OHST OXFORD HIGHER SPECIALTY TRAINING

TRAUMA FOR THE FRCS (Tr + Orth) EXAMINATION

Edited by
Alex Trompeter | David Elliott

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FOREWORD

Trauma makes up half of the workload of the average consultant in trauma and orthopaedics and is a core component of the training curriculum in the United Kingdom. Competency in trauma management requires excellent judgement and good decisions: the majority of musculoskeletal trauma requires skilful, non-operative treatment, and so good decision-making is just as important as surgical skill in trauma management. The FRCS (Tr + Orth) examination includes a large trauma component and the candidate's decision-making will be tested in both written and oral examinations.

There are many excellent titles on trauma, but none that focus on the key questions the examiner is likely to ask. This title fills that void and will serve as a great revision aid and rehearsal for the examination. In addition, it will also be a very useful educational tool for decision-making. I am certain that many registrars will find it invaluable to quickly review *Trauma for the FRCS (Tr + Orth) Examination* before presenting a case at the morning trauma conference (and then facing the inevitable questions from the boss).

Chris Moran
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PREFACE

The Intercollegiate Fellowship of the Royal College of Surgeons (FRCS) exam in Trauma and Orthopaedics (Tr + Orth) is one of the last hurdles to cross in the progression from registrar to consultant. This exam has always been held in high regard and is rightfully respected. Despite its reputation as being tough and full of mysterious cases, it is actually a very fair assessment of a trainee's ability and his or her likelihood of coping as a new consultant. The curriculum for the exam is huge and includes a significant focus on orthopaedic trauma. It is reasonable therefore to expect to have your knowledge of orthopaedic trauma surgery tested in both the written and oral parts of the exam. Trauma topics can not only appear in the dedicated trauma viva, but also in the basic sciences, paediatric, hand, and adult pathology viva tables, as well as in the clinical cases. Trauma topics could quite easily represent a third of the questions in the exam as a whole.

Many trainees mistakenly assume that because they have been exposed to trauma throughout their training they have a thorough understanding of the topic. Unfortunately, for a simple long bone nailing, for example, or something else one has performed many times, it is perhaps harder to explain in detail the biomechanics and evidence base around the topic in the pressure situation of a viva. It is for this reason that many people come unstuck in the exam, and exactly why this text has been compiled. For too long, trauma topics have been relegated to a chapter or two in books for the FRCS exam as a whole—we hope that this book will allow candidates to revise, understand, and discuss orthopaedic trauma to the level required.

Orthopaedic trauma surgery is fast becoming a recognized subspeciality in its own right. It is clear that, much like arthroplasty, foot and ankle surgery, spinal surgery, and so forth, trainees who have an interest in that field will excel at the exam and throughout their career in that topic. This book is predominantly aimed at providing trainees with the knowledge, technique, and evidence base to pass the trauma component of the FRCS exam. For trainees with an interest in a trauma career this title will polish your knowledge and viva skills, and for those who see trauma as a burden it will help you gain and organize the basic understanding required to get you through the exam. Furthermore, for those who choose not to pursue careers as dedicated trauma surgeons yet still are required to cover the on-call rota in their consultant appointment, this book should give a sound foundation in and understanding of orthopaedic trauma.

We hope you find it useful.

Alex Trompeter
David Elliott

ACKNOWLEDGEMENTS

There is no doubt that this book could not have been produced without the help of many amazing people. All the people who contributed questions are the real authors, and in an ideal world they should all have their names on the front cover! For putting up with so many emails and nagging messages and still coming up with such excellent material, I am truly grateful to you. Without you there would be no book. Thanks also to the publishers, Oxford University Press, for taking all this material and turning it into a reality. You have been very patient with me and your guidance along the way has been invaluable.

Perhaps the biggest thank-you ought to go to my wife, Kirsty, and children, Oscar and Eve, who have sat by and watched me spend many an evening toiling away. For those moments when it seemed all was lost as the computer crashed (again) to the points where I was searching in desperation for yet another image to use in a viva, you kept me sane and made me remember the reasons behind all of this. As always, you make it all worthwhile.

