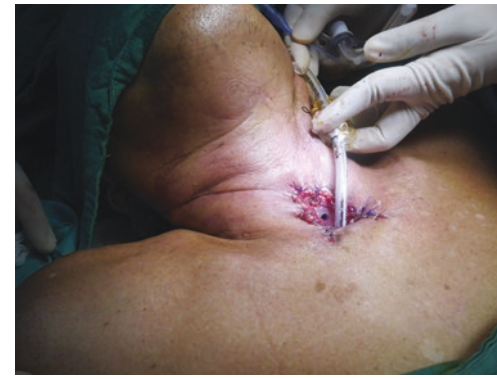

Fig. 18.20 The new stoma and V skin flap have been sutured. The prosthesis is visualized in situ

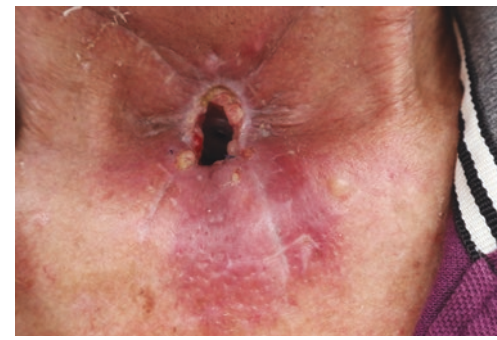

Fig. 18.21 The new stoma at 4 weeks post-operatively with Provox prosthesis in situ

Post-operatively, the patient is able to use his Provox prosthesis better as the stoma has widened (Fig. 18.21).

18.4 Submandibulectomy with Abdominal Fat Graft

This is the case of a 35-year-old Malay lady with a history of right submandibular swelling for 3 years. She is also a newly diagnosed diabetic patient. Clinical examination revealed a firm mass at the right submandibular area measuring 6.0 cm × 4.0 cm (Fig. 18.22). It is mobile and ballottable. The FNAC reported as benign salivary gland tumours. The ultrasound showed a homogenous mass with well-defined capsule. Patient was planned for a submandibulectomy with dermal fat graft as the mass is huge. This can cause significant cosmesis embarrassment postoperatively as retromandibular depression can be disfiguring, especially in a young female patient.

Intraoperatively, a regular transcervical skin incision is made with a scalpel along the skin crease two finger breadths below the inferior border of mandible (Fig. 18.23). The subplatysmal skin flap is raised (Figs. 18.24 and 18.25). The dissection continues and exposes the submandibular mass and its capsule. The marginal mandibular nerve should be identified and preserved (Fig. 18.26).

The dissection continues around the glands (Figs. 18.27 and 18.28). The facial artery and vein are ligated, anterior and posterior to the mass. The LigaSure, an ultrasonic appliance, is used to dissect the tissue inferiorly below the submandibular mass (Fig. 18.29). The lingual nerve and hypoglossal nerve need to be identified and preserved before the submandibular mass is excised (Figs. 18.30 and 18.31). The

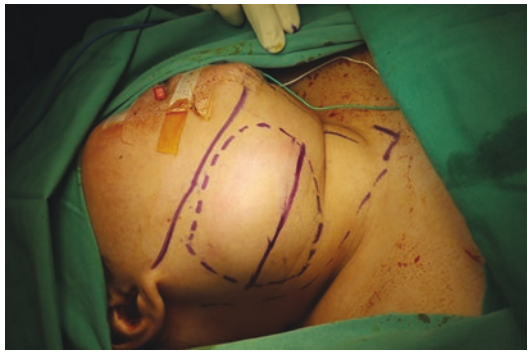

Fig. 18.22 The border of submandibular mass is marked as a dotted line. The skin incision is at the epicentre of the mass. The incision is at two finger breadths below the angle of mandibular. This is to avoid marginal mandibular nerve paresis

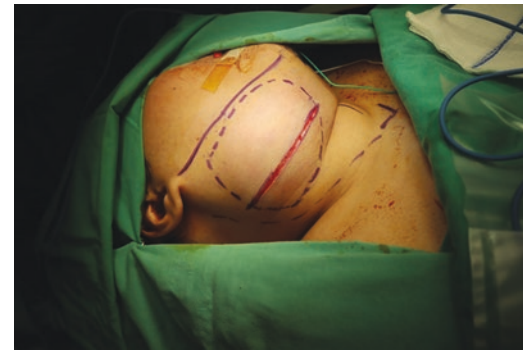

Fig. 18.23 The skin incision is made with a blade size 11

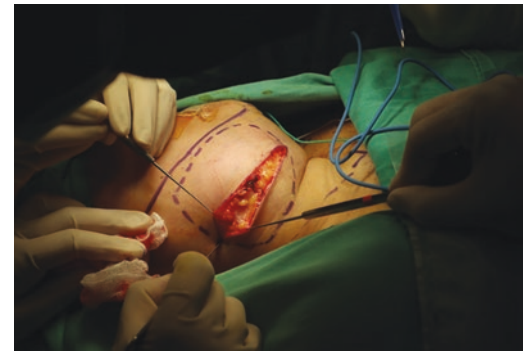

Fig. 18.24 The skin flap is raised while observing for platysma muscle

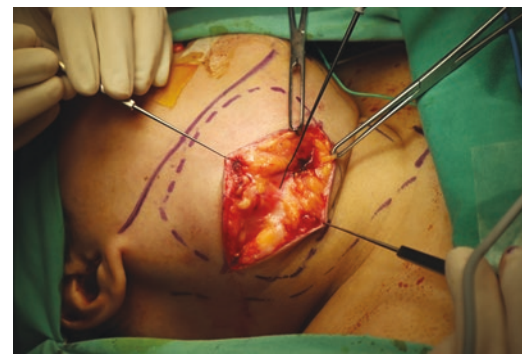

Fig. 18.25 The platysma muscle is very thin and is visualized beneath the subcutaneous and fatty tissue

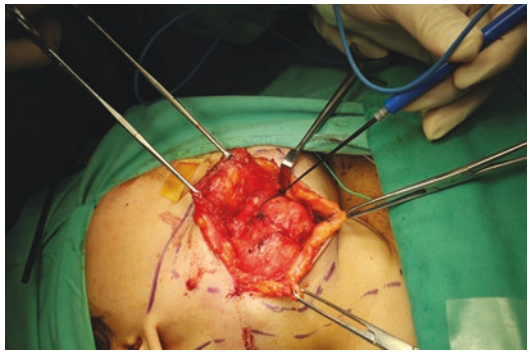

Fig. 18.26 The platysma flap has been raised superiorly and inferiorly, exposing the submandibular mass

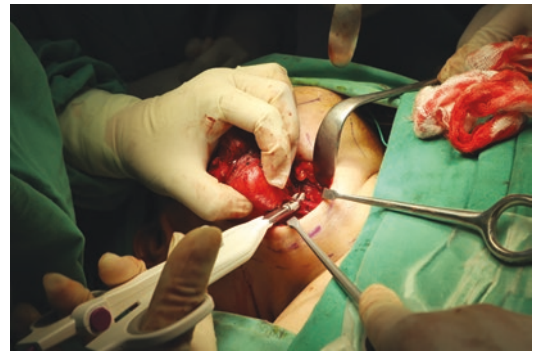

Fig. 18.29 The ultrasonic scissors or LigaSure is used to cut the surrounding tissue during dissection. The LigaSure is also used to cauterize the vessels. This shortens the duration of surgery in contrast if suture ligation is used

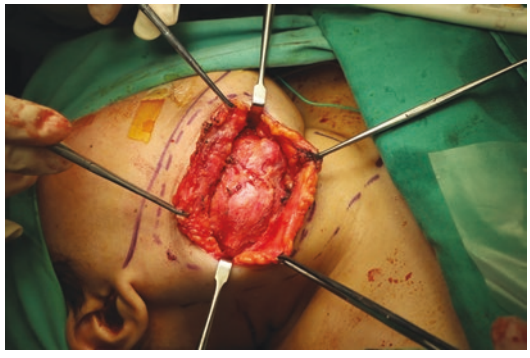

Fig. 18.27 The capsule of submandibular mass is intact

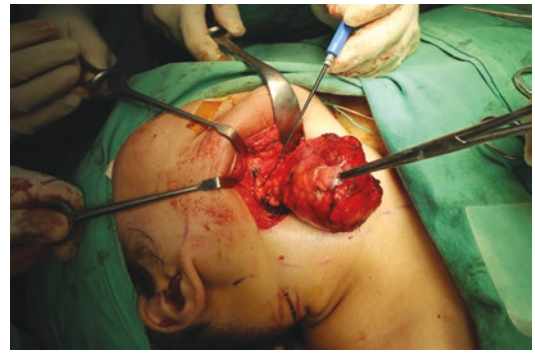

Fig. 18.30 The submandibular mass is retracted inferiorly exposing the tendon of digastric muscle

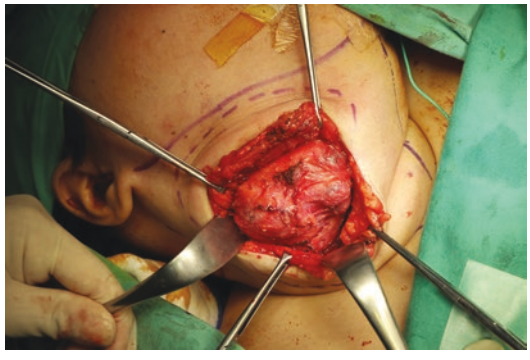

Fig. 18.28 Subsequent dissection facilitates mass removal by exposing the medial, lateral and inferior borders of the mass

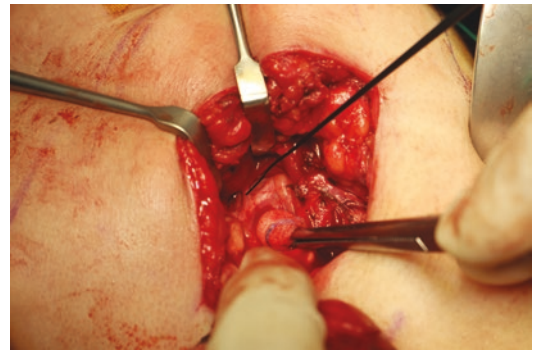

Fig. 18.31 The lingual nerve is identified. It forms a V shape as the submandibular gland and its duct are retracted inferiorly

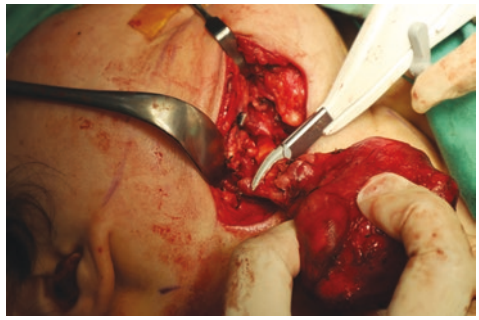

Fig. 18.32 The pedicle of submandibular mass together with a submandibular duct is transected with the LigaSure

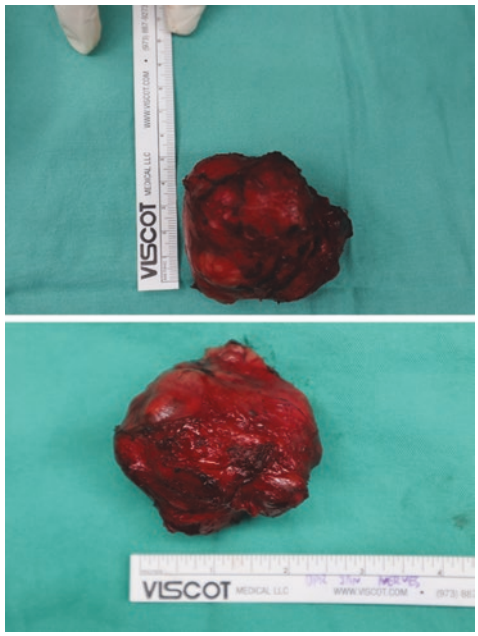

Fig. 18.33 The submandibular mass is out. It measures 2.5 cm × 3.0 cm

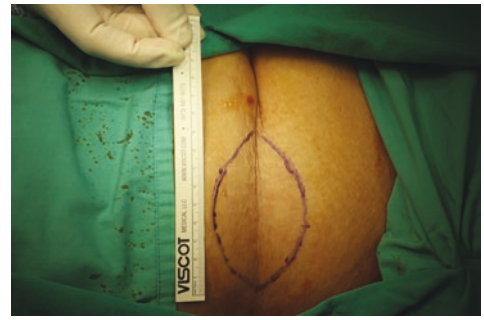

Fig. 18.34 The abdominal skin incision is marked. The size is 1.0 cm bigger than the mass considering the dermal fat graft atrophies with time

LigaSure is used to cauterize and cut the tissue pedicle (Fig. 18.32). Once the mass is out (Fig. 18.33), the haemostasis is secured, and a wet gauze is placed on the surgical bed. Then, the abdominal fat graft is harvested using a monopolar (Fig. 18.34). The size is measured accordingly. Once the dermal fat graft is ready, it is placed in the submandibular surgical defect and the two-layer sutures are applied to secure the graft. Post-operatively, the wound appeared as mild oedematous as it is in early healing period (Fig. 18.35). Patient had infection of the wound that requires regular dressing. The wound completely healed at 5 months post-surgery.

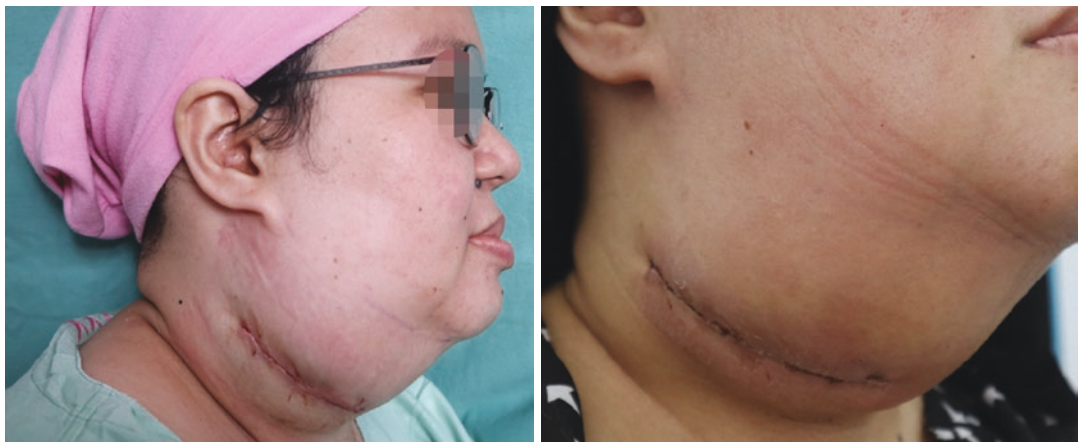

Fig. 18.35 Post-op wound at days 1 and 3 showed oedematous wound

18.5 Platysma-Based Rotational Flap

Flap reconstruction plays critical roles in selected cases of head and neck malignancy. In the majority of cases, reconstruction is necessary for restoration of function and improving aesthetic outcomes. In advanced cases of head and neck carcinoma, several rotational flaps may be performed to palliate the symptoms such as facial disfigurement and smelling discharge and lessen the pain.

18.5.1 Case Illustration

This is the case of a 60-year-old male who presented with an extensive right buccal carcinoma (Fig. 18.36). He has no medical comorbidities. CT scan imaging showed a heterogenous mass at right buccal region with ulcerative mass and skin involvement. There was no distant metastasis.

Intraoperatively, the skin incision is marked around the mass. The mass has been excised with 1.0 cm margin (Fig. 18.37). The mass is removed in total. The medial part at the buccinator muscle is infiltrated by the tumour. The tissue is sent to pathology for HPE confirmation. The platysma-based skin flap is harvested, to be rotated superiorly and cover the surgical defect.

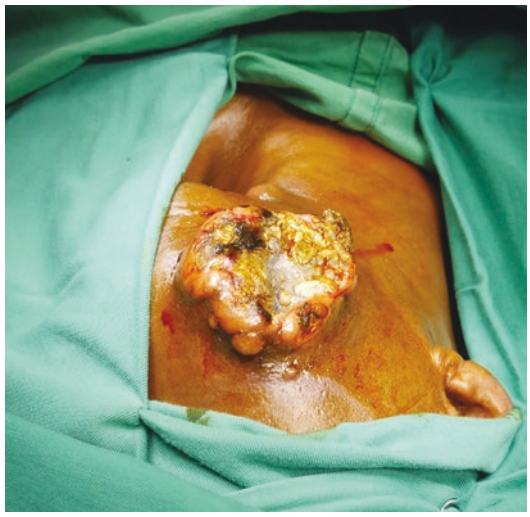

Fig. 18.36 Right buccal cancerous growth with everted edges and central necrosis

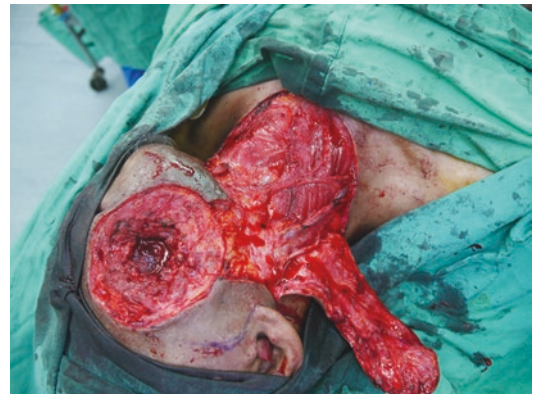

Fig. 18.37 The mass has been excised with 1.0 cm margin and platysma-based skin flap is harvested

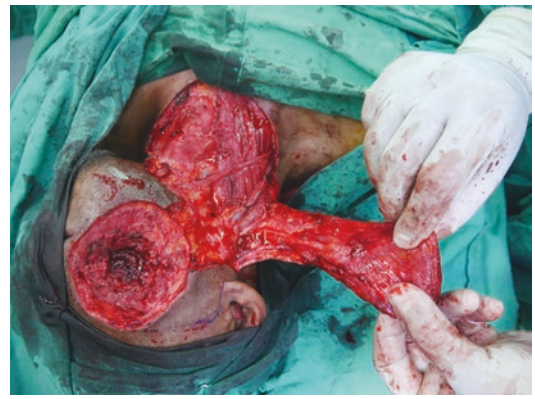

Fig. 18.38 The platysma skin flap is measured to cover the defect sufficiently. The external jugular vein and the greater auricular nerve cross superficial to sternocleidomastoid muscle

The platysma skin flap is measured meticulously to cover the defect sufficiently. The external jugular vein and the greater auricular nerve were observed to cross the superficial to sternocleidomastoid muscle (Fig. 18.38). Subsequently, the platysma skin flap is rotated and superimposed on the surgical defect (Fig. 18.39). The skin is sutured with surgical stapler.