Alex Trompeter

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ABBREVIATIONS

A&E	accident and emergency
ACDF	anterior cervical discectomy and fusion
ACE	angiotensin-converting enzyme
ACJ	acromioclavicular joint
ACL	anterior cruciate ligament
AIN	anterior interosseous nerve
AIS	Abbreviated Injury Scale
AISmax	Maximum Abbreviated Injury Score
ASIS	anterior superior iliac spine
ATLS	Advanced Trauma Life Support
AVN	avascular necrosis
BMI	body mass index
BMP	bone morphogenetic protein
BOAST	British Orthopaedic Association Standards for Trauma
CABG	coronary artery bypass graft
COPD	chronic obstructive pulmonary disease
CPN	common peroneal nerve
CPP	cerebral perfusion pressure
CRPS	complex regional pain syndrome
CSF	cerebrospinal fluid
CT	computed tomography
DHS	dynamic hip screw
DISH	diffuse idiopathic skeletal hyperostosis
DISI	dorsal intercalated segment instability
DPN	deep peroneal nerve
DRUJ	distal radioulnar joint
ECRB	extensor carpi radialis brevis
ECU	extensor carpi ulnaris
EDB	extensor digitorum brevis
EDC	extensor digitorum communis
EDL	extensor digitorum longus
EHL	extensor hallucis longus

EPL	extensor pollicis longus
ESR	erythrocyte sedimentation rate
FCR	flexor carpi radialis
FCU	flexor carpi ulnaris
FHL	flexor hallucis longus
FPL	flexor pollicis longus
FSH	follicle-stimulating hormone
GCS	Glasgow Coma Scale
GDF	growth differentiation factor
GT	greater trochanter
HIT	heparin-induced thrombocytopenia
ICP	intracranial pressure
IL	interleukin
IM	intramedullary
ISS	Injury Severity Score
ITB	iliotibial band
LEAP	Lower Extremity Assessment Project
LOS	length of hospital stay
LSV	long saphenous vein
MAP	mean arterial blood pressure
MC	metacarpal
MCFA	medial circumflex femoral artery
MCL	medial collateral ligament
MCP(J)	metacarpophalangeal (joint)
M-CSF	macrophage colony-stimulating factor
MIPO	minimally invasive plate osteosynthesis
MISS	Modified Injury Severity Score
MOF	multiple organ failure
MRI	magnetic resonance imaging
MSC	mesenchymal stem cell
MT	metatarsal
NASCIS	National Acute Spinal Cord Injury Study
NICE	National Institute of Health and Care Excellence
NV	neurovascular
NVB	neurovascular bundle
Occ	occiput
OECs	olfactory ensheathing cells
ORIF	open reduction and internal fixation
PCL	posterior cruciate ligament
PDGF	platelet-derived growth factor

PER	pronation–external rotation
PET	positron emission tomography
PIN	posterior interosseous nerve
PIP(J)	proximal interphalangeal (joint)
PITFL	posterior inferior tibiofibular ligament
PLC	posterior ligamentous complex
RLN	recurrent laryngeal nerve
RTA	road traffic accident
SCJ	sternoclavicular joint
SER	supination–external rotation
SNAC	scaphoid non-union advanced collapse
SPN	superficial peroneal nerve
SSSC	superior shoulder suspensory complex
STASCIS	Surgical Treatment of Acute Spinal Cord Injury Study
TAD	tip to apex distance
TFCC	triangular fibrocartilage complex
TFL	tensor fascia latae
THR	total hip replacement
TKR	total knee replacement
TMT	tarsometatarsal
TLSO	thoracolumbosacral orthosis
VEGF	vascular endothelial growth factor
VTE	venous thromboembolism
WHO	World Health Organization

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INTRODUCTION

The FRCS (Tr + Orth) exam and the scoring system

The Intercollegiate FRCS (Tr + Orth) exam is the last exam that most orthopaedic registrars will take in their progression toward the consultant grade. It is a fair but tough assessment of the curriculum set out by the Joint Committee on Surgical Training (JCST) and Specialist Advisory Committees (SAC), and now governed by the Intercollegiate Surgical Curriculum Project (ISCP).

The JCST is an advisory body to the four surgical royal colleges and surgical speciality associations of the UK and Ireland for all matters relating to surgical training. It is the parent body for the ISCP. The JCST enrols surgical trainees, monitors their progress, and makes recommendations to the regulator when they are ready for the Certificate of Completion of Training (CCT). The FRCS exam makes up one vital component of the award of the CCT.

This book is designed around the curriculum and exam in its current state (as of 2013–15). It is advised that any trainee applying to sit the exam is familiar with the curriculum and the exam structure. As this may change, one should familiarize oneself with the JSCT and ISCP websites, as well as information from the Intercollegiate exam website. Of course, all of this can, and does, change. Indeed the governing bodies may now be different from those above, which were correct at the time of writing.