The flap is secured with surgical stapler (Fig. 18.40). The exposed neck donor requires skin graft. The diameter of the neck donor-site wound is measured (Fig. 18.41). The measurement is necessary for accurate harvest of split skin graft. This avoids unnecessary excess skin graft. Then, the skin graft is placed in situ in the

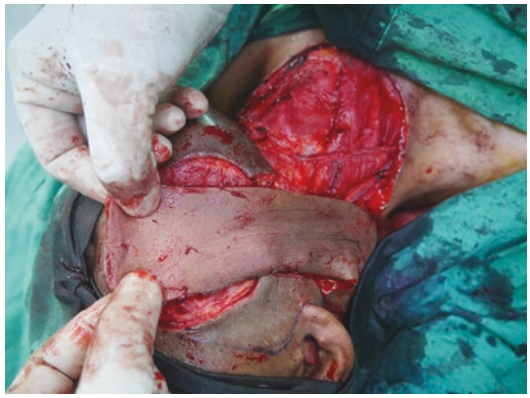

Fig. 18.39 The platysma skin flap is superimposed on the buccal surgical defect. The skin is sutured with surgical stapler

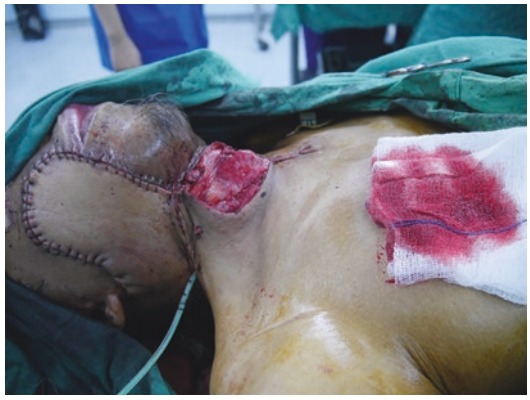

Fig. 18.40 The flap is secured. The neck donor site requires skin graft

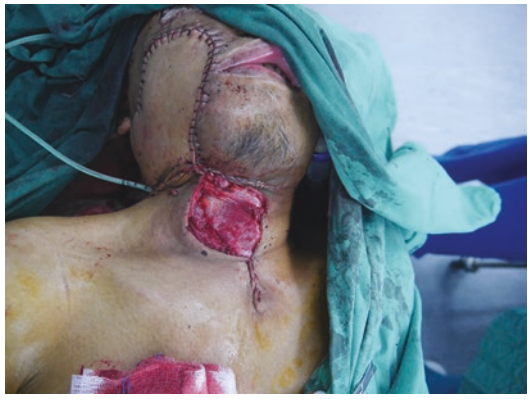

Fig. 18.41 The diameter of the neck donor-site wound is measured. The measurement is necessary for accurate harvest of split skin graft

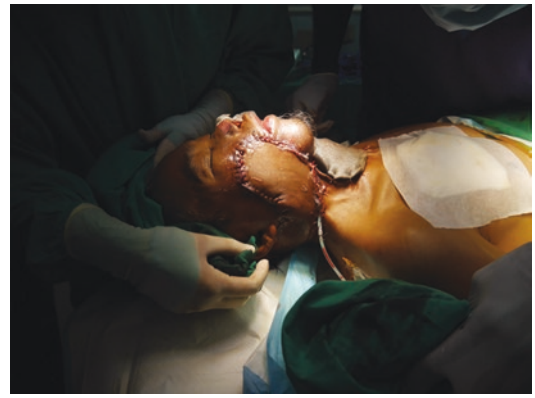

Fig. 18.42 The skin graft has been placed in situ and the sponge gauze is placed on the graft to promote healing

Fig. 18.43 The antibiotic cream is applied at the wound edge. The drainage tube is secured in situ to promote drainage post-operatively. This avoids seroma formation that will impair the flap

surgical bed and the sponge gauze is placed on the donor graft to promote healing (Fig. 18.42). The antibiotic cream is applied at the wound edge, and the drain is secured in situ (Fig. 18.43), to promote drainage post-operatively. This avoids seroma formation that can compromise the flap and post-operative wound healing.

Post-operatively, the patient recovered uneventfully. He was on double antibiotics and local dressing daily. His drainage tube was removed at day 5 post-operatively. He was discharged home on day 12. On follow-up at the outpatient clinic, the patient had wound breakdown. He was admitted and managed conservatively. The patient however succumbed to disease on day 3 of readmission.

18.6 Excision of Vagal Schwannoma

Paraganglioma is a rare head and neck tumour. It commonly occurs in young and middle-aged patients [5]. The majority of paragangliomas in the head and neck region are vagal schwannomas and carotid body tumour. The glomus jugulare that affects the surrounding structures near the jugular foramen is rare. Notably, about 5% of head and neck paragangliomas originate from the vagus nerve. The vagus nerve is the dominant nerve of the parasympathetic division of the autonomic nervous system, and a vagal paraganglioma is a prime example of an endocrine tumour associated with the vagus nerve [6].

Vagal paraganglioma is mostly present with a neck mass. The mass can be at level II or III neck region. It mostly firms in consistence, and occasionally the palpation on the mass causes patients to cough, because of stimulation of vagal nerve and recurrent laryngeal nerve. A small tumour with no symptoms can be observed. However, a large tumour with compressive symptoms needs a surgical removal.

18.6.1 Case Illustration

This is the case of a young lady presented with right-neck swelling for 2-year duration. On clinical examination, the mass was firm and mobile and measured 3.0 cm × 4.0 cm at level II and III neck (Fig. 18.44). The CT scan reported that the mass is a heterogenous mass and displaced the carotid artery and internal jugular vein posteriorly. FNAC of the mass revealed a suspicion of schwannoma. Patient was counselled about the treatment, and she agreed for surgical removal of the mass.

Intraoperatively, patient lies supine with neck hyperextended. The recurrent laryngeal nerve monitoring is applied to patients. The neck region is cleaned with the diluted povidone iodine and the surgical landmarks, which include the inferior border of mandible and anterior border of sternocleidomastoid muscle drawn on the patient (Fig. 18.44). The margin of the mass is in dotted lines. The angle of mandible is superior, and the medial border of sternocleidomastoid muscle is abutting the posterior border of the mass.

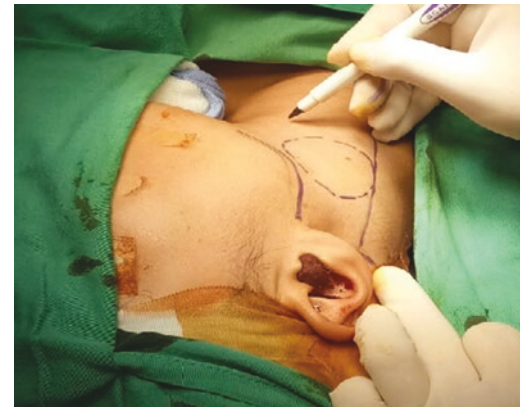

Fig. 18.44 The landmarks are drawn on the patient; the outline of the mass is in dotted lines. The angle of mandible is superior, and the medial border of sternocleidomastoid muscle is abutting the posterior border of the mass

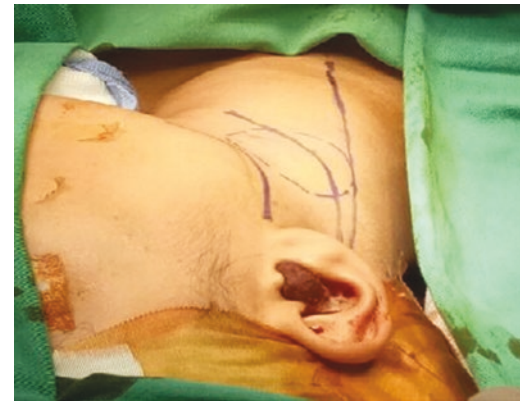

Fig. 18.45 The skin incision is marked at the middle of the mass following the curvilinear skin crease of the neck

The skin incision is marked at the middle of the mass following the curvilinear skin crease of the neck (Fig. 18.45). The skin incision is always placed well below the inferior border of mandible at 2.0–3.0 cm below so as to avoid the risk of injury to marginal mandibular nerve.

Subsequently, after the skin incision is performed, inferior and superior subplatysmal skin flap is raised (Fig. 18.46). The superior flap is raised till mandible, whereas the inferior flap is raised till the level of cricoid cartilage, just

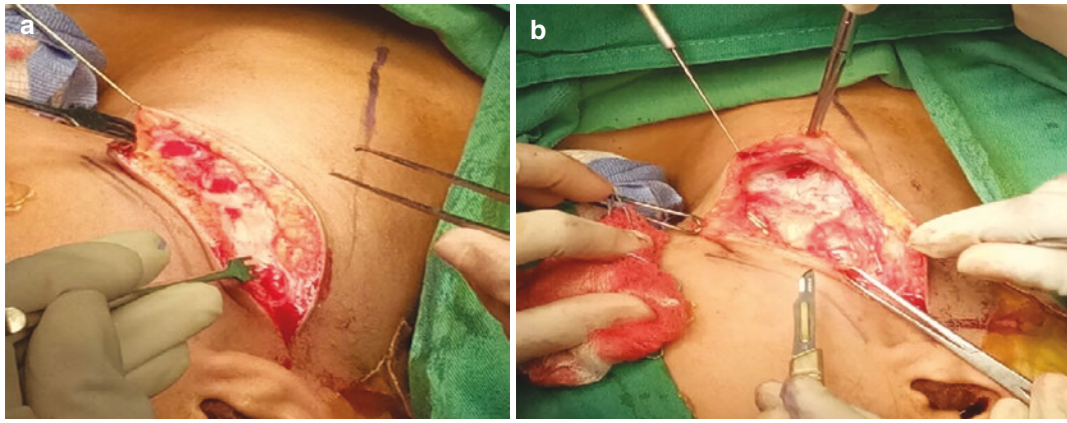

Fig. 18.46 The skin incision is performed (**a**), and inferior and superior skin flap is raised (**b**)

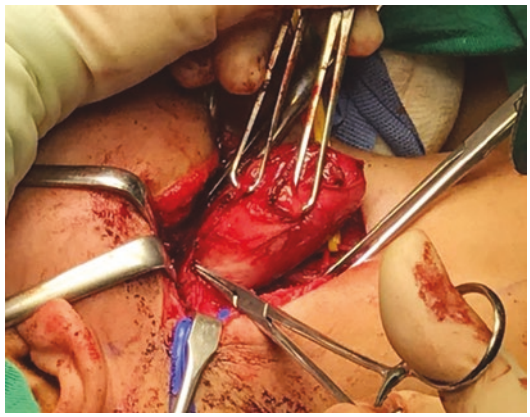

Fig. 18.47 The mass is exposed and dissected away from the vagus nerve

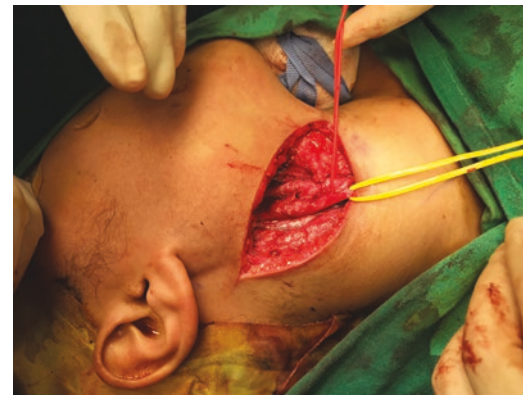

Fig. 18.48 The mass has been excised from the vagus nerve (yellow vessel loupe). The carotid artery is located medially (red vessel loupe), and the IJV is visualized laterally deep to the anterior border of SCM

1–2 cm below the inferior margin of the mass. This is to facilitate better dissection around the mass. The dissection continues, and the carotid artery and IJV are identified. The vagus nerve is located in between the carotid artery and IJV. The mass is exposed and dissected away from the vagus nerve (Fig. 18.47). As the mass arises from the periphery of vagus nerve, i.e. the perineurium, the mass is able to be resected without transection of the vagal nerve (Fig. 18.48). The carotid artery is located medially, and the IJV is visualized laterally deep to the anterior border of SCM (Fig. 18.49), which is preserved together with vagal nerve. The excised mass measured 8.0 cm × 4.0 cm and had intact capsule (Fig. 18.50).

Patient is doing well post-operatively, and the sterile strip has been applied to the wound. The drainage tube is placed in situ to prevent seroma formation that could compromise wound healing during post-operative period (Fig. 18.51).

Indication for surgery of vagal paraganglioma includes enlarging mass, the mass that causes discomfort or neck pain or other compressive symptoms like dysphagia, or a long-standing mass which carries a high risk of malignant transformation. Meticulous dissection is necessary when dissecting the mass as the carotid artery and internal jugular vein are intimately closed to the mass. Vessel branches from these two vessels may be accidentally cut and it causes active

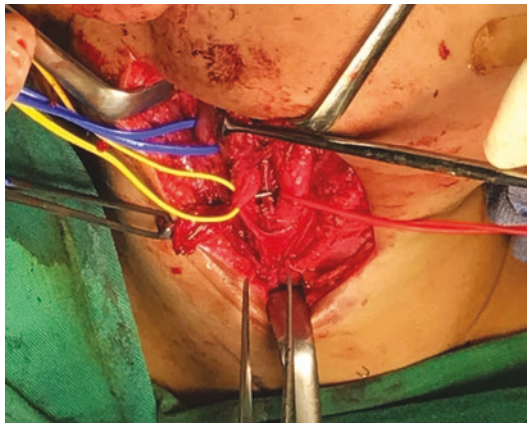

Fig. 18.49 All three critical neurovascular structures are preserved, the vagus nerve (yellow vessel loupe), the carotid artery (red vessel loupe) and the IJV (blue vessel loupe)

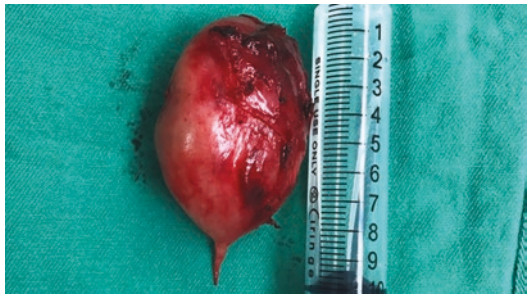

Fig. 18.50 The mass excised measuring 8.0 cm × 4.0 cm, with intact capsule

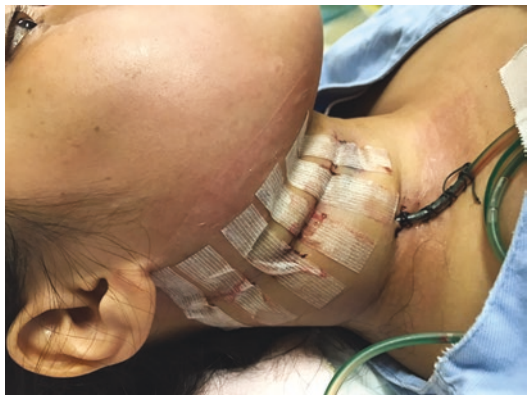

Fig. 18.51 The neck wound post-operatively on day 1. The sterile strip has been applied to the wound. The drainage tube is in situ to prevent seroma formation that could compromise wound healing

bleeding in the surgical field, which impairs effective dissection.

The mass can be carefully dissected from the nerve if there is plane between the capsule of the mass and the nerve. The perineurium and epineurium of the nerve can still be preserved in this case as the mass arises from the lateral part of the nerve. In case the mass engulfs the whole nerve, the proximal and distal parts of the nerve can be transected. A cable nerve graft can be performed using greater auricular nerve or hypoglossal nerve.

18.7 Deep Lobe Parotidectomy

Deep lobe parotidectomy is indicated for benign tumours limited to deep lobe, small recurrent tumours confined to deep lobe or metastases to deep lobe.

The approach can be either transoral or transcervical depending on the nature of the mass. In extensive cases, mandibulotomy is necessary. This includes the size, exact location and patient's anatomy. Some patients might have trismus, so this precludes the transoral approach.

This is a case of a middle-aged female patient who was diagnosed with deep lobe parotid pleomorphic adenoma. She was planned for a deep lobe parotidectomy. As the tumour is not large, she was planned for transcervical approach. Intraoperatively, the standard modified Blair incision is used. The facial nerve monitor is secured, and after the landmark has been identified, the subplatysmal skin flap is elevated superiorly and inferiorly (Fig. 18.52). The anterior border of sternocleidomastoid is skeletonized, and the lower branches of facial nerve are preserved. The dissection continues to expose the posterior belly of digastric. The dissection continues deep to the muscle, and this allows access to the parapharyngeal space where the mass is located. The mass is identified, and the capsular dissection allows the removal of the mass fairly easily, with intact capsule (Figs. 18.53 and 18.54).

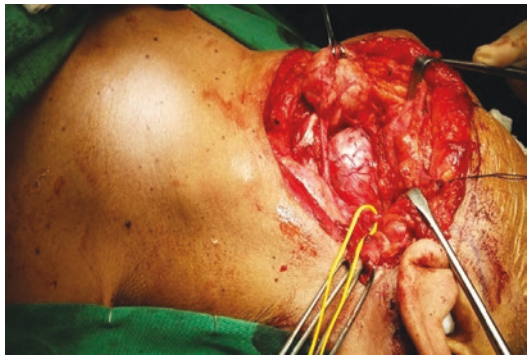

Fig. 18.52 The transcervical approach for removing a deep lobe of parotid mass. The skin flap is elevated superiorly and inferiorly. The branches of facial nerve are preserved. The tissue over the posterior belly of digastric is dissected, and this allows access to the parapharyngeal space

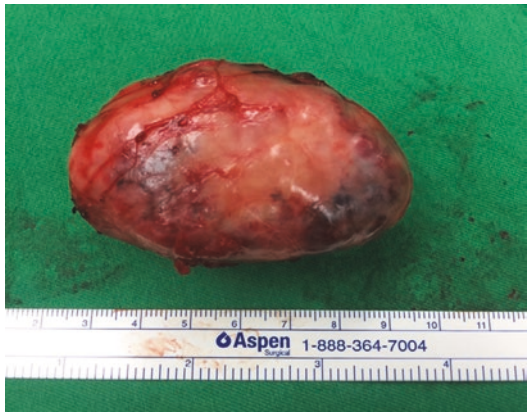

Fig. 18.53 The mass is excised with intact capsule. It measures 6.0 cm × 3.0 cm

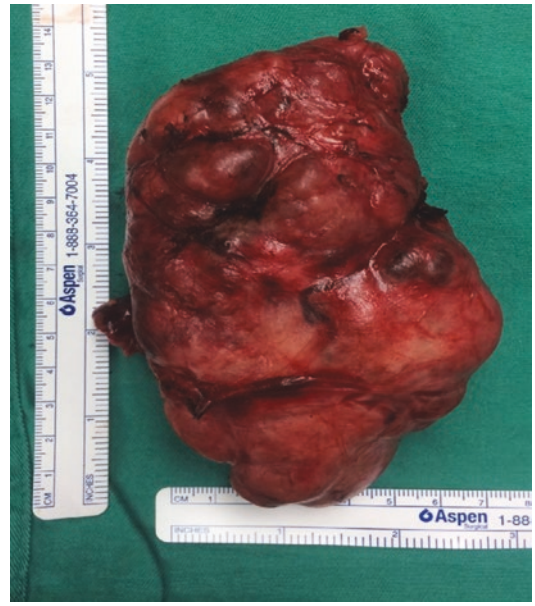

Fig. 18.54 The medial surface of the mass appears irregular; however, the capsule is maintained intact. This is important for avoiding breach into tissue that can cause tumour cell seedling and recurrence

18.8 Conclusion

Selected head and neck surgery should be meticulously performed even though it is a minor head and neck case, as most of these neck masses are located adjacent to major vasculature of carotid artery and IJV. Additionally, some cases of recur-

rent tumour for example need a good treatment plan in order to avoid unnecessary repeated surgery if the surgical margin is positive and the patient had received maximal radiation dose. During the dissection, all critical structures whether muscles, vessels or nerves need to be addressed properly. This ensures a safe surgery without serious sequelae to the patients. Hence, optimal treatment outcomes can be achieved.

References

1. Grønlund S, Mey K, Andersen E, Rasmussen ER. The true malignancy rate in 135 patients with preoperative diagnosis of a lateral neck cyst. Laryngoscope Investig Otolaryngol. 2016;1(4):78–82. Published 2016 Jun 21. https://doi.org/10.1002/lio2.23.
2. Gaszyńska E, Gaszyński T, Arkuszewski P. Diagnosis and treatment of cervical branchial cleft cysts based on the material from the Department of Cranio-Maxillofacial Surgery, Medical University in Łódź and literature review. Pol Przegl Chir. 2012;84(11):547–50. https://doi.org/10.2478/v10035-012-0091-3.
3. Kadhim AL, Sheahan P, Colreavy MP, Timon CV. Pearls and pitfalls in the management of branchial cyst. J Laryngol Otol. 2004;118(12):946–50. https://doi.org/10.1258/0022215042790637.
4. Bradley PT, Bradley PJ. Branchial cleft cyst carcinoma: fact or fiction? Curr Opin Otolaryngol Head Neck Surg. 2013;21(2):118–23. https://doi.org/10.1097/MOO.0b013e32835cebde.
5. Mat LN. Challenges in managing a vagal schwannoma: lesson learnt. Int J Surg Case Rep. 2018;53:5–8. https://doi.org/10.1016/j.ijscr.2018.10.025.
6. Kotsis T, Christoforou P. Vagal paraganglioma: surgical removal with superior laryngeal nerve preservation. Vasc Specialist Int. 2019;35(2):105–10. https://doi.org/10.5758/vsi.2019.35.2.105.