Currently the FRCS (Tr + Orth) exam is divided into a written section, comprising single best answers (SBAs) and extended matching questions (EMQs) over two 3-hour papers sat on a single day. These questions are now set electronically and candidates are able to take these papers at local testing centres. There is no negative marking so all questions should be attempted. Ten to twelve questions will be based on interpretation of a scientific paper only seen on the day. Approximately 245 questions will cover the whole syllabus over the two papers. The pass mark is adjusted according to the scores from all candidates sitting that specific exam—it usually sits around 65%.

Assuming success, most candidates progress to Part 2 about 3 or 4 months later. Part 2 is made up of both viva and clinical exams, taken over 2–3 days at various hospitals, hotels, and conference facilities around the country.

The marking system for the viva and clinical exams historically uses a scale from 4 to 8. A mark of 4 represents an outright fail for that station, while 8 is an excellent pass. A score of 6 is considered a pass for that station. Getting a 4 does not mean an automatic fail of the whole exam, but will require you to make up the marks elsewhere. There are 96 ‘marking opportunities’ over the whole viva/clinical—48 in each section. In fact, two of these marking opportunities are awarded at each point, one by each examiner, so there are only 48 topics in the whole viva/clinical. Ninety-six marking opportunities means 768 marks is the maximum, with 576 (96 × 6) being the overall pass mark.

The viva tables (trauma, adult pathology, basic science, paediatrics/hands) account for 12 marking opportunities each (48 in total). One table will cover six topics, three from each examiner, each being topic marked twice; therefore there are 12 marking opportunities. The clinicals account for the other 48 marking opportunities—12 for each station (two short case stations, two intermediate). It is recommended that you check the latest method/breakdown of scoring prior to the exam as this can (and does) change!

Approach to revision and the work required

The sheer volume of work required for the exam makes for a daunting prospect at the start of your revision programme. Most people allow somewhere between 9 and 12 months for the whole process. It takes a month or two to build up to meaningful levels of work, and this time is typically spent procrastinating by buying books, booking courses, and designing the revision timetable! Five to 6 months of reading is required for the written paper, with another 3–4 months dedicated to the viva/clinical thereafter.

A lot of money can be spent on courses, and some are better than others. The same goes for textbooks. Remember, the revision-style textbooks are likely to be easier to work through than all four volumes of a major orthopaedic reference text! This book fills the gaps left by others—there is not a single book currently that focuses on trauma for the FRCS (Tr + Orth), whilst there are dedicated books for basic sciences, the clinical, hand surgery, paediatrics, and so forth.

Many people get very hung up on the need to know all the latest evidence and research for the exam. This is useful only if you have done so well in the viva or clinical that you actually get asked about a paper you may have read to score 8 points! It is much better to have the basics sorted, then rely on guidelines (British Orthopaedic Association, National Institute for Health and Care Excellence, etc.) and Cochrane summary reviews as support for your answers. While this title is evidence based, and references are provided for each topic, the focus for the exam should above all else be on the principles and concepts.

The hardest part of revision is the juggling act between the day job as a registrar, family life, revision, and the necessary breaks. Social activities tend to be put on hold, and weekday TV watching in the evening is one of the first things to go! But do not forget how important it is to step away from the books at times. Some candidates feel happiest working in groups, others prefer to fly solo. There is no substitute for practising viva technique out loud, and demonstrating examination skills, but any sessions spent with others need to be productive. I personally favoured asking consultants and senior registrars who have passed the exam to give viva sessions, as opposed to the more gentle chats you have with other candidates.

Overall a good 10–20 hours revision per week is required on top of your normal working week. This can easily be achieved with good use of a research session, and a weekend morning—together allowing for up to 12 hours' work. If this is done, only one or two evenings a week are necessary. It is hard to do any work when on call, and you should assume none will get done. Use the morning trauma meetings to your advantage—ask for a viva on every case. If you can stand up to a viva in front of your colleagues you can cope with the stress in the exam hall.

Exam days

For all exams, you should take the time to familiarize yourself with the location and information regarding the process through the day(s). It is helpful to find out that there is no parking available on the morning of the exam! For the clinical and viva you must be smartly presented—this is a test of your competency as a new consultant and that starts with your appearance. Understandably the stress and anxiety will peak as the exam approaches. Whilst there is no method that works for everyone, most people would advise trying to sleep well the night before, avoiding alcohol, and to set an alarm early enough to allow you to have a proper breakfast without rushing!

The written exams now take place at dedicated testing centres. These are utilized by all sorts of companies, including the DVLA, so you may find yourself sitting next to a teenager doing their driving theory test! This is beneficial in as much as you can often take the exam very close to home, but it is well worth turning up early and asking for a computer in a quiet corner, away from others.