19 Updates and Controversies in the Management of Head and Neck Malignancy

Belayat Hossain Siddiquee

19.1 Introduction

Since the early part of the last century, enrichment of knowledge about the cancer etiology and pathogenesis has led to rapid evolution in the treatment of HNSCC. Advances in different therapeutic modalities have a commendable impact on locoregional cure and suppression, overall and disease-free survival, and issues concerning the quality of life. Relatively better consequences contribute to shifting the therapeutic aim from drastic ablation to organ conservation and functional revival. HNSCCs include mucosal carcinomas of the nose and paranasal sinuses, oral cavity, nasopharynx, oropharynx, hypopharynx, and larynx and also salivary gland cancers. These together constitute one of the most common cancers worldwide. The oncosurgical management of these diseases is evolving, which is attributable to the advancement in anesthetic support, emergence of efficient antibiotics and transfusion and infusion technology, as well as development of newer concepts and skills for reconstruction. Drastic excision has changed into preservation of function without compromising the ultimate aim of cure.

In the early decades of the twentieth century, radiotherapy had just been started, and outcomes of surgery were frustrating. These reasons drive the concerned clinician to use radiotherapy (RT) as the first choice. From the middle of the same century, improvements of perioperative care, and recognizing frustrating result and side effects of radiotherapy, led them to build up a combined approach consisting of surgery followed by adjuvant radiotherapy for the majority of HNSCC patients. Later modernization of radiotherapy came up with increased cure rates and decreased toxicities. Nowadays, radiotherapy is established as a vital solitary option in early lesions and also plays an imperative role as adjuvant therapy. During the later decades of the last century, emphasis revolved around organ-specific functional status following treatment and role of emerging chemotherapy, which influence both nonsurgical and surgical organ-conservation tactics. In the last few decades, for advanced cancers, management concentrated on combining chemotherapy and radiotherapy for both primary and adjuvant treatment. Recently, the targeted molecular therapies upcoming as a novel option for managing head and neck cancers (HNSCCs) have been claiming improved survival rate and better functional results.

Previously, the concepts regarding etiopathogenesis, local invasiveness, regional and distant metastasis, and also clinical behavior of HNSCC were not mature enough. In 1948, Morton Levin recognized the impact of sex in cancer formation of the upper aerodigestive tract [1]. Despite

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N. Mat Lazim et al. (eds.), *Head and Neck Surgery : Surgical Landmark and Dissection Guide*,
https://doi.org/10.1007/978-981-19-3854-2_19

providing information about age, socioeconomic status, chemical carcinogens, and radiation, the crucial etiological role of tobacco in cancer formation had not been realized for long. Ernst Wynder demonstrated the carcinogenic effect of tobacco in mice in the late 1950s and 1960s [2–5]. Moreover, Wynder and coworkers reported the causal relation of tobacco and alcohol in oral, laryngeal, and esophageal cancers [6–8]. Subsequently, Vogler and associates also linked tobacco to oral, pharyngeal, and laryngeal cancers [9]. Now, all forms of tobacco are universally established as contributing elements for HNSCC. Alcohol also raises the probability of HNSCC, and it has been demonstrated that the risk of consuming tobacco and alcohol together has synergistic effect rather than simple additive effect [10, 11]. But the fact is that all tobacco and alcohol consumers do not suffer from HNSCC, signifying that individual disparity in genetic susceptibility is crucial [12].

Slaughter and associates in 1953 launched the idea of "field cancerization" in oral cavity squamous cell carcinoma (OCSCC) [13]. That thinking offered a validation for the synchronous or metachronous second primary cancers in HNSCC patients. Over 500,000 new cases of HNSCC occur yearly in the world [14]. The US National Cancer Institute's report shows increased detection of oropharyngeal cancers (OPSCC) since 1973, although there has been a significant decrease in tobacco consumption [15]. Recent trend is same in the majority of countries around the globe.

Human papillomavirus (HPV) is stated as a key risk factor for many HNSCCs. Reports recognizing the molecular link of HPV with HNSCC have also been published [16]. Around 20% of HNSCC samples have HPV genomic DNA, mostly HPV type 16 and occasionally type 18 [17]. E6 and E7 viral oncoprotein expression deactivates the tumor-suppressor proteins p53 and Rb, respectively [18]. Oropharynx, especially the tonsils, is the commonest site for HPV-related tumors [19, 20]. Peculiar sexual performances have been identified related to HPV transmission in oral and oropharyngeal regions [21, 22]. Causative relation of HPV with OPSCC has positive effects on preventive and therapeutic management, and favorable prognosis. HPV association is considered as a positive prognostic component for OPSCC, particularly in patients who are nonconsumers of tobacco and/or alcohol and may be related to increased radiosensitivity too [23–34]. HPV infections biologically relevant in laryngeal carcinogenesis are also reported, but its clinical impact on prevention and treatment is unclear [25]. Oncogenic strains of Epstein-Barr virus (EBV) are related to the development of nasopharyngeal carcinoma. Excitingly, some viruses own the cancer-abolishing character and reovirus (RV); a RNA virus is a noticeable one having research interest [26].

The biological relationship of chronic inflammation with cancers has been pronounced comprehensively as both inflammation and cancer are multifaceted processes under the influence of various stirring factors [27–29]. Bacteria, their endotoxins, enzymes, and some other metabolic by-products may bring genetic and epigenetic alterations directly in adjacent epithelial cells [30, 31]. They also raise the production of acetaldehyde and nitrosamine, which are carcinogenic [32, 33]. By all this relentless research about etiology, pathogenesis, invention of newer investigative tools especially radiological and biological scans, and different biochemical tests including tumor markers, clinicians and scientists are updating the treatment modules for different HNSCCs by modification and improvisation. Despite this fact, overall disease-free survival for HNSCCs is yet to be satisfactory. Controversies are existing at intra- and interdisciplinary levels. Hopefully, this dynamicity will get a new dimension in the twenty-first century to achieve the goal.

19.2 Investigations of Head and Neck Malignancy

19.2.1 Cross-Sectional Imaging

One major sector in the update management of HNSCC is tremendous development and modernization of investigations in the later part of the

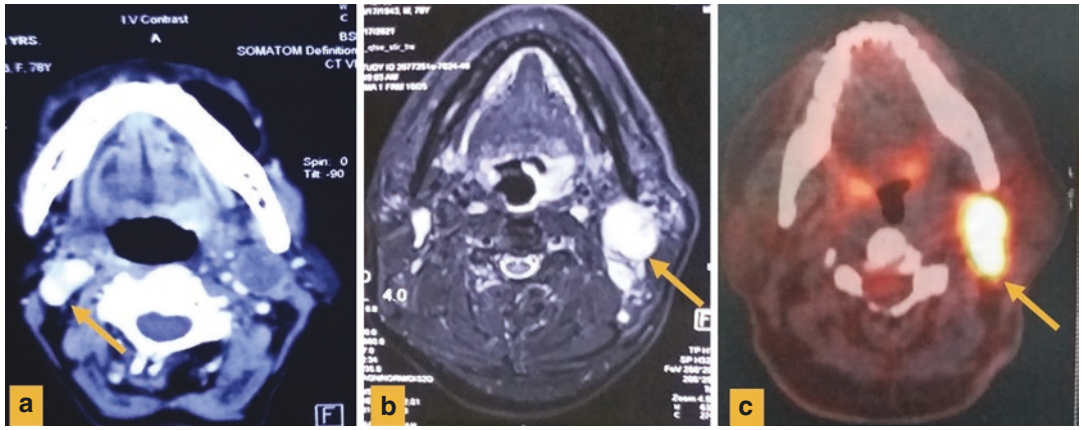

Fig. 19.1 (**a**–**c**) Cervical lymph node metastasis in different patients: (**a**) CT scan, (**b**) MRIT2W1, and (**c**) PET/CT

Table 19.1 Role of PET scan in the assessment of head and neck malignancy

1. Differentiate malignancy from normal tissue and benign lesions	It shows a hypermetabolic state of tissue, which is a characteristic of malignant tissue.
2. Staging of HNSCC	By determining the precise location of a tumor, its extension and whether the cancer has spread in regional or distal sites of the body.
3. Diagnosis and assessment of residual or recurrent tumor	FDG-PET/CT is a perfect noninvasive imaging, which can differentiate post-therapeutic changes in cancer from residual or recurrent lesions [34].
4. Assessment of therapeutic response	FDG-PET/CT is competent to evaluate therapeutic response in HNSCC following chemoradiation. FDG-PET should be advised 12 weeks after the treatment is over to minimize the false positivity created by radiation-induced inflammation [35].
5. Prognostic evidence	Undetectable lesions on FDG-PET/CT 6 months after finishing radiotherapy are found to have higher control over locoregional and distant recurrence, longer disease-free survival, and overall survival, when compared to the counterpart [36].
6. Tumor volume assessment for radiotherapy scheduling	FDG-PET/CT is suitable for tumor volume contouring as the metabolic activity of the lesion delineates the border between tumor and surrounding normal tissue [37]. FDG-PET also decreases inter-observer variations in tumor volume calculation, ascertains lymph node involvement not detected by CT/MRI, and differentiates tumor areas potentially requiring additional radiation dose [38].

twentieth and early decades of the twenty-first century. Computerized tomography (CT) and magnetic resonance imaging (MRI) have revolutionized the role of imaging in the diagnosis and assessment of HNSCC. CT and MRI (with and without contrast) have definite strengths and limitations. Thus, these are complementary to each other in the assessment and treatment scheduling (Fig. 19.1).

The application of (18F-FDG) positron-emission tomography (PET) in the later part of 1990s, use of a metabolic factor for imaging, and fusion of functional (PET) and structural (CT) imaging further facilitated disease management. PET/CT fusion scan has the ability to provide an inclusive evaluation of the patient with HNSCC. The following role of PET/CT has been explored and established (Table 19.1).

19.2.2 Emerging Applications

Some applications make the biologic imaging unique and an integral part of standard care for HNSCC. Tumor hypoxia is a factor which can influence therapeutic response.

19.2.3 Imaging of Hypoxia

Tissue hypoxia may decrease sensitivity to chemoradiation. Hypoxic cells are resilient to the toxic properties of chemotherapy and radiotherapy and require higher radiation dose than for the non-hypoxic counterpart to achieve the same therapeutic effect. Thus, concerned clinicians have increasing awareness to diagnose hypoxic HNSCC beforehand with the hope to modify therapeutic approaches to avoid this limitation of chemoradiation [39].

19.2.4 Evaluation of Tumor Cell Proliferation

Cellular multiplication during treatment is unfavorable for desired post-radiotherapy result in HNSCC. A new PET element is advanced (3′-deoxy-3′-18F-FLT-PET) whose signal intensity is more specific for aggressively multiplying tumor cells in comparison to 18F-FDG-PET [40].

19.2.5 Prevention of Neoangiogenesis

18F-Galacto-RGD-PET images a receptor associated with tumor angiogenesis and metastasis. This is utilized for the evaluation of tumor response to targeted therapies. The intensity of 18F-RGD peptide accumulation relates to the existence of stimulated endothelial cells and microvessel attenuation [39].

19.2.6 PET-MR

PET-MR fusion image in HNSCC is promising for further accuracy in staging. Study shows that the precision for tumor node metastasis staging is almost similar in PET/CT and MRI (74.6% and 73%, respectively). MRI along with PET improves the correctness up to 92% [41]. PET-MR fusion scan is likely to be used widely for assessing HNSCC in the near future.

19.2.7 Future of Molecular Imaging in HNSCC

Molecular imaging is refining the tumor detection, assessment, plus treatment planning. This highly sophisticated technique also helps to develop:

1. Screening tools—more accurate but noninvasive method to evaluate people at risk.
2. Efficacy of newer drugs by quick understanding of the treatment response.
3. Personalized medicine, where medical treatment depends on patient-specific exclusive genetic profile.
4. In the coming years, molecular imaging is likely to be frequently used in:
   (a) Hybrid imaging—more than one imaging technique will be combined to yield single image.
   (b) Optical imaging [42].

19.2.8 Others

19.2.8.1 SPECT

Primary HNSCC and cervical lymph nodal metastasis can be imaged with 201 Tl SPECT. This could furnish evidence beyond structural changes and may be a complementary technique for the evaluation of HNSCC [43].

19.2.8.2 Elastography

A recent development in ultrasound technique may be used to evaluate primary lesion and also to get information about lymph node metastases in HNSCC patients.

19.2.8.3 Fluoroscopy

There are situations where simultaneous use of contrast swallowing and fluoroscopy is required. Possibility of aspiration or entry of dye through fistula in airway is dynamically observed by video fluoroscopy. Consistency of a surgical anastomosis or a pharyngo-cutaneous fistula tract could be assessed too [44]. These assessments are usually done together with speech therapists to facilitate management planning for better functional outcomes.

19.2.8.4 Narrowband Imaging

The endoscopy with narrowband imaging (NBI) facility can create sharp image contrast in recognizing small mucosal lesions. Intraepithelial microvasculature becomes highlighted which helps to understand the lesion's pathology. This unique technique has real efficiency in the early identification of hypopharyngeal, oropharyngeal, oral cavity, laryngeal, and nasopharyngeal cancers and metastatic lymph nodes with unknown primary. NBI endoscopy is a useful instrument in detecting cancers at initial stage and offers chance for minimally invasive surgery [45, 46].

19.2.9 Biochemical Investigations

Quantitative changes have been shown to occur in a variety of substances in serum during the development of HNSCC. These substances are collectively called tumor biomarkers. The potential role of tumor biomarkers includes early detection, monitoring tumor volume whether decreasing or increasing, detecting recurrence and/or metastasis, and anticipating prognosis. Changes from the initial serum level of biomarkers reflect the existence/nonexistence of tumor and also favorable/unfavorable prognosis following therapy. The tumor biomarkers can be categorized as oncofetal proteins, hormones, enzymes, proteins, etc. Although many of these are considered as nonspecific, some have been shown to be of value in the detection and management of various HNSCCs.

Though overall prognosis improved a little with modern therapies, further improvement of disease-free survival can be achieved by early detection and relapse prevention. Research about molecular changes and categorization during HNSCC development and identifying biomarkers related to different HNSCC are likely to play a crucial role in the overall management of these diseases in the coming decades [47].

Many biomarkers possess inspiring potential but require further clinical validation. The following markers have raised the interest of researchers: chemokine receptors, human papillomavirus, microsatellite instability, microRNA, p53, etc.

19.2.10 Imaging Biomarkers

In addition to biochemical biomarkers, imaging biomarkers also have a significant role in detecting HNSCC at initial stage. These are noninvasive newer tools for monitoring therapeutic response and follow-up of HNSCC patients. PET/CT is superior to MRI or CT individually in respect to sensitivity and specificity. Newly hosted regional PET/Gd (gadolinium-enhanced T1-weighted)-MRI jointly with whole-body PET-MRI seems to be fairly capable in noticing early lesions [47].

19.3 Surgical Management of HNSCC

Surgical treatment of HNSCC has got a momentum as a result of tremendous advancements in anesthesia, safe blood transfusion technique, invention of efficient antibiotics, and newer reconstructive ideas and skill. The philosophy of radical resection is replaced by organ preservation expertise to restore function without compromising the ultimate goal of disease-free survival. Changing policy in the surgical management of neck metastasis, depending upon the site and type of HNSCC, reflects in the treatment planning.

19.3.1 Neck Dissection

Efficient surgical maneuver to address the neck metastasis in HNSCC is a crucial factor in the overall management of HNSCC. Metastasis in the neck is the topmost individual prognostic factor and reduces survival by 50%, but the extracapsular spread and presence of contralateral node metastasis reduce the prognosis by another 50%. Neck dissection not only clears the metastatic neck disease but also helps in realistic staging of the disease. The basic concept of neck dissection is to remove all the lymphatic and nonlymphatic structures in between the investing layer and deeper layer of the deep fascia of the neck. These may include IJV, SCM, and SAN but never ever carotid arteries and vagus nerve. Other

structures to be preserved are actually beneath the deeper layer, e.g., brachial plexus and phrenic nerve. Prime targets of neck dissection are:

1. To control the manifested neck metastasis in head and neck malignancy
2. To reduce locoregional spread of head-neck malignancy and improve survival in clinically and radiologically negative neck
3. As salvage surgical procedure in recurrent malignant disease of the neck (post-surgery/post-RT)

In 1880, Emil Theodor Kocher, a Swiss researcher and physician (1909 Nobel laureate), proposed the removal of cervical nodal metastasis for HNSCC. In 1888, a Polish surgeon Jawdynski described en bloc resection of the neck along with carotid, IJV, and SCM. This article was published in polish language. In 1906, George W. Crile (Ohio, USA) defined the radical neck dissection (RND). His surgical procedure included excision of all the lymph nodes along with SAN, IJV, and SCM on one side of the neck. In 1950s, Hays Martin who is known as the father of modern head and neck surgery started using RND routinely to control neck metastasis.

In 1960s, Oscar Suarez, E. Bocca, and Pignataro pronounced functional neck dissection (FND) with the idea of few structural conservation but nearly equal efficacy where SAN, IJV, and SCM are preserved according to the situational demand. Oncologic success of the FND was definitively reported by Bocca in the mid-1970s. This operation included meticulous dissection of cervical lymph nodes in different compartments of the neck and conservation of IJV, SAN, and SCM, considering functional and cosmetic aspects [48, 49]. Minimum adverse post-surgery consequences during the management of clinically negative neck and opportunity to do bilateral neck dissections in the same session avoiding the hazard of cerebral and facial edema likely to develop after removing both sided IJVs are the main advantages [50]. FND is also known as modified radical neck dissection (MRND).

From the conceptual point of view, RND comprises all lymph node levels (I–V) together with the IJV, SAN, and SCM. MRND embraces the similar lymph node levels like RND but saves IJV, SAN, and SCM (any one/two or all the three). The selective neck dissection (SND) addresses some of the lymph node groups included in MRND leaving others. Therapeutic neck dissection is done in preoperative or preoperatively positive (high clinical suspicion or frozen section proven) neck. Elective neck dissection (END) is done on the basis of recognized threat for occult metastases.

Lindberg and colleagues published an article in 1972 based on the review of the records of HNSCC patients illustrating that cervical lymph node metastases from any subsite of the head neck region follow a predictable pattern [51]. In 1990, Shah and his team at MSKCC, New York, showed the histological patterns of nodal metastases in HNSCC patients subjected to elective and therapeutic neck dissections [52, 53]. These two works acted as rotating points. Depending on this idea about the order of metastasis, elective dissection of selected levels of lymph nodes (elective SND) has developed as a replacement for elective MRND.

In oral cavity squamous cell carcinoma (OCSCC), level IIb lymph node metastasis is rarely found and nodal recurrence after supraomohyoid neck dissection (SOHND) is infrequent [54]. Therefore, this region may be preserved in elective SOHND in patients of oral cavity carcinoma.

Super-selective neck dissections conserving level IIb are safe oncosurgical procedures if done prophylactically in carefully chosen patients, e.g., elective treatment of the cN0 neck and salvage treatment of persistent lymph node disease after chemoradiation. It has been observed that shoulder morbidity is higher in the first few weeks in patients undergoing IIb-sparing neck dissections, but in the course of time recovery is satisfactory [55]. The following classification covers all types of neck dissection currently in practice:

1. Comprehensive neck dissections:
   (a) Radical neck dissection
   (b) Modified radical neck dissection with 03 classical types

(c) Extended radical neck dissection

2. Selective neck dissections:
   (a) Classical selective neck dissection:
       All four classical types
   (b) Extended selective neck dissection,
       SND plus any nonlymphatic structure is excised like IJV, SCM, or SAN
   (c) Super-selective neck dissection:
       SND-sparing L-IIb (in laryngeal carcinoma)
       SOHND-sparing L-Ia (in small posterior lesions of the oral cavity)

The idea of sentinel lymph node biopsy (SLNB) is put forward as a new precise method for histopathological staging of the negative neck parallel to elective SND [56]. Facial lymph nodes' frozen-section biopsy during surgery for parotid malignancy is also described to determine the necessity of neck dissection [56]. SLNB using radiotracer to isolate the first echelon nodes is in practice for management of breast cancer and melanoma. There is argument whether SLNB is good for staging HNSCC with N0 neck [57]. Endoscopic neck dissection has been described in porcine and humans with papillary thyroid cancer [58, 59]. These super-selective nominally invasive methods may take over an important part in the forthcoming staging system of HNSCC [60].

19.4 Surgery for Laryngeal Carcinoma

Undesirable death rate of surgery for laryngeal carcinoma rendered it as a disappointing situation in the early part of the last century. Most of the patients used to refuse major surgical procedure because of limited hope for survival and little chance of cure. So, both the clinicians and patients got inclined towards radiotherapy as the first choice. But quickly the limitations of primitive radiotherapy were understood. Rapid development of surgical skill, availability of antibiotics and safer anesthetic agents plus efficient perioperative care directed the consensus again towards radical surgery as the preferred choice for laryngeal cancer usually diagnosed in advance stage. Total laryngectomy with neck dissection has become the prime choice (Figs. 19.2 and 19.3).

But the operation's consequences are loss of voice along with loss of nasal function, swallowing complications, altered lung function, tracheostomy hazards, and also psychological impacts during the remaining part of life.

Subsequently, two methods for surgical restoration of voice had been designed: (1) neoglottic reconstruction and (2) shunts. Various systems have been tried for neoglottic reconstruction to develop a tracheohyoidopexy pro-

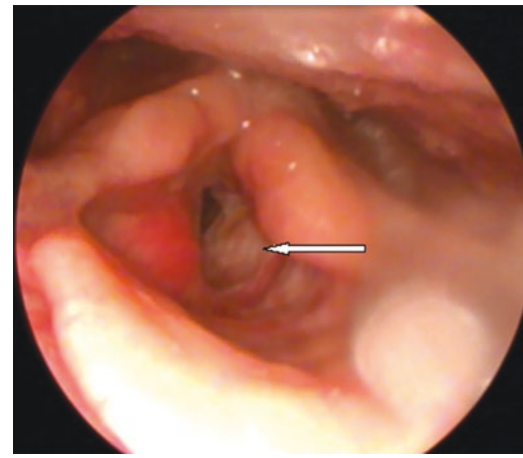

Fig. 19.2 Laryngeal carcinoma (FOL picture)

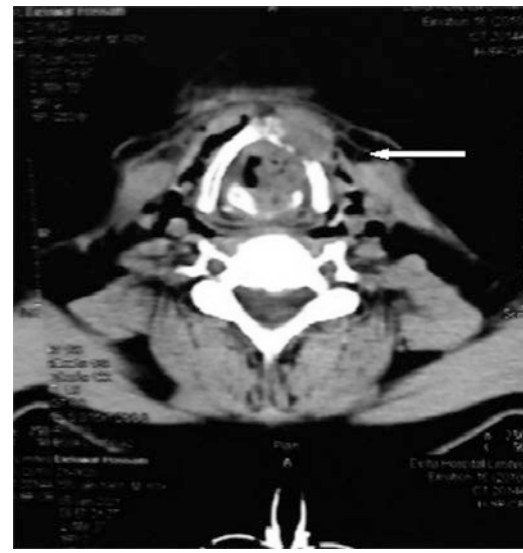

Fig. 19.3 CT scan showing cartilage invasion

cedure, but almost all are abandoned because of multiple complications. Guttman fashioned a surgical tracheoesophageal fistula in 1932 [61]. A great conceptual upgrading surfaced in 1970s through Eric Blom and Mark Singer. Tracheoesophageal puncture and use of prosthesis have dramatically changed the rehabilitation of the patients following laryngectomy. Subsequently in Europe, indwelling voice prosthesis was developed [62, 63]. The Provox voice prosthesis, developed in the Netherlands (1988), is currently one of the widely used devices [64, 65]. The Provox Vega is the latest version which can be used for both primary and secondary procedures. Other available solutions for voice rehabilitation are esophageal speech and electro-larynx.

Pressman et al. noticed the compartmentalized structure of the larynx and its implication for feasibility of subtotal laryngectomies [66]. Subsequently, approaches for various partial laryngectomies came into practice. Supraglottic laryngectomy was reported in 1940s and supracricoid laryngectomy in the late 1950s [67, 68]. The objective of these procedures was to ensure oncologic disease clearance along with restoration of the functions (speech and swallowing) and to avoid permanent tracheostome. Transoral laryngeal surgery (TOLS) by carbon dioxide laser started in the 1970s with reported cure rates as good as open surgery and radiotherapy [69, 70]. Transoral endoscopic laser resection became popular for smaller lesions (T1 and T2) and also for some selected larger tumors. Now the robot-assisted supraglottic laryngectomy has been validated (TORS), which is rationalizing the transoral resection of laryngeal cancer [71].

The robotic system makes a provision for a very clear and accurate operation field, ensuring wonderful hemostasis, superb visualization with identification of submucosal soft tissue and skeletal landmarks of the larynx, and three-dimensional resection of cancer [72]. The robotic system also provides tremendous visualization as well as controlled microdissection at the vocal cord level [73].

19.5 Oral Cavity Cancer (OCSCC)

OCSCC is still a major component of HNSCC causing suffering as well as death among patients, especially in Southeast and East Asia. Although the incidence has been declining over the last few decades, outcomes remain as before with little improvement in the overall survival. Although surgical resection is considered as the primary therapeutic modality, many sectors of dispute and disagreement are persisting about investigations, overall surgical management, and also concerning adjuvant therapy.

Subsites of oral cavity proper are buccal mucosa, hard palate, lower alveolus, upper alveolus, floor of mouth, and oral tongue. Retromolar trigone SCCs are classified as buccal mucosa tumors although they have special features of early posterior spread and mandible involvement (Figs. 19.4 and 19.5).

Subsite of the oral cavity involved and stage of the tumor are key issues influencing the selection of therapeutic modality for OCSCC. The performance status of individuals is also a major consideration because primary therapeutic approach is often drastic with many untoward effects. Oral cavity cancer cases are conventionally treated by surgery, chemoradiation, or combinations of these modalities. The NCCN guideline generally

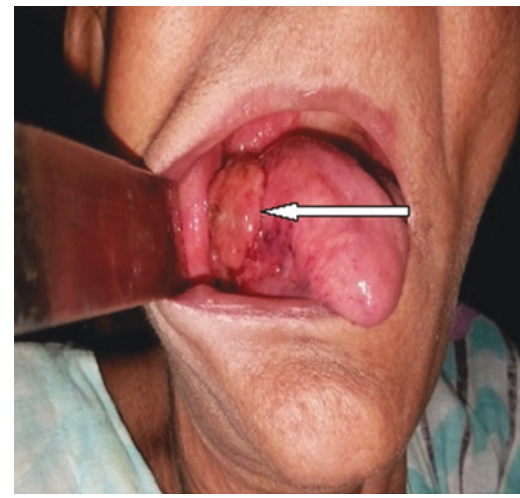

Fig. 19.4 Tongue carcinoma

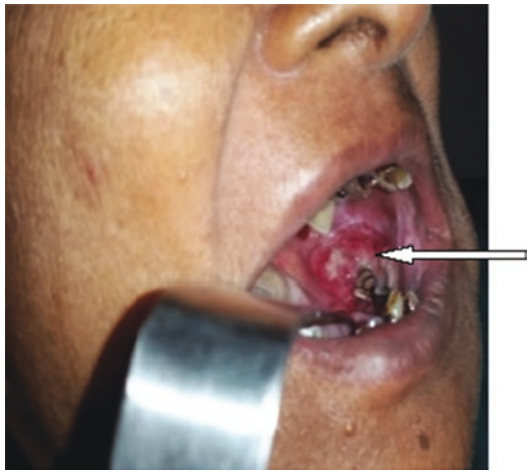

Fig. 19.5 Buccal carcinoma of the retromolar area

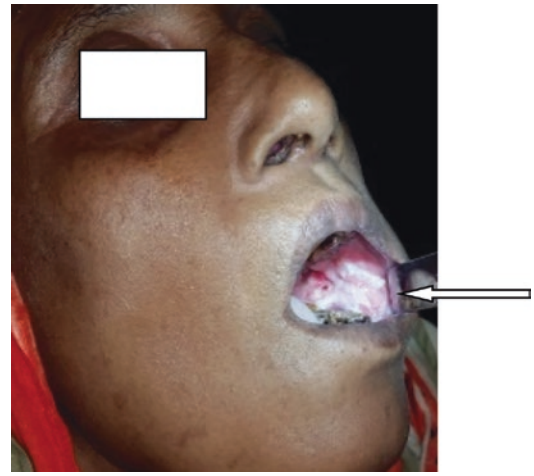

Fig. 19.6 Buccal carcinoma with adjacent leukoplakia

endorses surgery for early lesions and surgery or concurrent chemoradiotherapy for those with advanced lesions [74]. But the decision is absolutely individualized and multifactorial. The combined treatment can be offered concurrently or sequentially. Surgery is typically the starting modality in sequential therapy. Definitive high-dose radiation may induce osteoradionecrosis [75, 76]. The target of operation is resection of the entire primary tumor maintaining safe margins around and comprehensive/selective removal of cervical lymph nodes and also perfect staging of the disease.

Operating approaches for oral cavity resection are decided by the site, surface extension, and deep invasion. To achieve three-dimensional margin clearance is the crucial issue in choosing surgical approach. There are a wide range of approaches in practice, e.g., transoral for smaller lesion up to transmandibular approaches (mandibulotomy/segmental mandibulectomy) along with free flap reconstruction. The standard treatment for this type of cancer is radical excision and preservation of function and aesthetics as much as possible. Surgery can be performed with electrocautery or laser to minimize bleeding and to get a clear operating area (Figs. 19.6 and 19.7).

Different prognostic factors are identified like primary subsite, levels of lymph nodes involved, tumor thickness, and surgical margins. Status of the excision margin is one of the critical variables related to survival [77, 78]. Macroscopic tridimensional margins from 15 mm onwards should be obtained for a microscopic margin >5 mm taking into account that up to 70% shrinkage may occur in pathology specimen [79]. Somewhat poor survival is seen in cases where instant repeat resection is done to ensure negative margins after excising through positive margins in comparison to resection done confirming negative margin on the first attempt (31% vs. 49%, respectively) [80].

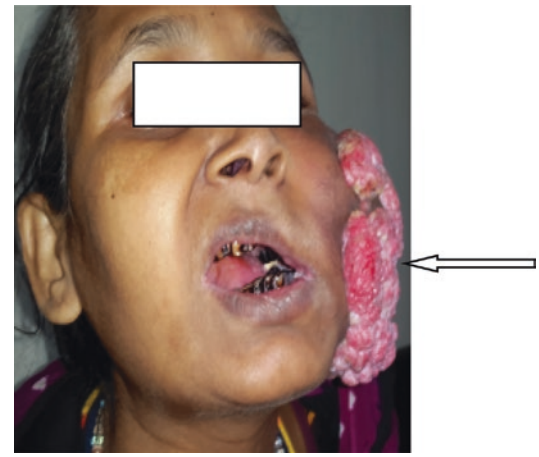

Fig. 19.7 Skin carcinoma involving buccal mucosa

Narrowband imaging p53 chromosomal analysis mutation status of the excision margins has revealed potentiality to identify tumors with his-

tologically negative margins but biologically positive margins [81, 82]. NBI shows great potential to improve detection rates of oral premalignant conditions, identify oral and oropharyngeal squamous cell carcinoma, and define surgical margins and thus reduce the risk of recurrence for OCSCC and OPSCC. However, lot of controversies still exist about the utility of molecular analysis of the resection margin, and this is yet to be used routinely in medical practice. Time and financial involvement are other factors limiting its use.

Evolution of oncosurgery has exerted decisive influence to perform less invasive surgical procedures. CO_2 laser demonstrates that this is an acceptable surgical method for the management of small lesions of the oral cavity [83]. Transoral robotic surgery (TORS), a minimal invasive surgery, has been practiced in many centers to treat early OCSCC with minimum or no blood loss and favorable outcome.

19.6 Oropharyngeal Cancer (OPSCC)

With the advent of laser and robotic instruments, the surgery for OPSCC has undergone noteworthy refinement. Until the end of the twentieth century, open surgery was the primary choice. Because of severe morbidities associated with these approaches leading to functional incapacity of the patients, these were largely abandoned. Formerly, most OPSCC cases were related to consumption of tobacco and alcohol and affected older people. Nowadays, most patients diagnosed with a tonsillar or base-of-tongue disease are usually HPV-positive cases. These patients are somewhat younger, and their long-term prognosis is relatively favorable [84, 85]. These facts have altered the clinical scenario and imposed a plea to design minimally invasive techniques to reduce functional morbidity and also treatment-related toxicity induced by nonsurgical therapy, i.e., chemoradiation.

The relentless advances in minimally invasive surgical procedures, particularly the transoral laser microsurgery (TOLS) and transoral robotic surgery (TORS), have redesigned the surgical landscape. These procedures assure excellent functional outcome, and surgery appears to be reestablishing its position as the primary therapeutic option for these cancers (Fig. 19.8).

Taking into account the complex structural arrangement and functional significance of the oropharynx, several open-access surgical options are available. Mandibulotomy, mandibulectomy, and/or pharyngotomy along with reconstructions by different flaps are suitable to treat advanced-stage cancers and for salvage operation after radiotherapy/chemoradiation failure. But because of the significant morbidity induced by surgery including prolonged hospital stay, nasogastric/gastrostomy feeding tube, necessity for tracheostomy, and also cosmetic deformity, there is a mounting preference for transoral minimally invasive procedures.

The benefits of transoral techniques are slightest damage to the normal tissues, better safeguard for the vital neurovascular structures, as well as quick recovery [86]. Initially although used for smaller lesions limited within the oropharynx, presently less invasive procedures are proved as feasible, useful, and fruitful techniques in selected cases of advanced OPSCC [87, 88]. Both TOLS and TORS techniques have exhibited appreciable local control of cancer and disease-

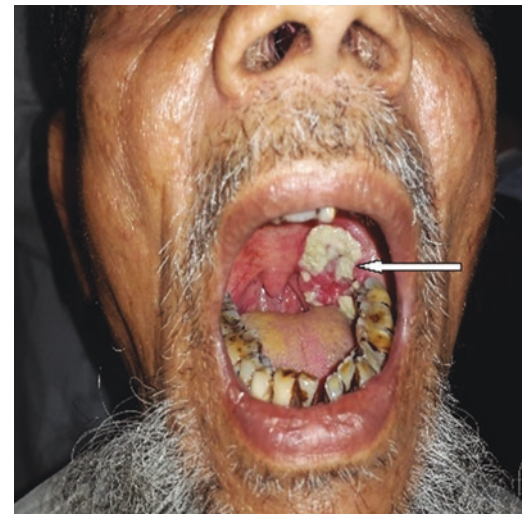

Fig. 19.8 Left tonsillar carcinoma

free survival for primary OPSCC while minimizing functional and aesthetic shortcomings [89, 90]. TOLS and TORS are also efficient for salvage surgical procedure in cases following RT/CRT failures [91, 92].

TORS provides clearer and wider visualization of the operating ground and better 3D idea of tissue plane than TOLS, allowing safer access to the cancer. Another benefit of TORS is miniaturized multiarticulate equipment, which mimics ordinary surgical instruments but offers wider range arm rotation, with tremor filtration. It also allows to reach "blind corners" of the pharynx and larynx by using a 30° telescope [72]. Complications of TORS are also not ignorable. Hemorrhage represents 23% of complication related to TORS. Even revision surgical procedure may be required for hemostasis [93]. Cost is also a major constraint. While comparing the cost with that of conventional surgery, it appears excessive. But actually, it should be compared with nonsurgical options like radiation or chemoradiation or with transcervical/transmandibular operations. Reducing hospital stay itself could be enough to balance the cost. Superiority due to less invasive method, faster recovery, and functional consequences rationalize the expenditure.

TORS, as surgical maneuver, allows assessment of the primary lesion for pathological staging. Concomitant neck dissections permit the perfect staging based on the histopathological examination. TORS may be the decisive treatment in selected T1–T2 cases of OPSCC and erases the necessity of adjuvant treatments [94].

19.7 Hypopharyngeal Cancer

In smaller hypopharyngeal carcinomas, surgical resection keeping adequate safe margin and external beam radiotherapy (EBRT) were the options depending on the expertise and experience of the treating physicians. For advanced hypopharyngeal carcinomas, radical resection plus reconstruction of the surgical defect followed by postoperative adjuvant irradiation was the standard form of management in the 1970s–1990s [95, 96].

In the present era, standard protocol is multimodal treatment, using surgery, radiotherapy, and chemotherapy with curative intent. Most studies dealing with hypopharyngeal cancer compare various chemo- and radiotherapy regimens, but do not compare with a surgical protocol [97]. For patients categorized as unfit for curative treatment, palliation is a choice. Because of significant submucosal spread, hypopharyngeal carcinoma is generally diagnosed in advanced stage (III and IV), commonly with cervical and/or distant metastases, and therefore bears worse prognosis [98].

Surgical treatment of hypopharyngeal cancers is determined by the lesion's subsite involvement and extension and often requires reconstruction. Postsurgical reconstructive policies for hypopharynx are usually flexible and vary according to whether the larynx is to be preserved or not. If the whole larynx is excised, separate channels for respiration and swallowing are to be created for maintaining the chief purposes of this organ. In 2003, Disa et al. suggested various types of repairs depending on the surgical defect in the pharyngo-esophageal portion after total laryngectomy [99]. The defect including the lateral wall of the pyriform fossa can be repaired straightway if it is small. In other cases, reconstruction is required. These procedures may involve a pedicled myocutaneous flap or free flap like radial forearm (RFFF) anterolateral thigh flap (ALT) [100, 101]. If the patient has been exposed to radiation/chemoradiation prior to surgery, the risk of pharyngo-cutaneous fistula or a stricture formation is much higher.

Recent upsurge in robotics technology is providing scope for more delicate surgical procedures to be performed utilizing minimal invasive route. It has many advantages over conventional surgical approaches, including rapid recovery, lower incidence of postoperative infection, decreased intensity of pain, better postoperative functional restoration, and cosmetic superiority [102]. Moore et al. stated that almost all patients regain normal swallowing at different stages of follow-up within 2 years [103]. Boudreaux et al. found effective swallowing in 79% at the end of 3 months, while Weinstein et al. reported a successful swallowing in 97.6% at 12-month follow-up [88, 104].

19.8 Nasopharynx Carcinoma (NPC)

The incidence of nasopharyngeal carcinoma is highest in Southern China. Southeast Asia and North Africa have a lot of cases, but it is rare in other parts of the globe. There has been a significant conceptual change regarding etiology and pathogenesis of NPC in the recent past. Hypothesis has been put forward that NPC is initiated by an interplay between essential basic factors (persistent Epstein-Barr virus) and cofactors (bacterial fatty acid and catalytic ingredients of plant origin habitually consumed). Epstein-Barr virus (EBV) is triggered by this approach, which initiates a series of events leading to the malignant transformation [105].

To develop clear knowledge about the biological behavior of NPC, some molecular variables have been evaluated to testify the hypothesis that p53 dysfunction in NPC is linked with EBV. The existence of EBV seems to be the predictor for higher survival, but the mechanism is yet to be clarified [106]. In contrast to other HNSCCs, NPC was previously considered as "unresectable" due to difficult and narrow surgical access, high incidence of early extension beyond the nasopharyngeal cavity, and also cervical metastasis at presentation. External beam radiotherapy (EBRT) was the prime option for treating such cases. The USA's NCCN guidelines endorse intensity-modulated radiotherapy (IMRT) as the primary curative treatment for freshly detected NPC, but radiotherapy-induced hazards are hardly acceptable [107, 108].

Various surgical approaches to nasopharynx have been designed since the starting of skull base surgery. Multiple approaches are in practice for tumours of different size and subsite involved within the nasopharyngeal space, like Infratemporal fossa, Transpalatal, Mandibular swing, Maxillary swing approaches and also Facial translocation combined with neurosurgical craniotomy approach for tumours with skull base extension [109].

With the availability of CT scan and other imaging, an increasing number of patients are screened and diagnosed in early stage [110, 111]. This creates an opportunity to radically resect out the lesions limited in the nasopharyngeal cavity surgically. Moreover, emergence of nasoendoscopic systems in the modern era, the endoscopic endonasal approach (EEA), provides scope for surgeons to excise deeply situated cancers, even those once labeled as inoperable [112]. Still there are some limitations and obstacles remaining during performing the radical excision of NPC due to troubles faced during instrumentation via a narrow nasal cavity. Another shortcoming is to perform en bloc resection. To overcome these problems and for recurrent NPC, a technical system has been established and employed successfully for using endoscopic nasopharyngectomy (ENPG) plus reconstruction by pedicle mucoperiosteal flap from nasal septum and floor [113, 114]. ENPG could overcome the previous limitations and achieve satisfactory overall survival, minimizing posttreatment complications in locally recurrent NPC [115].