For the Vivas and clinical you may well need to stay in a hotel. It is worth finding out where the examiners are staying and booking a different hotel. Sitting for breakfast opposite the examiner who gave you a tough time in the clinical the day before will make for an awkward situation!

The vivas and clinical involve quite a lot of waiting around. You may have up to 90 minutes between some tables. It is important to remain relaxed during this time. Certainly there is no point in fretting over the station you have just had, as nothing can be done to change it. It is also best to avoid the groups of people who have books in their hands and seem to be discussing some topic you have never heard of—it will just make you more stressed! Stay calm, read the newspaper, or gloss over a revision card covering a topic you know well to make you feel more at ease. As you are called to the next station, dry your hands, walk forward, smile, and begin . . .

When you sit at the viva table, you should sit confidently, upright, with your hands on the table. Do not cross your arms or slouch. Most examiners will offer to shake your hand as you sit down, let them do this. If they do not offer their hand it is best to just sit down. Smile at them—they will be bored, and if you come across as pleasant and confident, they will be more relaxed. As soon as you sit down, the questions will begin. Listen extremely carefully to every question you are asked. Pause for a second and digest what you have heard. The examiner will usually ask a very specific question; thus if you answer a different question you will start to experience difficulty. Most people struggle because of technique, not a lack of knowledge. If you have an opportunity to draw, you should do so—pictures tell a thousand words. You should, however, speak as you draw—it adds to your point scoring more quickly, and draw big so both examiners can see. If you are shown pictures on a screen do *not* touch the images, just use descriptive terminology.

The favoured approach to a viva is to start simply and give an overview statement. Imagine your answer as like a tree—describe the trunk and major branches before you follow the path down to the finer detail of each leaf. Once the main branches have been described, the examiner will probably guide you to which leaf they want you to talk about. This way you have already picked up marks. If you go straight to one leaf you may end up talking about something you know little about, or indeed is not the topic the examiner wanted to discuss. A good example is bone grafts: it is much better to start by say they can be structural or biological, or they can be classified as autograft, allograft, or xenograft. If you start by talking about beta-tricalcium phosphate or coralline substitutes you will run out of things to say pretty quickly! The caveat to this is that if something is obvious, you should be confident and say it outright: i.e. 'This is a radiograph of an anterior shoulder dislocation because . . . (then describe the features) and I would confirm this with an orthogonal view', rather than 'This is an AP radiograph of a shoulder joint. The glenoid and humeral head seem overlapped, but I cannot identify any fractures. It could be that this is a shoulder dislocation but I would need to see more images.'

As the viva progresses the questions will evolve. Either because you are doing well or you are going off track. A tricky question may be one designed to push and challenge you, so do not be worried. If you are being asked about evidence or literature to support your answer it will usually imply you are pushing for a mark of 7 or 8. If you do not know an answer, say so—do not make things up—get back to something to talk about that will pick up marks. If you seem to be going down a path you did not want to take, pause, and offer to either start again, or suggest an alternative. When the time is up, or if you have run out of things to be asked about, the examiner will suggest you move on, and the next topic begins.

The layout of the book

This book shall attempt to cover the main aspects of the exam in relation to trauma. There are sections of SBAs, EMQs, and vivas, with questions and answers separated as well as an anatomy section in Chapter 17. Almost all acute trauma topics are touched upon in at least one section. Most answers are supported by discussion or evidence, if appropriate, for those who want more. The question format reflects that of the exam in its current state.

The SBAs and EMQs have been organized into sections with common themes. The questions and answers are separate to allow you to test yourself. The vivas have their answers and discussion directly after each individual question to allow someone else to viva you with ease; they are again organized into common themed sections.

Single best answer questions (SBAs)

SBAs have a statement or question followed by five possible answers. Only one correct answer is possible from the five options. There is no negative marking so it is worth a guess if you genuinely do not know the answer. It is vital that you read the questions and answer stems very carefully—double negatives are common and can easily trick you.

Extended matching questions (EMQs)

EMQs in this book start by offering the list of possible answers. Then there is a principal statement or question that sets the direction for the specific questions that follow. There are three or four specific questions or statements for each main stem that require you to choose an appropriate 'answer' from the preceding list. Each answer can be used once, more than once, or not at all.

Anatomy and approaches

The book includes a summary chapter (Chapter 17) covering anatomy approaches—these come up frequently in the exam. There is a set 'patter' for description of a surgical approach in the viva, which is described in this chapter. While it is not the only way it does allow you to sound confident when describing an approach you have never performed.