19.9 Nose and Paranasal Sinuses

Paranasal sinus cancers are a group of heterogeneous malignancies, which originate in proximity to vital structures. Close relation with orbit, cranial nerves, carotid arteries, and intracranial structures including brain makes surgical resection highly critical with risk of serious morbidity. Relatively low incidence and heterogeneity render randomized controlled trials regarding management of these cancers difficult. Till the transition between the twentieth and the twenty-first centuries, the operative procedures for paranasal sinus cancers were mainly different types of maxillectomy, nasal cavity exenteration, exenteration of ethmoid cells, and exploration and curettage of sphenoid sinuses with an average 5-year survival rate of 28% [116]. In 1963, Ketcham et al. reported the craniofacial resection (CFR) for paranasal sinus cancers [117]. In the 1980s and 1990s, the craniofacial approach became the gold standard for sinus malignancies. Overall 5-year survival rate reported was around 51% except for olfactory neuroblastoma [118] (Fig. 19.9).

Endoscopic endonasal approaches (EEA) to sino-nasal malignancies were the first that came into practice at that time. Increase in skill over endoscopic handling; availability of sophisticated investigative tools, e.g., intraoperative imaging systems; understanding of detailed complex anatomy of the paranasal sinuses and their relations with the adjacent vital structures; and expertise in endoscopic resection are growing rapidly [119] (Fig. 19.10).

At the beginning, early-stage malignancies were handled endoscopically and combined with craniotomy for more advanced cancers. Indications for EEA expanded as experience with endoscopic cancer surgery and cerebrospinal fluid (CSF) leak repair increased. The limit has now extended up to resecting cancers invading intracranial structures. The idea of the EEA derives from the observation that these sinus cancers are frequently polypoidal and have a localized attachment and the main tumor bulk fills up the hollow sinus or nasal cavity at its starting. The endoscopic surgery removes tumor by piecemeal with the target to reach, identify, and excise the tumor pedicle and ensure a safe margin facilitated by minimizing bleeding, better illumination, and improved visualization of the tumor origin [120]. The application of da Vinci robotic system in the paranasal sinuses has been less successful. Morbidities associated with these approaches are not negligible [121].

Fig. 19.9 Orbital bulging in sino-nasal carcinoma

19.10 Salivary Gland Malignancy

19.10.1 Parotid Tumors

Salivary gland malignancies are infrequent, and the understanding of this disease is mostly based on reported clinical series rather than randomized evidence. Salivary gland tumors manifest a diverse range of histological and clinical behaviors. Parotid tumors are usually found in the superficial lobe. This lobe is well imagined by high-frequency ultrasonogram (US) [122]. In addition, ultrasonography is helpful for guided fine needle aspiration cytology (FNAC). FNAC under US guidance has a high rank in investigative accuracy and safety [123]. The trunk of the

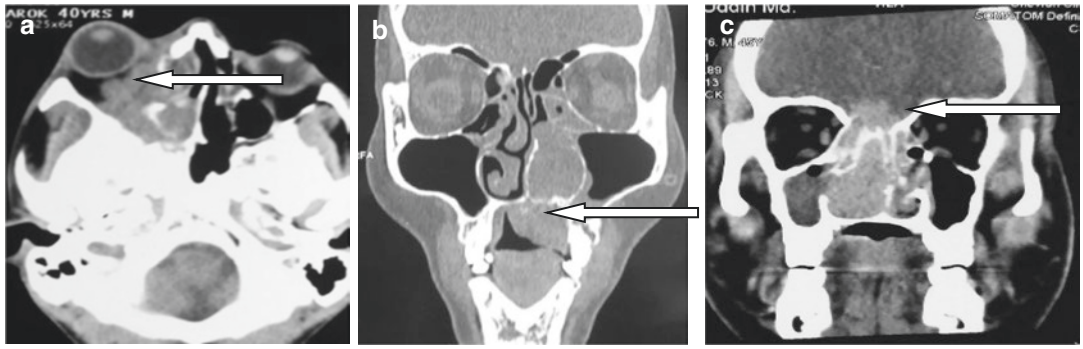

Fig. 19.10 (**a**–**c**) CT scans of sino-nasal carcinoma: (**a**) ocular extension, (**b**) palatal extension, and (**c**) intracranial extension

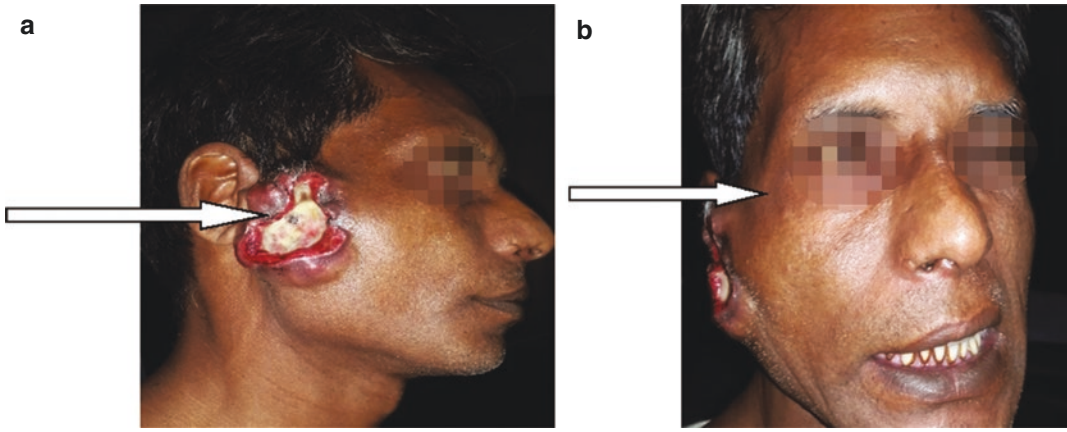

Fig. 19.11 (**a**, **b**) Parotid gland carcinoma with skin involvement and facial nerve palsy

facial nerve cannot be pictured by usual ultrasonography. MRI is an excellent imaging for cases with clinically obvious swellings in parotid gland with suspicious findings of malignancy. MRI offers accurate evidence about the location and extension of the tumor, even if it is in the deep lobe or parapharyngeal space. It exposes the scenario of cervical lymph node status. MRI allows detection of bone invasion, perineural extension, and meningeal infiltration [124]. CT scan may be advised for staging if MRI is contraindicated or not available. FDG-PET/CT cannot practically distinguish malignant, benign, or metastatic parotid tumors [125] (Fig. 19.11).

19.11 Intraoperative Facial Nerve Monitoring

Electromyographic (EMG) monitoring of facial nerve is almost in regular use during parotid surgery. But prospective randomized controlled study regarding usefulness of the EMG monitoring is lacking. One meta-analysis showed that preoperative EMG monitoring of facial nerve lessens the chance of facial nerve weakness in early postoperative period after parotidectomy [126]. Its role in revision cases and in final outcome of cranial nerve VII is yet to be elucidated. It helps to locate the nerve trunk and its branches while using a combination device for electrostimulation and monitoring. This can reduce the operation time for parotid surgery [127]. Nerve monitoring is also helpful to elude nerve injury if the facial nerve is not identified during parotid surgery.

If the cranial nerve VII is sectioned during surgery, it should be repaired as soon as possible. Repair under microscope without tension, or repair with a nerve graft, offers the chance of good recovery. If the nerve trunk or main branches are invaded by the tumor but functional, then sacrificing overtly involved part of any of the nerves and primary nerve grafting following radical resection of the tumor are the prime choice.

19.12 Carcinoma of Unknown Primary (CUP)

This is a heterogeneous group of metastatic tumors where even a wide-ranging diagnostic workup cannot detect the site of origin. Clinically, CUPs are categorized by a set of unique features like early metastatic spread of unpredictable pattern, apparently aggressive clinical behavior, and relatively poor prognosis (Fig. 19.12).

The diagnosis of CUP can be made after through clinical history, physical examination, laboratory tests, imaging, and a careful review of the histology with immunohistochemistry (IHC), and also PET/CT if necessary. IHC staining has been a standard pathologic practice for evaluation in CUP for the last two decades. CUP

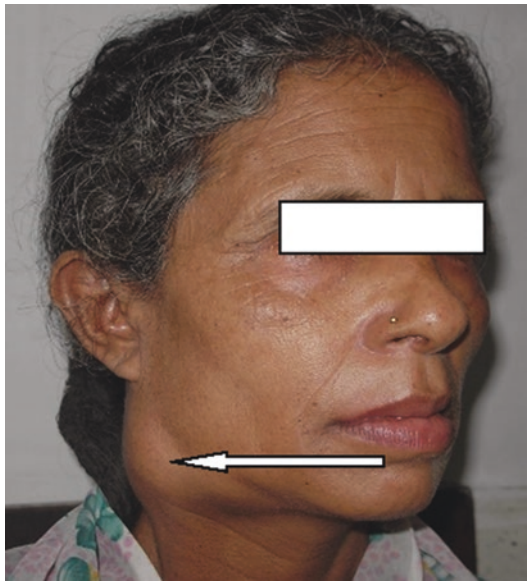

Fig. 19.12 Cervical metastatic carcinoma with unknown primary (CUP)

accounts for 3–5% of all cancers. The proportion of CUP to the cervical lymph nodes (HNCUP) accounts for around 60% among all such carcinomas. The biology of these cancers is yet to be well understood. Two opinions regarding the origin of CUP have been put forward. The primary suggestion is that CUPs are a heterogeneous cluster of site-specific tumors, which share the properties of primary site from where they derive, and the second postulation is that these are distinct entities having a specific genetic asset [128]. Advanced age, advanced N stage (N3, N2b, and N2c), and ECS (extracapsular spread from metastatic lymph nodes) are negative prognostic factors, and HPV-induced origin is considered as a positive prognostic factor. Diagnostic criteria or treatment policies so far recognized remain unaltered [129, 130].

19.12.1 Treatment

There are two treatment options:

1. Neck dissection and postoperative adjuvant radiation
2. Primary radiation or chemoradiation (CRT)

Three types of neck dissections are generally offered: (1) radical neck dissection, (2) modified neck dissection, or (3) selective neck dissection (levels 1–3). Usually, full-dose radiotherapy (RT) is advocated. There are no differences in techniques (conventional or IMRT) or dose of radiotherapy, whether the neck dissection has been performed or not. If the nodes are present in level V or retropharyngeal space, chance of nasopharyngeal primary is higher [131].

Survival is encouragingly higher, and the recurrence is markedly lower for patients with HPV-related than non-HPV-induced HNCUP [132, 133]. The survival of patients with CUP in distal sites like lungs, bones, and other sites is very poor, usually in months. Overall 5-year survival rate is still frustrating, although improving reasons for this development might be the detailed understanding of different prognostic factors, including extranodal extension, stage of metastatic lymph nodes, and HPV involvement [134, 135].

Treatment of HNCUP is yet to reach consensus; some studies have revealed higher survival rate for treatment comprising neck dissection [136, 137]. But indication for neck dissection was questioned by a few, as no substantial variation in survival could be shown between cases with or without neck dissection [138]. Precise gene expression profiles can be identified in most cancers relating to the site of origin. These different expression profiles reflect their tissues of origin. Gene expression profiling assays, called molecular cancer classifier assays (MCCAs), are competent to ascertain around 40 cancers and cancer subtypes [139, 140]. The fast advancement of immune checkpoint inhibitors (targeted therapy) and other immune-modulatory agents is likely to be promising for treating patients with CUP. Right now, only few case reports are available about these treatments [141].

19.13 Parapharyngeal Space Tumors (PPS)

The parapharyngeal space is a structurally composite region. Tumors arising in this area are not very common, and surgery is considered as a

preferable option in the majority of cases. Various operating approaches have been practiced by surgeons. Most of the parapharyngeal space tumors are of neurogenic or salivary tissue origin. Ectopic salivary tissue tumors originate in the PPS, and deep lobe tumors from parotid gland may extend to the PPS. Schwannoma or neurofibroma is a common neurogenic tumor. These may become large enough before giving rise to symptoms. Because of the close proximity with the internal carotid artery and lower cranial nerves, precise information about tumor location and its relation, adhesion, and invasion to the vital structures is crucial for surgery. The transcervical route, transparotid route, or a combination of these two is the standard surgical approach [142] (Fig. 19.13).

Mandibulotomy is rarely necessary nowadays, and most of the cases can be handled via transcervical approach with endoscopic assistance. This allows meticulous clearance and better hemostasis (Fig. 19.14).

Minimally invasive robotic-endoscopic techniques are coming up as effective alternatives in some cases. TORS has been used for removing smaller lesions, especially salivary tumors perorally and via a transcervical route for bigger tumors, likely to be fragmented during removal.

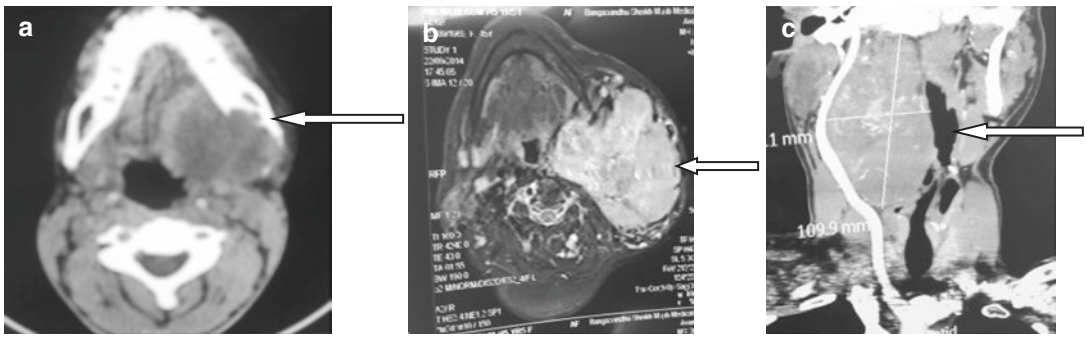

Fig. 19.13 (**a**–**c**) Imaging of parapharyngeal tumors (different patients). (**a**) CT scan (malignant tumor). (**b**) MRI. (**c**) CT angiogram

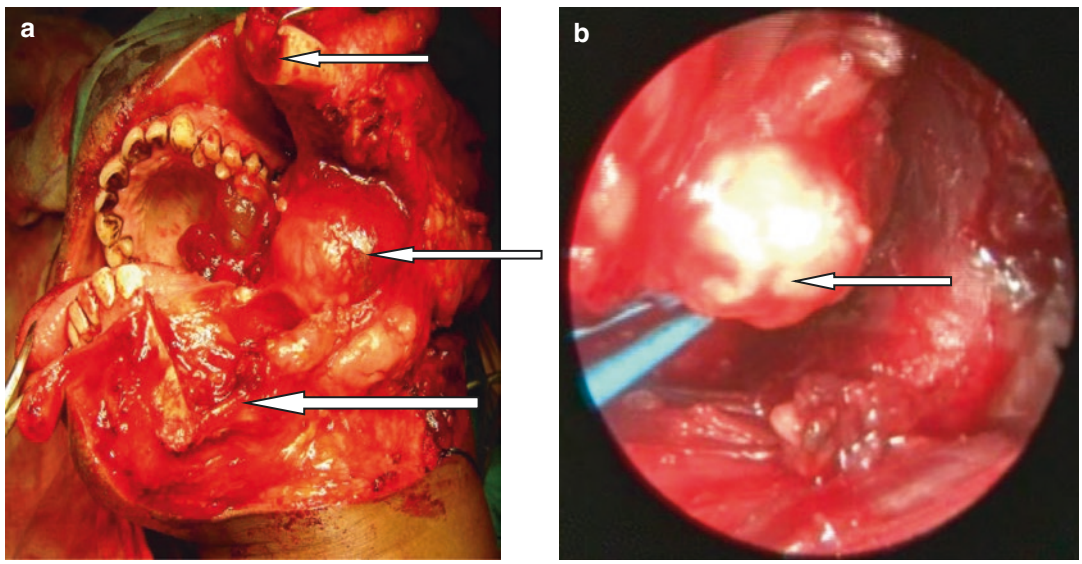

Fig. 19.14 (**a**) Transmandibular approach. (**b**) Endoscopic removal via cervical approach

TORS is also indorsed for taking tissue for biopsy from adversely located PPS tumors with suspicious manifestation, which are inaccessible without a mandibulotomy [143]. Cases of neurogenic tumors from the difficult area like retrostyloid space treated with TORS have also been reported. Safety and feasibility of the TORS for PPS tumors achieve a high local control with low perioperative/postoperative complication rate [144].

19.14 Ongoing Controversies in Management of HNSCC

19.14.1 Controversy in Staging System

In the eighth edition of the AJCC's TNM staging system, the depth of invasion (DOI) of the primary OCSCC has been integrated into the T category and has been considered as a major constituent in the staging system. But how efficiently this new system will reflect prognosis in respect to survival, occult metastasis, and recurrence is controversial. According to the eighth edition staging system, DOI 5 mm is the cut margin for upgrading from T1 to T2 and 10 mm for upgrading to T3. This is debatable because research-based opinion prevailing on 3 or 4 mm is crucial. DOI >4 mm is associated with high risk of locoregional spread and poor prognosis [145].

19.14.2 Diagnostic Controversy

The opinion varies regarding diagnostic strategies for many HNSCCs, especially after the availability of 18-FDG-PET/CT. Should it be a part of routine preoperative checkup? PET/CT can reveal second primary efficiently. Incidence of synchronous primary has been reported to be in between 5% and 12% [146, 147]. Second primary is often small and curable. Detection of synchronous carcinoma is crucial because it may alter the therapeutic approach. Can this replace pan-endoscopy in early-stage diseases? Opinion differs; PET/CT may not be as efficient as endoscopy to detect small superficial lesions [148, 149]. Routine 18-FDG-PET/CT may be considered as an overdoing in nonsmoker HPV-positive patients harboring OPSCC. Reduced rate of second primary has been reported in such cases [150, 151].

In 10–15% of stage III or IV HNSCC, distant metastases are likely to be existing at the time of therapeutic evaluation, which obviously influences treatment [152]. Competence of 18-FDG-PET/CT for discovery of distant metastases is well recognized, but as the incidence is low in early-stage HNSCC at presentation, it should be advised only in advanced N-stage cases.

In cases of carcinoma with unknown primaries (CUP), the supplementary diagnostic benefit of 18-FDG-PET/CT is admiring [153]. PET/CT possesses higher sensitivity compared to CT or MRI for identifying the occult primary, with additional benefit of its ability to identify distant metastatic lesion/s and synchronous second primary [154]. PET/CT can also discover non-HNSCC occult primaries in the thorax or abdomen, responsible for cervical nodal metastasis [155, 156].

Cartilage invasion is a crucial finding for proper planning of laryngeal cancer treatment. This generally beyond clinical access and a dependable investigative assessment is required. A meta-analysis of CT scan findings demonstrates frequency of cartilage invasion from 19% to 27%. False positives are frequent, whereas false negatives relatively infrequent. False negativity in negligible cartilage invasion does not contraindicate nonsurgical policies like chemoradiation or conservative surgeries, e.g., partial laryngectomies [157]. But the capability of CT for extralaryngeal extension of cancer is not as per expectation [158]. MRI for its unique soft-tissue delineation is the preferred assessment tool for cancer spread beyond the larynx [159].

19.14.3 Sentinel Lymph Node Biopsy (SLNB)

One major area of controversy is about the diagnostic value of SLNB in HNSCC. SLNB may be a valuable diagnostic method to appropriately evaluate cervical lymph node metastases. SLNB could

avoid morbidity of elective neck dissection (END) and primary chemoradiation therapy in smaller oral cavity cancer [160]. Although the diagnostic value of sentinel node assessment by fine needle aspiration cytology appears to be promising, it was later shown as not acceptably fruitful [161].

Authentication of the sentinel lymph node biopsy technique demands that cases undergoing SLNB should have identical therapeutic efficacy as patients treated by END. Therapeutic and prognostic significance of tumor-positive sentinel lymph nodes should be judged critically. Succeeding therapeutic neck dissection should be deferred until detailed histopathological and immunohistochemistry reports are available. Type of neck dissection will depend on the individual merit of the case, but it may cause some additional morbidity. Otherwise, radiotherapy could be an option though this may also precipitate morbidity. It would be better if per-operative sentinel lymph node frozen-section biopsy enables to take instant decision on whether a formal therapeutic neck dissection has to be carried out or not to avoid hassle and hazards of second surgery. Frozen-section biopsy of the sentinel lymph nodes has been practiced for breast cancer and malignant melanomas. But sensitivity for micrometastases is poor and not justifiable in these tumors [162, 163].

Thus, there are still a number of questions yet to be solved before incorporating SLNB in routine practice. Further clarification is required whether only sentinel node biopsy is capable enough to identify early regional metastases. If it comes true, additional elaborate studies will be necessary to determine whether regional therapeutic control after SLNB is identical to END. It is desirable that morbidity for secondary therapeutic neck dissection following SLNB should not exceed that of primary selective END [164].

19.14.4 Strategy for Advanced Neck Carcinomas

Chemoradiation (CRT) has become the favored approach for treating oropharyngeal, hypopharyngeal [165], and laryngeal [166] primary carcinomas in many settings. Advanced carcinomas are generally having large primary or lymph node metastasis in several levels (N2b/c, N3), and the ideal policy to address these neck metastases is still debatable. Options are (1) neck dissection prior to CRT and (2) primarily planned neck dissection after CRT.

Those practicing neck dissection before chemoradiation do not find any logic to shift from their dogma [167]. Is the neck dissection following CRT based on primary planning only is justified or should require further scrutinization by 18 FDG PET-CT after CRT to sort out patients demanding surgical clearence? This is the main controversy, but this issue has been settled by a randomized controlled trial revealing that an 18-FDG-PET/CT scan, 10–12 weeks after CRT, is efficient enough to find out which patients require neck dissection [168].

One of the main purposes of neck dissection, whether therapeutic (cN+) or elective (cN0), is to select patients requiring adjuvant therapy. Precise information about the involved metastatic lymph node groups is important to the radiation oncologist to irradiate neck by intensity-modulated radiotherapy (IMRT). The neck specimen should be separated into levels and sublevels just after the operation, and each level should be put into a separate container with appropriate labeling [169]. Locating negative margins in big metastatic nodes may not be possible sometimes, which makes it difficult to separate adjacent levels.

19.14.5 Optimal Resection Margins

The Royal College of Pathologists, UK, has defined 5 mm clear margin in histopathology specimen as the safe resection margin in T1–2 oral cavity tumor [170]. Opinion varies from 5 to 10 mm. A “sufficient” histopathological clear margin signifies lesser risk for tumor recurrence. Necessity for adjuvant treatment in these cases requires further justification by other findings. Bad prognostic features other than close or positive margins demanding adjuvant CRT subsequent to surgical resection include metastatic lymph nodes with extranodal extension. Reports assessing oral cavity N0 patients with margins smaller than 5 mm,

treated only surgically, have shown that these were not associated with inferior local control, while depth of invasion and perineural invasion were predictive of local recurrence [171].

19.15 Controversies in Oral Cavity Carcinoma (OCSCC)

19.15.1 Nonsurgical Treatment

Surgery is the primary choice for large T2, T3, and T4 OCSCC. Achievement in laryngeal cancer and OPSCC with nonsurgical treatment modalities has encouraged researchers to see their role in OCSCC. Several studies have assessed the effectiveness of definitive CRT for advanced HNSCC, demonstrating improved survival. However, OCSCC-based studies in this regard are rare [172]. So far, no prospective study is available in the literature comparing surgery with CRT.

Induction chemotherapy prior to surgery has been advocated to reduce the chance for distant metastasis. But this is yet to be proved authentically that any significant difference occurs in overall survival between the two groups, those who have induction chemotherapy prior to surgery and the group where surgical treatment is followed by chemoradiation [173].

19.15.2 HPV in OCSCC

Despite the well-recognized advantages of HPV-positive OPSCC, its impact on OCSCC is yet to be ascertained. The prevalence of HPV in OCSCC is low (5.9–21.3%), and p16 expression in OCSCC does not reveal any survival benefit [174, 175].

19.16 Controversies in the Management of Oropharynx Cancer (OPSCC)

OPSCC generally presents with locally advanced lesion. Multimodality approach is required for treatment considering the gravity of the tumor and functional aspect of the organ. Targeting the preservation of vital functions concerned, concurrent chemoradiotherapy (CRT) is usually preferred over surgery plus adjuvant radiotherapy. Controversies exist regarding whether to include induction chemotherapy prior to chemoradiation and what is the best way to manage the neck. Moreover, HPV is now an established risk factor mainly for OPSCC. Prognosis is much better than that of patients with non-HPV tumors. Considering the distinct differences between these HPV-positive and HPV-negative cancers, controversy is going on regarding the management. The burning question is that are the HPV-positive cases undergoing overtreatment.

19.16.1 Treatment Modality Options for Resectable Tumor

Sorting of patients for definitive CRT versus primary surgery for locally advanced OPSCC is complex and controversial, better to be decided in a multidisciplinary board. In the recent literature, no prospective randomized control trials are available comparing concurrent CRT with primary surgery plus adjuvant RT. Quality of life appears to be more or less alike with either modality [176].

19.16.2 Induction Chemotherapy

Induction chemotherapy (IC) followed by CRT for locally advanced OPSCC may eradicate early micrometastatic foci and also provide early symptomatic control. Additionally, radiotherapy disrupts vascular supply to the tumor, resulting in decreased chemoperfusion. IC can avoid this issue, allowing greater tissue penetration before definitive chemoradiation. Despite significant improvements in locoregional disease control, the issue of development of distant metastases still remains controversial [177].

19.17 Controversies in Laryngeal Carcinoma

19.17.1 Treatment of Primaries in Laryngeal Glottic Carcinoma

Vocal cord mobility is crucial for treating glottic cancer. The absence of mobility indicates infiltration of the vocalis part of the thyroarytenoid muscle or hardly ever involvement of cricoarytenoid joint. This is considered as poor prognostic issue. T1 carcinoma will be converted to T2 in case of impaired mobility, and T3 for immobility. The inference of impairment mobility of vocal cord is that the tumor has become considerably larger and extended laterally. It may require much extensive endoscopic surgery and thus end up with voice and swallowing impairment. In case of T3 lesions, negative resection margin may be tough to reach endoscopically. This again validates partial laryngectomy by external approach [178]. If chemoradiation is chosen as the therapeutic option in T2 glottic cancers, impairment of vocal cord mobility becomes the most significant adverse prognostic factor [179].

There are two treatment options for carcinoma of the anterior commissure of the larynx. The dilemma to treat it by primary irradiation or by conservative surgery is yet to be solved. MRI/CT scan findings may not be conclusive for staging at this point.

19.18 Controversies in Nasopharyngeal Carcinoma (NPC)

Primary treatment for NPC without cervical lymph node metastasis is by radiotherapy. The role of systemic therapy is also coming up. Cisplatin-based concurrent chemoradiation is the currently used protocol for locally advanced tumors. The prognosis of NPC has been improving significantly over the first two decades of the twenty-first century. But still there are some uncertainties and variations in thinking regarding the optimal treatment strategy. Distant metastases appear to be the main sector of treatment failure despite appreciable local control [180].

In advanced scenario of locoregional NPC, conventional treatment with radiotherapy is hopeless, because of local recurrences and development of distant metastases. The neoadjuvant and adjuvant chemotherapy has been consistently exhibiting better response, but randomized control trial (RCT)-based evidence is still lacking. Altered-fractionation radiation techniques could not demonstrate any improvement in disease-free or overall survival [181].

19.19 Future Trend of Therapeutic Strategies

19.19.1 Targeted Therapy

Advanced HNSCC usually requires multimodal treatment, which may precipitate significant toxicity. The promising options for these patients are molecular targeted therapies. The well-practiced targeted therapies are epidermal growth factor receptor (EGFR) monoclonal antibodies (e.g., cetuximab, panitumumab), EGFR tyrosine kinase inhibitors, vascular endothelial growth factor (VEGF) inhibitors, or vascular endothelial growth factor receptor (VEGFR) inhibitors. Some other inhibitors of different pathways and targets are also promising and require evaluation by further research [182].

EGFR overexpression has been detected in about 90% of HNSCC. It is considered as a negative prognostic factor, which increases the size of the cancer, decreases its radiosensitivity, and also increases the risk of recurrence [183].

The heterogeneity of molecular disorders in HNSCC still makes it difficult to put on estimable strategy for targeted treatment. Few biopharmaceuticals are being tested in clinical and preclinical settings. The fact is that they could not bring any revolutionary change in the treatment of HNSCC, and yet remain to be standard therapeutic options. Identification of molecular markers connected with the treatment response will help personalize targeted and nontargeted treatment. Ongoing interest of scientists in genetic

and molecular biology may render targeted therapy a fundamental modality of cancer treatment in the coming years.

19.19.2 Immunotherapy

PD-1 and PD-L1 are immune checkpoint proteins present on the cellular surface. Inhibitors of immune checkpoints are emerging as a frontline treatment for several types of cancer [184].

HNSCCs are quite common cancers. Although many patients with locally advanced stage enjoy a long period of disease-free survival with combined modality treatment comprising surgery, radiation, and chemotherapy, lot of cases develop local recurrence and regional or distant metastasis and are labeled as incurable. Chemotherapy has limited efficacy due to significant toxicity in metastatic HNSCC, with an average overall survival of less than a year [185]. Immunotherapy with PD-1 and PD-L1 inhibitors has dramatically altered the treatment of multiple cancers [186, 187]. Till now, the strongest evidence for the application of immunotherapy in cisplatin-refractory disease is for PD-1-directed antibodies [188]. Research focusing on biomarkers to find out a rational combination and more refined method for patient selection is essential to expand the benefit to suffering people through these emerging inspiring drugs.

19.19.3 Cancer Stem Cells (CSCs)

Cancer stem cells (CSCs) are the subgroup of cells contained by the cancerous lesion that contribute to resistance to therapies and potential for recurrence. These have significant influence on the treatment success and disease progression. In addition to two well-known types of stem cells, embryonic and adult stem cells, existence of a third variety, named as cancer stem cells (CSCs), has been discovered recently [189].

Conventional concept regarding malignant transformation is that it starts from a randomized genetic mutation, which can affect any cell. The mutant cell population, which has gained proliferative properties and resultant genomic instability, ensues further epigenetic and genetic events, prompting assembly of the new aggressive subclones with consequent tumor development [190].

In contrary to the ordinary model of clonal evolution in carcinogenesis, a new theory has been put forward based on the CSC's role. This "CSC hypothesis" can logically illuminate the reasons for poor response to therapies, high mortality rate, and tendency to develop synchronous and metachronous primaries in HNSCC patients [191].

Among the heterogeneous cell population of HNSCC lesions, the small subpopulation of CSCs is considered as responsible for resistance to radio- and chemotherapy, local recurrence of cancer, and also initiation of metastasis due to high migration capability [192, 193].

The CSC hypothesis may have major implications on cancer treatment and may lead to development of new therapeutic strategies even shifting from conventional to a new treatment paragon.

19.20 Conclusion

Head and neck malignancy is a vast, interesting, and controversial chapter of medicine, which involves multiple disciplines for management. Still, surgery, radiotherapy, and chemotherapy are the main treatment modalities, although significant qualitative changes have occurred in these during the last several decades. The foremost mounting idea is the functional organ preservation without compromising prognosis. In case of radiotherapy and chemotherapy, research has been destined to make them more target specific and to reduce toxicity. Future trend of experimentation will be concentrated on detecting HNSCC in its premanifestation stage and also anticipating behavioral pattern with the help of immunological and non-immunological biomarkers. Targeted therapy, immunotherapy, and cancer stem cell management will get due importance in therapeutic policies.

References

1. Levin ML. Some epidemiological features of cancer. Cancer. 1948;1(3):489–97. https://doi.org/10.1002/1097-0142(194809)1:3<489::aid-cncr2820010317>3.0.co;2-6.
2. Hoffmann D, Wynder EL. A study of tobacco carcinogenesis. XI. Tumor initiators, tumor accelerators, and tumor promoting activity of condensate fractions. Cancer. 1971;27(4):848–64. https://doi.org/10.1002/1097-0142(197104)27:4<848::aid-cncr2820270415>3.0.co;2-4.
3. Wynder EL, Gottlieb S, Wright G. A study of tobacco carcinogenesis. IV. Different tobacco types. Cancer. 1957;10(6):1206–9. https://doi.org/10.1002/1097-0142(195711/12)10:6<1206::aid-cncr2820100618>3.0.co;2-p.
4. Wynder EL, Kopf P, Ziegler H. A study of tobacco carcinogenesis. II. Dose-response studies. Cancer. 1957;10(6):1193–200. https://doi.org/10.1002/1097-0142(195711/12)10:6<1193::aid-cncr2820100616>3.0.co;2-y.
5. Wynder EL, Taguchi KT, Baden V, Hoffmann D. Tobacco carcinogenesis. IX. Effect of cigarette smoke on respiratory tract of mice after passive inhalation. Cancer. 1968;21(1):134–53. https://doi.org/10.1002/1097-0142(196801)21:1<134::aid-cncr2820210122>3.0.co;2-p.
6. Wynder EL, Bross IJ, Day E. A study of environmental factors in cancer of the larynx. Cancer. 1956;9(1):86–110. https://doi.org/10.1002/1097-0142(195601/02)9:1<86::aid-cncr2820090108>3.0.co;2-6.
7. Wynder EL, Bross IJ, Feldman RM. A study of the etiological factors in cancer of the mouth. Cancer. 1957;10(6):1300–23. https://doi.org/10.1002/1097-0142(195711/12)10:6<1300::aid-cncr2820100628>3.0.co;2-2.
8. Wynder EL, Covey LS, Mabuchi K, Mushinski M. Environmental factors in cancer of the larynx: a second look. Cancer. 1976;38(4):1591–601. https://doi.org/10.1002/1097-0142(197610)38:4<1591::aid-cncr2820380425>3.0.co;2-r.
9. Vogler WR, Lloyd JW, Milmore BK. A retrospective study of etiological factors in cancer of the mouth, pharynx, and larynx. Cancer. 1962;15:246–58. https://doi.org/10.1002/1097-0142(196203/04)15:2<246::aid-cncr2820150206>3.0.co;2-5.
10. Mashberg A, Boffetta P, Winkelman R, Garfinkel L. Tobacco smoking, alcohol drinking, and cancer of the oral cavity and oropharynx among U.S. veterans. Cancer. 1993;72(4):1369–75. https://doi.org/10.1002/1097-0142(19930815)72:4<1369::aid-cncr2820720436>3.0.co;2-l.
11. MuscatJE,WynderEL.Tobacco,alcohol,asbestos,and occupational risk factors for laryngeal cancer. Cancer. 1992;69(9):2244–51. https://doi.org/10.1002/1097-0142(19920501)69:9<2244::aid-cncr2820690906>3.0.co;2-o.
12. Liang C, Marsit CJ, Houseman EA, et al. Gene–environment interactions of novel variants associated with head and neck cancer. Head Neck. 2012;34(8):1111–8. https://doi.org/10.1002/hed.21867. Accessed 2 Nov 2011.
13. Slaughter DP, Southwick HW, Smejkal W. Field cancerization in oral stratified squamous epithelium; clinical implications of multicentric origin. Cancer. 1953;6(5):963–8. https://doi.org/10.1002/1097-0142(195309)6:5<963:aid-cncr2820060515>3.0.co;2-q.
14. Jemal A, Bray F, Center M, Ferlay J, Ward E, Forman D. Global cancer statistics. CA Cancer J Clin. 2011;61(2):69–90. https://doi.org/10.3322/caac.20107.
15. Hayat M, Howlader N, Reichman M, Edwards B. Cancer statistics, trends, and multiple primary cancer analyses from the surveillance, epidemiology, and end results (SEER) program. Oncologist. 2007;12(1):20–37. https://doi.org/10.1634/theoncologist.12-1-20.
16. Shindoh M, Chiba I, Yasuda M, et al. Detection of human papillomavirus DNA sequences in oral squamous cell carcinomas and their relation to p53 and proliferating cell nuclear antigen expression. Cancer. 1995;76(9):1513–21. https://doi.org/10.1002/1097-0142(19951101)76:9<1513::aid-cncr2820760903>3.0.co;2-4.
17. Kreimer AR, Clifford GM, Boyle P, Franceschi S. Human papillomavirus types in head and neck squamous cell carcinomas worldwide: a systematic review. Cancer Epidemiol Biomark Prev. 2005;14(2):467–75. https://doi.org/10.1158/1055-9965.EPI-04-0551.
18. Münger K, Howley PM. Human papillomavirus immortalization and transformation functions. Virus Res. 2002;89(2):213–28. https://doi.org/10.1016/s0168-1702(02)00190-9.
19. Hobbs CG, Sterne JA, Bailey M, Heyderman RS, Birchall MA, Thomas SJ. Human papillomavirus and head and neck cancer: a systematic review and meta-analysis. Clin Otolaryngol. 2006;31(4):259–66. https://doi.org/10.1111/j.1749-4486.2006.01246.x.
20. Mork J, Lie AK, Glattre E, et al. Human papillomavirus infection as a risk factor for squamous-cell carcinoma of the head and neck. N Engl J Med. 2001;344(15):1125–31. https://doi.org/10.1056/NEJM200104123441503.
21. D'Souza G, Kreimer AR, Viscidi R, et al. Case-control study of human papillomavirus and oropharyngeal cancer. N Engl J Med. 2007;356(19):1944–56. https://doi.org/10.1056/NEJMoa065497.
22. Schwartz SM, Daling JR, Doody DR, et al. Oral cancer risk in relation to sexual history and evidence of human papillomavirus infection. J Natl Cancer Inst. 1998;90(21):1626–36. https://doi.org/10.1093/jnci/90.21.1626.
23. Licitra L, Perrone F, Bossi P, et al. High-risk human papillomavirus affects prognosis in patients with

surgically treated oropharyngeal squamous cell carcinoma. J Clin Oncol. 2006;24(36):5630–6. https://doi.org/10.1200/JCO.2005.04.6136.
24. Lindel K, Beer KT, Laissue J, Greiner RH, Aebersold DM. Human papillomavirus positive squamous cell carcinoma of the oropharynx: a radiosensitive subgroup of head and neck carcinoma. Cancer. 2001;92(4):805–13. https://doi.org/10.1002/1097-0142(20010815)92:4<805::aid-cncr1386>3.0.co;2-9.
25. Torrente M, Rodrigo J, Haigentz M, et al. Human papillomavirus infections in laryngeal cancer. Head Neck. 2011;33(4):581–6. https://doi.org/10.1002/hed.21421.
26. Maitra R, Ghalib M, Goel S. Reovirus: a targeted therapeutic—progress and potential. Mol Cancer Res. 2012;10(12):1514–25. https://doi.org/10.1158/1541-7786.mcr-12-0157.
27. Lin W, Karin M. A cytokine-mediated link between innate immunity, inflammation, and cancer. J Clin Investig. 2007;117(5):1175–83. https://doi.org/10.1172/jci31537.
28. Mantovani A, Allavena P, Sica A, Balkwill F. Cancer-related inflammation. Nature. 2008;454(7203):436–44. https://doi.org/10.1038/nature07205.
29. Zhu Z, Zhong S, Shen Z. Targeting the inflammatory pathways to enhance chemotherapy of cancer. Cancer Biol Ther. 2011;12(2):95–105. https://doi.org/10.4161/cbt.12.2.15952.
30. Lax A, Thomas W. How bacteria could cause cancer: one step at a time. Trends Microbiol. 2002;10(6):293–9. https://doi.org/10.1016/s0966-842x(02)02360-0.
31. Karin M, Lawrence T, Nizet V. Innate immunity gone awry: linking microbial infections to chronic inflammation and cancer. Cell. 2006;124(4):823–35. https://doi.org/10.1016/j.cell.2006.02.016.
32. Homann N, Tillonen J, Rintamäki H, Salaspuro M, Lindqvist C, Meurman J. Poor dental status increases acetaldehyde production from ethanol in saliva: a possible link to increased oral cancer risk among heavy drinkers. Oral Oncol. 2001;37(2):153–8. https://doi.org/10.1016/s1368-8375(00)00076-2.
33. Salaspuro M. Acetaldehyde, microbes, and cancer of the digestive tract. Crit Rev Clin Lab Sci. 2003;40(2):183–208. https://doi.org/10.1080/713609333.
34. Wong R, Lin D, Schöder H, et al. Diagnostic and prognostic value of [18F]fluorodeoxyglucose positron emission tomography for recurrent head and neck squamous cell carcinoma. J Clin Oncol. 2002;20(20):4199–208. https://doi.org/10.1200/jco.2002.02.590.
35. Isles MG, McConkey C, Mehanna HM. A systematic review and meta-analysis of the role of positron emission tomography in the follow up of head and neck squamous cell carcinoma following radiotherapy or chemoradiotherapy. Clin Otolaryngol. 2008;33(3):210–22. https://doi.org/10.1111/j.1749--4486.2008.01688.x. Accessed 5 Jun 2008.
36. Kao J, Vu HL, Genden EM, et al. The diagnostic and prognostic utility of positron emission tomography/computed tomography-based follow-up after radiotherapy for head and neck cancer. Cancer. 2009;115(19):4586–94. https://doi.org/10.1002/cncr.24493. Accessed 19 Jun 2009.
37. Subramaniam R, Truong M, Peller P, Sakai O, Mercier G. Fluorodeoxyglucose–positron-emission tomography imaging of head and neck squamous cell cancer. Am J Neuroradiol. 2009;31(4):598–604. https://doi.org/10.3174/ajnr.a1760.
38. Troost E, Schinagl D, Bussink J, et al. Innovations in radiotherapy planning of head and neck cancers: role of PET. J Nucl Med. 2009;51(1):66–76. https://doi.org/10.2967/jnumed.108.061499.
39. Schoder H, Fury M, Lee N, Kraus D. PET monitoring of therapy response in head and neck squamous cell carcinoma. J Nucl Med. 2009;50(Suppl_1):74S–88S. https://doi.org/10.2967/jnumed.108.057208.
40. Kim J, Tannock I. Repopulation of cancer cells during therapy: an important cause of treatment failure. Nat Rev Cancer. 2005;5(7):516–25. https://doi.org/10.1038/nrc1650.
41. Czernin J, Benz M, Allen-Auerbach M. PET/CT imaging: the incremental value of assessing the glucose metabolic phenotype and the structure of cancers in a single examination. Eur J Radiol. 2010;73(3):470–80. https://doi.org/10.1016/j.ejrad.2009.12.023.
42. Society of Nuclear Medicine and Molecular Imaging. Molecular imaging and head and neck cancers. SNMMI; 2020. https://s3.amazonaws.com/rdcms-snmmi/files/production/public/images/MI%20and%20Head%20and%20Neck%20cancer%20%28Master%29.pdf. Accessed 5 Sept 2020.
43. Nagamachi S, Hoshi H, Jinnouchi S, et al. 201TI SPECT for evaluating head and neck cancer. Ann Nucl Med. 1996;10(1):105–11. https://doi.org/10.1007/bf03165062.
44. Lewis-Jones H, Colley S, Gibson D. Imaging in head and neck cancer: United Kingdom National Multidisciplinary Guidelines. J Laryngol Otol. 2016;130(S2):S28–31. https://doi.org/10.1017/s0022215116000396.
45. Ni X, Wang G. The role of narrow band imaging in head and neck cancers. Curr Oncol Rep. 2016;18(2) https://doi.org/10.1007/s11912-015-0498-1.
46. Zhou H, Zhang J, Guo L, Nie J, Zhu C, Ma X. The value of narrow band imaging in diagnosis of head and neck cancer: a meta-analysis. Sci Rep. 2018;8(1) https://doi.org/10.1038/s41598-017-19069-0.
47. Dahiya K, Dhankhar R. Updated overview of current biomarkers in head and neck carcinoma. World J Methodol. 2016;6(1):77. https://doi.org/10.5662/wjm.v6.i1.77.
48. Bocca E. Supraglottic laryngectomy and functional neck dissection. J Laryngol Otol. 1966;80(8):831–8. https://doi.org/10.1017/s0022215100066032.
49. Bocca E, Pignataro O, Sasaki CT. Functional neck dissection. A description of operative technique. Arch Otolaryngol. 1980;106(9):524–7. https://doi.org/10.1001/archotol.1980.00790330004004.
50. Bocca E, Pignataro O, Oldini C, Cappa C. Functional neck dissection: an evaluation and review of 843

cases. Laryngoscope. 1984;94(7):942–5. https://doi.org/10.1288/00005537-198407000-00015.
51. Lindberg R. Distribution of cervical lymph node metastases from squamous cell carcinoma of the upper respiratory and digestive tracts. Cancer. 1972;29(6):1446–9. https://doi.org/10.1002/1097-0142(197206)29:6<1446::aid-cncr2820290604>3.0.co;2-c.
52. Shah JP. Patterns of cervical lymph node metastasis from squamous carcinomas of the upper aerodigestive tract. Am J Surg. 1990;160(4):405–9. https://doi.org/10.1016/s0002-9610(05)80554-9.
53. Shah JP, Candela FC, Poddar AK. The patterns of cervical lymph node metastases from squamous carcinoma of the oral cavity. Cancer. 1990;66(1):109–13. https://doi.org/10.1002/1097-0142(19900701)66:1<109::aid-cncr2820660120>3.0.co;2-a.
54. Lim Y, Song M, Kim S, Kim K, Choi E. Preserving level IIb lymph nodes in elective supraomohyoid neck dissection for oral cavity squamous cell carcinoma. Arch Otolaryngol Head Neck Surg. 2004;130(9):1088. https://doi.org/10.1001/archotol.130.9.1088.
55. Pandey M, Karthikeyan S, Joshi D, Kumar M, Shukla M. Results of a randomized controlled trial of level IIb preserving neck dissection in clinically node-negative squamous carcinoma of the oral cavity. World J Surg Oncol. 2018;16(1) https://doi.org/10.1186/s12957-018-1518-z.
56. Gould EA, Winship T, Philbin PH, Kerr HH. Observations on a "sentinel node" in cancer of the parotid. Cancer. 1960;13:77–8. https://doi.org/10.1002/1097-0142(196001/02)13:1<77::aid-cncr2820130114>3.0.co;2-d.
57. Shoaib T, Soutar DS, MacDonald DG, et al. The accuracy of head and neck carcinoma sentinel lymph node biopsy in the clinically N0 neck. Cancer. 2001;91(11):2077–83. https://doi.org/10.1002/1097-0142(20010601)91:11<2077::aid-cncr1235>3.0.co;2-e.
58. Lombardi CP, Raffaelli M, Princi P, De Crea C, Bellantone R. Minimally invasive video-assisted functional lateral neck dissection for metastatic papillary thyroid carcinoma. Am J Surg. 2007;193(1):114–8. https://doi.org/10.1016/j.amjsurg.2006.02.024.
59. Terris DJ, Monfared A, Thomas A, Kambham N, Sáenz Y. Endoscopic selective neck dissection in a porcine model. Arch Otolaryngol Head Neck Surg. 2003;129(6):613–7. https://doi.org/10.1001/archotol.129.6.613.
60. Malloy KM, Cognetti DM, Wildemore BM, et al. Feasibility of endoscopic sentinel node biopsy in the porcine neck. Otolaryngol Head Neck Surg. 2007;136(5):806–10. https://doi.org/10.1016/j.otohns.2006.11.025.
61. Guttman MR. Rehabilitation of voice in laryngectomized patients. Arch Otolaryngol. 1932;15:478–9.
62. Nijdam H, Annyas A, Schutte H, Leever H. A new prosthesis for voice rehabilitation after laryngectomy. Arch Otorhinolaryngol. 1982;237:27–9.
63. Jebria AB, Henry C, Petit J, Gioux M, Devars F, Traissac L. Physical and aerodynamic features of the Bordeaux voice prosthesis. Artif Organs. 2008;11(5):383–7. https://doi.org/10.1111/j.1525-1594.1987.tb00949.x.
64. Hilgers F, Schouwenburg P. A new low-resistance, self-retaining prosthesis (Provox) for voice rehabilitation after total laryngectomy. Laryngoscope. 1990;100(11):1202–7. https://doi.org/10.1288/00005537-199011000-00014.
65. Hilgers F, Cornelissen M, Balm A. Aerodynamic characteristics of the Provox low-resistance indwelling voice prosthesis. Eur Arch Otorhinolaryngol. 1993;250(7) https://doi.org/10.1007/bf00180379.
66. Pressman JJ, Simon MB, Monell CM. Anatomic studies related to the dissemination of cancer of the larynx. Cancer. 1961;14:1131–8. https://doi.org/10.1002/1097-0142(196109/10)14:5<1131::aid-cncr2820140536>3.0.co;2-#.
67. Alonso JM. Conservative surgery of cancer of the larynx. Trans Am Acad Ophthalmol Otolaryngol. 1947;51:633–42.
68. Majer EH, Rieder W. Technique de laryngectomie permetant de conserver la permeabilite. Ann Otol Rhinol Laryngol. 1959;76:677–81.
69. Ambrosch P. The role of laser microsurgery in the treatment of laryngeal cancer. Curr Opin Otolaryngol Head Neck Surg. 2007;15(2):82–8. https://doi.org/10.1097/MOO.0b013e3280147336.
70. Genden EM, Ferlito A, Silver CE, et al. Evolution of the management of laryngeal cancer. Oral Oncol. 2007;43(5):431–9. https://doi.org/10.1016/j.oraloncology.2006.08.007.
71. Weinstein GS, O'Malley BW Jr, Snyder W, Hockstein NG. Transoral robotic surgery: supraglottic partial laryngectomy. Ann Otol Rhinol Laryngol. 2007;116(1):19–23. https://doi.org/10.1177/000348940711600104.
72. Weinstein G, O'Malley BW Jr, Hockstein NG. Transoral robotic surgery: supraglottic laryngectomy in a canine model. Laryngoscope. 2005;115(7):1315–9. https://doi.org/10.1097/01.mlg.0000170848.76045.47.
73. O'Malley B, Weinstein G, Hockstein N. Transoral robotic surgery (TORS): glottic microsurgery in a canine model. J Voice. 2006;20(2):263–8. https://doi.org/10.1016/j.jvoice.2005.10.004.
74. National Comprehensive Cancer Network. NCCN practice guidelines in oncology: head and neck cancers. 2013. http://www.nccn.org/professionals/physician_gls/f_guidelines.asp.
75. Pederson A, Salama J, Witt M, et al. Concurrent chemotherapy and intensity-modulated radiotherapy for organ preservation of locoregionally advanced oral cavity cancer. Am J Clin Oncol. 2011;34(4):356–61. https://doi.org/10.1097/coc.0b013e3181e8420b.

76. Bedwinek J, Shukovsky L, Fletcher G, Daley T. Osteonecrosis in patients treated with definitive radiotherapy for squamous cell carcinomas of the oral cavity and naso- and oropharynx. Radiology. 1976;119(3):665–7. https://doi.org/10.1148/119.3.665.
77. Loree T, Strong E. Significance of positive margins in oral cavity squamous carcinoma. Am J Surg. 1990;160(4):410–4. https://doi.org/10.1016/s0002-9610(05)80555-0.
78. Cooper J, Pajak T, Forastiere A, et al. Postoperative concurrent radiotherapy and chemotherapy for high-risk squamous-cell carcinoma of the head and neck. N Engl J Med. 2004;350:1937–44. https://doi.org/10.1056/NEJMoa032646.
79. Montero PH, Patel SG. Cancer of the oral cavity. Surg Oncol Clin N Am. 2015;24(3):491–508. https://doi.org/10.1016/j.soc.2015.03.006.
80. Farah C, Dalley A, Nguyen P, et al. Improved surgical margin definition by narrow band imaging for resection of oral squamous cell carcinoma: a prospective gene expression profiling study. Head Neck. 2015;38(6):832–9. https://doi.org/10.1002/hed.23989.
81. Vu A, Farah C. Narrow band imaging: clinical applications in oral and oropharyngeal cancer. Oral Dis. 2016;22(5):383–90. https://doi.org/10.1111/odi.12430.
82. Schmalbach C, Chepeha D, Giordano T, et al. Molecular profiling and the identification of genes associated with metastatic oral cavity/pharynx squamous cell carcinoma. Arch Otolaryngol Head Neck Surg. 2004;130(3):295. https://doi.org/10.1001/archotol.130.3.295.
83. Gourin C, Boyce B, Vaught C, Burkhead L, Podolsky R. Effect of comorbidity on post-treatment quality of life scores in patients with head and neck squamous cell carcinoma. Laryngoscope. 2009;119(5):907–14. https://doi.org/10.1002/lary.20199.
84. Ang K, Harris J, Wheeler R, et al. Human papillomavirus and survival of patients with oropharyngeal cancer. N Engl J Med. 2010;363:24–35. https://doi.org/10.1056/NEJMoa0912217.
85. Mydlarz W, Chan J, Richmon J. The role of surgery for HPV-associated head and neck cancer. Oral Oncol. 2015;51:305–13. https://doi.org/10.1016/j.oraloncology.2014.10.005.
86. Tateya I, Shiotani A, Satou Y, et al. Transoral surgery for laryngo-pharyngeal cancer—the paradigm shift of the head and cancer treatment. Auris Nasus Larynx. 2016;43(1):21–32. https://doi.org/10.1016/j.anl.2015.06.013.
87. Kass J, Pool C, Teng M, Miles B, Genden E. Initial experience using transoral robotic surgery for advanced-stage (T3) tumors of the head and neck. Int J Radiat Oncol Biol Phys. 2016;94(4):899. https://doi.org/10.1016/j.ijrobp.2015.12.106.
88. Weinstein G, O'Malley B, Cohen M, Quon H. Transoral robotic surgery for advanced oropharyngeal carcinoma. Arch Otolaryngol Head Neck Surg. 2010;136(11):1079. https://doi.org/10.1001/archoto.2010.191.
89. Hinni M, Nagel T, Howard B. Oropharyngeal cancer treatment: the role of transoral surgery. Curr Opin Otolaryngol Head Neck Surg. 2015;23(2):132–8. https://doi.org/10.1097/MOO.0000000000000143.
90. Kelly K, Johnson-Obaseki S, Lumingu J, Corsten M. Oncologic, functional and surgical outcomes of primary Transoral Robotic Surgery for early squamous cell cancer of the oropharynx: a systematic review. Oral Oncol. 2014;50(8):696–703. https://doi.org/10.1016/j.oraloncology.2014.04.005.
91. Reynolds L, Rigby M, Trites J, Hart R, Taylor S. Outcomes of transoral laser microsurgery for recurrent head and neck cancer. J Laryngol Otol. 2013;127(10):982–6. https://doi.org/10.1017/S0022215113001953.
92. White H, Ford S, Bush B, et al. Salvage surgery for recurrent cancers of the oropharynx. JAMA Otolaryngol Head Neck Surg. 2013;139(8):773. https://doi.org/10.1001/jamaoto.2013.3866.
93. Dallan I, Castelnuovo P, Vicini C, Tschabitscher M. The natural evolution of endoscopic approaches in skull base surgery: robotic-assisted surgery? Acta Otorhinolaryngol Ital. 2011;31(6):390–4.
94. Mercante G, Ruscito P, Pellini R, Cristalli G, Spriano G. Transoral robotic surgery (TORS) for tongue base tumours. Acta Otorhinolaryngol Ital. 2013;33(4):230–5.
95. Mirimanoff R, Wang C, Doppke K. Combined surgery and postoperative radiation therapy for advanced laryngeal and hypopharyngeal carcinomas. Int J Radiat Oncol Biol Phys. 1985;11(3):499–504. https://doi.org/10.1016/0360-3016(85)90180-4.
96. Hoffman H, Karnell L, Shah J, et al. Hypopharyngeal cancer patient care evaluation. Laryngoscope. 1997;107:1005–17. https://doi.org/10.1097/00005537-199708000-00001.
97. Braendstrup P. Lehrbuch der Augenheilkunde. 2. AufL. 1954. Karger, Basel. Acta Ophthalmol. 2009;32(1):95–6. https://doi.org/10.1111/j.1755-3768.1954.tb07677.x.
98. Chu P, Chang S. Reconstruction of the hypopharynx after surgical treatment of squamous cell carcinoma. J Chin Med Assoc. 2009;72(7):351–5. https://doi.org/10.1016/s1726-4901(09)70386-7.
99. Disa J, Pusic A, Hidalgo D, Cordeiro P. Microvascular reconstruction of the hypopharynx: defect classification, treatment algorithm, and functional outcome based on 165 consecutive cases. Plast Reconstr Surg. 2003;111(2):652–60. https://doi.org/10.1097/01.prs.0000041987.53831.23.
100. Ho M, Houghton L, Gillmartin E, et al. Outcomes following pharyngolaryngectomy reconstruction with the anterolateral thigh (ALT) free flap. Br J Oral Maxillofac Surg. 2012;50(1):19–24. https://doi.org/10.1016/j.bjoms.2010.10.004.
101. Yu P, Hanasono M, Skoracki R, et al. Pharyngoesophageal reconstruction with the anterolateral thigh flap after total laryngopharyngec-

tomy. Cancer. 2010;116(7):1718–24. https://doi.org/10.1002/cncr.24947.
102. Kim V, Chapman W, Albrecht R, et al. Early experience with telemanipulative robot-assisted laparoscopic cholecystectomy using Da Vinci. Surg Laparosc Endosc Percutan Tech. 2002;12(1):33–40. https://doi.org/10.1097/00129689-200202000-00006.
103. Moore E, Olsen K, Kasperbauer J. Transoral robotic surgery for oropharyngeal squamous cell carcinoma: a prospective study of feasibility and functional outcomes. Laryngoscope. 2009;119(11):2156–64. https://doi.org/10.1002/lary.20647.
104. Boudreaux B, Rosenthal E, Magnuson J, et al. Robot-assisted surgery for upper aerodigestive tract neoplasms. Arch Otolaryngol Head Neck Surg. 2009;135(4):397. https://doi.org/10.1001/archoto.2009.24.
105. Hirayama T, Ito Y. A new view of the etiology of nasopharyngeal carcinoma. Prev Med. 1981;10(5):614–22. https://doi.org/10.1016/0091-7435(81)90051-7.
106. Shi W, Pataki I, MacMillan C, et al. Molecular pathology parameters in human nasopharyngeal carcinoma. Cancer. 2002;94(7):1997–2006. https://doi.org/10.1002/cncr.0679.
107. Zhang M, Li J, Shen G, et al. Intensity-modulated radiotherapy prolongs the survival of patients with nasopharyngeal carcinoma compared with conventional two-dimensional radiotherapy: a 10-year experience with a large cohort and long follow-up. Eur J Cancer. 2015;51(17):2587–95. https://doi.org/10.1016/j.ejca.2015.08.006.
108. Su S, Han F, Zhao C, et al. Long-term outcomes of early-stage nasopharyngeal carcinoma patients treated with intensity-modulated radiotherapy alone. Int J Radiat Oncol Biol Phys. 2012;82(1):327–33. https://doi.org/10.1016/j.ijrobp.2010.09.011.
109. Hao S, Tsang N, Chang C. Salvage surgery for recurrent nasopharyngeal carcinoma. Arch Otolaryngol Head Neck Surg. 2002;128(1):63. https://doi.org/10.1001/archotol.128.1.63.
110. Chan K, Woo J, King A, et al. Analysis of plasma Epstein–Barr virus DNA to screen for nasopharyngeal cancer. N Engl J Med. 2017;377(6):513–22. https://doi.org/10.1056/nejmoa1701717.
111. Ji M, Huang Q, Yu X, et al. Evaluation of plasma Epstein-Barr virus DNA load to distinguish nasopharyngeal carcinoma patients from healthy high-risk populations in Southern China. Cancer. 2014;120(9):1353–60. https://doi.org/10.1002/cncr.28564.
112. Na'ara S, Amit M, Billan S, Cohen J, Gil Z. Outcome of patients undergoing salvage surgery for recurrent nasopharyngeal carcinoma: a meta-analysis. Ann Surg Oncol. 2014;21(9):3056–62. https://doi.org/10.1245/s10434-014-3683-9.
113. Chen M, Wen W, Guo X, et al. Endoscopic nasopharyngectomy for locally recurrent nasopharyngeal carcinoma. Laryngoscope. 2009;119(3):516–22. https://doi.org/10.1002/lary.20133.
114. Chen M, Wang S, Zhu Y, et al. Use of a posterior pedicle nasal septum and floor mucoperiosteum flap to resurface the nasopharynx after endoscopic nasopharyngectomy for recurrent nasopharyngeal carcinoma. Head Neck. 2011;34(10):1383–8. https://doi.org/10.1002/hed.21928.
115. You R, Zou X, Hua Y, et al. Salvage endoscopic nasopharyngectomy is superior to intensity-modulated radiation therapy for local recurrence of selected T1–T3 nasopharyngeal carcinoma—a case-matched comparison. Radiother Oncol. 2015;115(3):399–406. https://doi.org/10.1016/j.radonc.2015.04.024.
116. Frazell E, Lewis J. Cancer of the nasal cavity and accessory sinuses. A report of the management of 416 patients. Cancer. 1963;16(10):1293–301. https://doi.org/10.1002/1097-0142(196310)16:10<1293::aid-cncr2820161010>3.0.co;2-4.
117. Ketcham A, Wilkins R, Van Buren J, Smith R. A combined intracranial facial approach to the paranasal sinuses. Am J Surg. 1963;106(5):698–703. https://doi.org/10.1016/0002-9610(63)90387-8.
118. Dulguerov P, Jacobsen M, Allal A, Lehmann W, Calcaterra T. Nasal and paranasal sinus carcinoma: are we making progress? Cancer. 2001;92(12):3012–29. https://doi.org/10.1002/1097-0142(20011215)92:12<3012::aid-cncr10131>3.0.co;2-e.
119. Banhiran W, Casiano R. Endoscopic sinus surgery for benign and malignant nasal and sinus neoplasm. Curr Opin Otolaryngol Head Neck Surg. 2005;13(1):50–4. https://doi.org/10.1097/00020840-200502000-00012.
120. Snyderman C, Carrau R, Kassam A, et al. Endoscopic skull base surgery: principles of endonasal oncological surgery. J Surg Oncol. 2008;97(8):658–64. https://doi.org/10.1002/jso.21020.
121. Schneider J, Burgner J, Webster R, Russell P. Robotic surgery for the sinuses and skull base. Curr Opin Otolaryngol Head Neck Surg. 2013;21(1):11–6. https://doi.org/10.1097/moo.0b013e32835bc650.
122. Brennan P, Ammar M, Matharu J. Contemporary management of benign parotid tumours—the increasing evidence for extracapsular dissection. Oral Dis. 2016;23(1):18–21. https://doi.org/10.1111/odi.12518.
123. Brennan P, Herd M, Howlett D, Gibson D, Oeppen R. Is ultrasound alone sufficient for imaging superficial lobe benign parotid tumours before surgery? Br J Oral Maxillofac Surg. 2012;50(4):333–7. https://doi.org/10.1016/j.bjoms.2011.01.018.
124. Thoeny H. Imaging of salivary gland tumours. Cancer Imaging. 2007;7(1):52–62. https://doi.org/10.1102/1470-7330.2007.0008.
125. Kendi A, Magliocca K, Corey A, et al. Is there a role for PET/CT parameters to characterize benign, malignant, and metastatic parotid tumors? Am J Roentgenol. 2016;207(3):635–40. https://doi.org/10.2214/ajr.15.15590.

126. Sood A, Houlton J, Nguyen S, Gillespie M. Facial nerve monitoring during parotidectomy: a systematic review and meta-analysis. Otolaryngol Head Neck Surg. 2014;151(1_Suppl):P56. https://doi.org/10.1177/0194599814541627a86.
127. Guntinas-Lichius O, Eisele D. Facial nerve monitoring. In: Salivary gland neoplasms. Basel: Karger; 2016. p. 46–52. https://doi.org/10.1159/000442124.
128. Krishnatreya M, Sharma J, Kataki A, Kalita M. Survival in carcinoma of unknown primary to neck nodes treated with neck dissection and radiotherapy. Ann Med Health Sci Res. 2014;4(8):165. https://doi.org/10.4103/2141-9248.138050.
129. Keller L, Galloway T, Holdbrook T, et al. p16 status, pathologic and clinical characteristics, biomolecular signature, and long-term outcomes in head and neck squamous cell carcinomas of unknown primary. Head Neck. 2014;36(12):1677–84. https://doi.org/10.1002/hed.23514.
130. Motz K, Qualliotine J, Rettig E, Richmon J, Eisele D, Fakhry C. Changes in unknown primary squamous cell carcinoma of the head and neck at initial presentation in the era of human papillomavirus. JAMA Otolaryngol Head Neck Surg. 2016;142(3):223. https://doi.org/10.1001/jamaoto.2015.3228.
131. Axelsson L, Nyman J, Haugen-Cange H, et al. Prognostic factors for head and neck cancer of unknown primary including the impact of human papilloma virus infection. J Otolaryngol Head Neck Surg. 2017;46(1) https://doi.org/10.1186/s40463-017-0223-1.
132. Sivars L, Näsman A, Tertipis N, et al. Human papillomavirus and p53 expression in cancer of unknown primary in the head and neck region in relation to clinical outcome. Cancer Med. 2014;3(2):376–84. https://doi.org/10.1002/cam4.19.
133. Vent J, Haidle B, Wedemeyer I, et al. p16 Expression in carcinoma of unknown primary: diagnostic indicator and prognostic marker. Head Neck. 2013;35(11):1521–6. https://doi.org/10.1002/hed.23190.
134. Perkins S, Spencer C, Chernock R, et al. Radiotherapeutic management of cervical lymph node metastases from an unknown primary site. Arch Otolaryngol Head Neck Surg. 2012;138(7):656. https://doi.org/10.1001/archoto.2012.1110.
135. Mistry R, Qureshi S, Talole S, Deshmukh S. Cervical lymph node metastases of squamous cell carcinoma from an unknown primary: outcomes and patterns of failure. Indian J Cancer. 2008;45(2):54. https://doi.org/10.4103/0019-509x.41771.
136. Huang C, Tseng F, Yeh T, et al. Prognostic factors of unknown primary head and neck squamous cell carcinoma. Otolaryngol Head Neck Surg. 2008;139(3):429–35. https://doi.org/10.1016/j.otohns.2008.05.015.
137. Christiansen H, Hermann R, Martin A, Nitsche M, Schmidberger H, Pradier O. Neck lymph node metastases from an unknown primary tumor. Strahlenther Onkol. 2005;181(6):355–62. https://doi.org/10.1007/s00066-005-1338-2.
138. Aslani M, Sultanem K, Voung T, Hier M, Niazi T, Shenouda G. Metastatic carcinoma to the cervical nodes from an unknown head and neck primary site: is there a need for neck dissection? Head Neck. 2007;29(6):585–90. https://doi.org/10.1002/hed.20581.
139. Su AI, Welsh JB, Sapinoso LM, et al. Molecular classification of human carcinomas by use of gene expression signatures. Cancer Res. 2001;61(20):7388–93.
140. Golub T, Slonim D, Tamayo P, et al. Molecular classification of cancer: class discovery and class prediction by gene expression monitoring. Science. 1999;286(5439):531–7. https://doi.org/10.1126/science.286.5439.531.
141. Kato S, Krishnamurthy N, Banks K, et al. Utility of genomic analysis in circulating tumor DNA from patients with carcinoma of unknown primary. Cancer Res. 2017;77(16):4238–46. https://doi.org/10.1158/0008-5472.can-17-0628.
142. Paderno A, Piazza C, Nicolai P. Recent advances in surgical management of parapharyngeal space tumors. Curr Opin Otolaryngol Head Neck Surg. 2015;23(2):83–90. https://doi.org/10.1097/moo.0000000000000134.
143. Chu F, De Berardinis R, Tagliabue M, Zorzi S, Bandi F, Ansarin M. The role of transoral robotic surgery for parapharyngeal space. J Craniofac Surg. 2020;31(1):117–20. https://doi.org/10.1097/scs.0000000000005912.
144. O'Malley B Jr, Quon H, Leonhardt F, Chalian A, Weinstein G. Transoral robotic surgery for parapharyngeal space tumors. ORL. 2010;72(6):332–6. https://doi.org/10.1159/000320596.
145. Kyubo K, Dong JL. The updated AJCC/TNM staging system (8th edition) for oral tongue cancer. Transl Cancer Res. 2019;8(Suppl 2):S164–6. https://doi.org/10.21037/tcr.2019.01.02.
146. Jain K, Sikora A, Baxi S, Morris L. Synchronous cancers in patients with head and neck cancer. Cancer. 2013;119(10):1832–7. https://doi.org/10.1002/cncr.27988.
147. Birkeland A, Rosko A, Chinn S, Prince M, Sun G, Spector M. Prevalence and outcomes of head and neck versus non-head and neck second primary malignancies in head and neck squamous cell carcinoma: an analysis of the surveillance, epidemiology, and end results database. ORL. 2016;78(2):61–9. https://doi.org/10.1159/000443768.
148. Hanamoto A, Takenaka Y, Shimosegawa E, et al. Limitation of 2-deoxy-2-[F-18]fluoro-d-glucose positron emission tomography (FDG-PET) to detect early synchronous primary cancers in patients with untreated head and neck squamous cell cancer. Ann Nucl Med. 2013;27(10):880–5. https://doi.org/10.1007/s12149-013-0765-x.
149. Suzuki H, Hasegawa Y, Terada A, et al. Limitations of FDG-PET and FDG-PET with computed tomography for detecting synchronous cancer in

pharyngeal cancer. Arch Otolaryngol Head Neck Surg. 2008;134(11):1191. https://doi.org/10.1001/archotol.134.11.1191.
150. Martel M, Alemany L, Taberna M, et al. The role of HPV on the risk of second primary neoplasia in patients with oropharyngeal carcinoma. Oral Oncol. 2017;64:37–43. https://doi.org/10.1016/j.oraloncology.2016.11.011.
151. Diaz D, Reis I, Weed D, Elsayyad N, Samuels M, Abramowitz M. Head and neck second primary cancer rates in the human papillomavirus era: a population-based analysis. Head Neck. 2015;38(S1):E873–83. https://doi.org/10.1002/hed.24119.
152. Ferlito A, Shaha A, Silver C, Rinaldo A, Mondin V. Incidence and sites of distant metastases from head and neck cancer. ORL. 2001;63(4):202–7. https://doi.org/10.1159/000055740.
153. Noij D, Martens R, Zwezerijnen B, et al. Diagnostic value of diffusion-weighted imaging and 18F-FDG-PET/CT for the detection of unknown primary head and neck cancer in patients presenting with cervical metastasis. Eur J Radiol. 2018;107:20–5. https://doi.org/10.1016/j.ejrad.2018.08.009.
154. Lee J, Kim J, Roh J, et al. Detection of occult primary tumors in patients with cervical metastases of unknown primary tumors: comparison of 18F FDG PET/CT with contrast-enhanced CT or CT/MR imaging—prospective study. Radiology. 2015;274(3):764–71. https://doi.org/10.1148/radiol.14141073.
155. Hermans R. Imaging in cervical nodal metastases of unknown primary. Cancer Imaging. 2011;11(1A):S9–S14. https://doi.org/10.1102/1470-7330.2011.9004.
156. Fletcher JW, Djulbegovic B, Soares HP, et al. Recommendations on the use of 18F-FDG PET in oncology. J Nucl Med. 2008;49(3):480–508.
157. Becker M, Zbären P, Laeng H, Stoupis C, Porcellini B, Vock P. Neoplastic invasion of the laryngeal cartilage: comparison of MR imaging and CT with histopathologic correlation. Radiology. 1995;194(3):661–9. https://doi.org/10.1148/radiology.194.3.7862960.
158. Beitler J, Muller S, Grist W, et al. Prognostic accuracy of computed tomography findings for patients with laryngeal cancer undergoing laryngectomy. J Clin Oncol. 2010;28(14):2318–22. https://doi.org/10.1200/jco.2009.24.7544.
159. Becker M, Burkhardt K, Dulguerov P, Allal A. Imaging of the larynx and hypopharynx. Eur J Radiol. 2008;66(3):460–79. https://doi.org/10.1016/j.ejrad.2008.03.027.
160. Thompson C, St. John M, Lawson G, Grogan T, Elashoff D, Mendelsohn A. Diagnostic value of sentinel lymph node biopsy in head and neck cancer: a meta-analysis. Eur Arch Otorhinolaryngol. 2012;270(7):2115–22. https://doi.org/10.1007/s00405-012-2320-0.
161. Colnot D, Nieuwenhuis E, van den Brekel M, et al. Head and neck squamous cell carcinoma: US-guided fine-needle aspiration of sentinel lymph nodes for improved staging—initial experience. Radiology. 2001;218(1):289–93. https://doi.org/10.1148/radiology.218.1.r01dc01289.
162. Turner R, Hansen N, Stern S, Giulino A. Intraoperative examination of the sentinel lymph node for breast carcinoma staging. Am J Clin Pathol. 1999;112(5):627–34. https://doi.org/10.1093/ajcp/112.5.627.
163. Koopal S, Tiebosch A, Albertus Piers D, Plukker J, Schraffordt Koops H, Hoekstra H. Frozen section analysis of sentinel lymph nodes in melanoma patients. Cancer. 2000;89(8):1720–5. https://doi.org/10.1002/1097-0142(20001015)89:8<1720::aid-cncr11>3.0.co;2-f.
164. Höft S, Maune S, Muhle C, et al. Sentinel lymph-node biopsy in head and neck cancer. Br J Cancer. 2004;91(1):124–8. https://doi.org/10.1038/sj.bjc.6601877. Accessed 8 Jun 2004.
165. Kuo P, Sosa J, Burtness B, et al. Treatment trends and survival effects of chemotherapy for hypopharyngeal cancer: analysis of the National Cancer Data Base. Cancer. 2016;122(12):1853–60. https://doi.org/10.1002/cncr.29962.
166. Timmermans A, van Dijk B, Overbeek L, et al. Trends in treatment and survival for advanced laryngeal cancer: a 20-year population-based study in The Netherlands. Head Neck. 2015;38(S1):E1247–55. https://doi.org/10.1002/hed.24200.
167. Elicin O, Nisa L, Dal Pra A, et al. Up-front neck dissection followed by definitive (chemo)-radiotherapy in head and neck squamous cell carcinoma: rationale, complications, toxicity rates, and oncological outcomes—a systematic review. Radiother Oncol. 2016;119(2):185–93. https://doi.org/10.1016/j.radonc.2016.03.003.
168. Mehanna H, Wong W-L, McConkey CC, et al. PET-CT surveillance versus neck dissection in advanced head and neck cancer. N Engl J Med. 2016;374(15):1444–54. https://doi.org/10.1056/NEJMoa1514493.
169. Miller M, Goldenberg D. AHNS series: do you know your guidelines? Principles of surgery for head and neck cancer: a review of the National Comprehensive Cancer Network guidelines. Head Neck. 2016;39(4):791–6. https://doi.org/10.1002/hed.24654.
170. Woolgar J, Triantafyllou A. A histopathological appraisal of surgical margins in oral and oropharyngeal cancer resection specimens. Oral Oncol. 2005;41(10):1034–43. https://doi.org/10.1016/j.oraloncology.2005.06.008.
171. Ch'ng S, Corbett-Burns S, Stanton N, et al. Close margin alone does not warrant postoperative adjuvant radiotherapy in oral squamous cell carcinoma. Cancer. 2013;119(13):2427–37. https://doi.org/10.1002/cncr.28081.
172. Cohen E, Karrison T, Kocherginsky M, et al. Phase III randomized trial of induction chemotherapy in patients with N2 or N3 locally advanced head and

neck cancer. J Clin Oncol. 2014;32(25):2735–43. https://doi.org/10.1200/jco.2013.54.6309.
173. Zhong L, Zhang C, Ren G, et al. Randomized phase III trial of induction chemotherapy with docetaxel, cisplatin, and fluorouracil followed by surgery versus up-front surgery in locally advanced resectable oral squamous cell carcinoma. J Clin Oncol. 2013;31(6):744–51. https://doi.org/10.1200/jco.2012.43.8820.
174. Lee L, Huang C, Liao C, et al. Human papillomavirus-16 infection in advanced oral cavity cancer patients is related to an increased risk of distant metastases and poor survival. PLoS One. 2012;7(7):e40767. https://doi.org/10.1371/journal.pone.0040767.
175. Chung C, Zhang Q, Kong C, et al. p16 protein expression and human papillomavirus status as prognostic biomarkers of nonoropharyngeal head and neck squamous cell carcinoma. J Clin Oncol. 2014;32(35):3930–8. https://doi.org/10.1200/jco.2013.54.5228.
176. Stransky N, Egloff AM, Tward AD, et al. The mutational landscape of head and neck squamous cell carcinoma. Science. 2011;333(6046):1157–60. https://doi.org/10.1126/science.1208130.
177. Adelstein D. Maximizing local control and organ preservation in stage IV squamous cell head and neck cancer with hyperfractionated radiation and concurrent chemotherapy. J Clin Oncol. 2002;20(5):1405–10. https://doi.org/10.1200/jco.20.5.14.
178. Chevalier D, Laccourreye O, Laccourreye H, Brasnu D, Piquet J. Cricohyoidoepiglottopexy for glottic carcinoma with fixation or impaired motion of the true vocal cord: 5-year oncologic results with 112 patients. Ann Otol Rhinol Laryngol. 1997;106(5):364–9. https://doi.org/10.1177/000348949710600502.
179. McCoul E, Har-El G. Meta-analysis of impaired vocal cord mobility as a prognostic factor in T2 glottic carcinoma. Arch Otolaryngol Head Neck Surg. 2009;135(5):479. https://doi.org/10.1001/archoto.2009.47.
180. Tham I, Lu J. Controversies and challenges in the current management of nasopharyngeal cancer. Expert Rev Anticancer Ther. 2010;10(9):1439–50. https://doi.org/10.1586/era.10.97.
181. Chan A, Teo P, Johnson P. Controversies in the management of locoregionally advanced nasopharyngeal carcinoma. Curr Opin Oncol. 1998;10(3):219–25. https://doi.org/10.1097/00001622-199805000-00008.
182. Kozakiewicz P, Grzybowska-Szatkowska L, Kozakiewicz P, Grzybowska-Szatkowska L. Application of molecular targeted therapies in the treatment of head and neck squamous cell carcinoma. Oncol Lett. 2018;15(5):7497–505. https://doi.org/10.3892/ol.2018.8300. Accessed 20 Mar 2018.
183. Argiris A, Karamouzis M, Raben D, Ferris R. Head and neck cancer. Lancet. 2008;371(9625):1695–709. https://doi.org/10.1016/s0140-6736(08)60728-x.
184. Alsaab H, Sau S, Alzhrani R, et al. PD-1 and PD-L1 checkpoint signaling inhibition for cancer immunotherapy: mechanism, combinations, and clinical outcome. Front Pharmacol. 2017;8 https://doi.org/10.3389/fphar.2017.00561.
185. Vermorken J, Mesia R, Rivera F, et al. Platinum-based chemotherapy plus cetuximab in head and neck cancer. N Engl J Med. 2008;359(11):1116–27. https://doi.org/10.1056/nejmoa0802656.
186. Seiwert T, Burtness B, Mehra R, et al. Safety and clinical activity of pembrolizumab for treatment of recurrent or metastatic squamous cell carcinoma of the head and neck (KEYNOTE-012): an open-label, multicentre, phase 1b trial. Lancet Oncol. 2016;17(7):956–65. https://doi.org/10.1016/s1470-2045(16)30066-3.
187. Bauml J, Seiwert T, Pfister D, et al. Pembrolizumab for platinum- and cetuximab-refractory head and neck cancer: results from a single-arm, phase II study. J Clin Oncol. 2017;35(14):1542–9. https://doi.org/10.1200/jco.2016.70.1524.
188. Licitra L, Haddad R, Even C, et al. EAGLE: a phase 3, randomized, open-label study of durvalumab (D) with or without tremelimumab (T) in patients (pts) with recurrent or metastatic head and neck squamous cell carcinoma (R/M HNSCC). J Clin Oncol. 2019;37(15_Suppl):6012. https://doi.org/10.1200/jco.2019.37.15_suppl.6012.
189. Lapidot T, Sirard C, Vormoor J, et al. A cell initiating human acute myeloid leukaemia after transplantation into SCID mice. Nature. 1994;367(6464):645–8. https://doi.org/10.1038/367645a0.
190. Campbell L, Polyak K. Breast tumor heterogeneity: cancer stem cells or clonal evolution? Cell Cycle. 2007;6(19):2332–8. https://doi.org/10.4161/cc.6.19.4914.
191. Elkashty O, Ashry R, Tran S. Head and neck cancer management and cancer stem cells implication. Saudi Dent J. 2019;31(4):395–416. https://doi.org/10.1016/j.sdentj.2019.05.010.
192. Clarke M, Fuller M. Stem cells and cancer: two faces of eve. Cell. 2006;124(6):1111–5. https://doi.org/10.1016/j.cell.2006.03.011.
193. Zhang P, Zhang Y, Mao L, Zhang Z, Chen W. Side population in oral squamous cell carcinoma possesses tumor stem cell phenotypes. Cancer Lett. 2009;277(2):227–34. https://doi.org/10.1016/j.canlet.2008.12.015.