Vivas

The viva section will cover most trauma topics. This book is not meant to be an exhaustive text or a complete revision aid, but rather it demonstrates examples of answers to common topics, with the focus on the structure and delivery of the salient points. Each viva starts with a prompt, as in the real exam. This is usually a radiograph, clinical photograph, or implant. It allows the scene to be set and an easy opening question to be asked. The questions and answers are again separated, and the questions have been designed to progress through the marking scheme from 4–8. Discussion and evidence for most questions are provided if appropriate.

There is no clinical section to this book. It stands to reason that trauma cases can appear in both the short and intermediate clinical cases, but normally these will be post-traumatic complications or sequalae. It would be well worth being confident in describing deformities, fixators, scars, etc. but the approach to the patient here should be the same as for the elective situation.

Finally, this book is written to help you pass the FRCS (Tr + Orth) and it will no doubt require some changes and updates to the second edition and beyond—especially as evidence or guidance changes and evolves, but also if there are (unintentional and very rare!) errors in the text. This is not intended to be an instructional text, but rather a platform for you to build and work from, giving you structure to your answers. It is not always possible to include every change in guidance and evidence as much of the text is written well in advance of publication. If you pass the exam and feel you would like to be a contributor to future editions, please do get in touch through the publishers.

Good luck!

Part 1 **Single Best Answers**

chapter 1

BASIC SCIENCE OF ORTHOPAEDIC TRAUMA

Questions

1. Which of the following is not a pre-requisite for the contact healing variant of primary bone healing?

Select the single most appropriate answer.

A. Absolute stability
B. Anatomical reduction
C. An ultra-low-strain environment
D. Formation of granulation tissue
E. Interfragmentary compression

2. Which phase of secondary bone healing most closely approximates the direct laying down of lamellar bone seen in primary bone healing?

Select the single most appropriate answer.

A. Haematoma formation
B. Hard callus
C. Inflammation
D. Remodelling
E. Soft callus

3. Which of the following is true of the cutting cones that characterize the contact healing variant of primary bone healing?

Select the single most appropriate answer.

A. Osteoblasts precede osteoclasts
B. They form bridging osteons that mature into lamellar bone by direct remodelling
C. They occur where strain is less than 10% and the gap between bone ends is less than 1 mm
D. They produce longitudinal cavities at a rate of 500 μm/day
E. They result in sequential generation of a bony union and the restoration of Haversian systems

4. Which of the following is not true of the gap-healing variant of primary bone healing?

Select the single most appropriate answer.

A. A second remodelling resembling contact healing occurs
B. Lamellar bone is formed over 3–8 weeks
C. Lamellar bone is formed perpendicular to the long axis
D. Simultaneous generation of a bony union and the restoration of Haversian systems
E. The fracture gap must not exceed 1 mm

5. Which strain environment is required for primary bone healing?

Select the single most appropriate answer.

A. Over 100%
B. Up to 100%
C. Up to 17%
D. 2–10%
E. Less than 2%

6. Which type of callus allows pluripotent cells to differentiate into osteoprogenitor cells which produce bone directly?

Select the single most appropriate answer.

A. Endosteal callus
B. Exosteal callus
C. Medullary callus
D. Periosteal callus
E. Soft callus

7. Which of the following is not a member of the transforming growth factor beta (TGF-β) superfamily?

Select the single most appropriate answer.

A. Activin
B. BMP4 (bone morphogenetic protein 4)
C. GDF2 (growth differentiation factor 2)
D. IL-1 (interleukin 1)
E. TGF-β1

8. What strain environment is required for the formation of the calcified fibrocartilage found in soft callus?

Select the single most appropriate answer.

A. Over 100%
B. 20–100%
C. 10–20%
D. 2–10%
E. Less than 2%

9. Which of the following statements is incorrect regarding indirect (secondary) fracture healing?

Select the single most appropriate answer.

A. Angiopoetin-12 is a regulator of vascular regeneration and neoangiogenesis
B. Generation of callus depends on the recruitment and differentiation of mesenchymal stem cells mobilized from local soft tissues, cortex, periosteum, and bone marrow
C. Generation of callus depends on the recruitment and differentiation of mesenchymal stem cells mobilized from remote haemopoietic sites
D. Indirect fracture healing involves both intramembranous and endochondral ossification
E. Osteoblasts express high levels of vascular endothelial growth factor (VEGF), which promotes the invasion of blood vessels

10. Which of the following does not occur during the mineralization and resorption of cartilaginous callus?

Select the single most appropriate answer.

A. Chondrocytes become hypertrophic
B. Mesenchymal stem cells differentiate into osteoblastic lineage
C. Mineralized cartilage is resorbed
D. Osteoclast apoptosis
E. The extracellular matrix is calcified

11. The correct sequence of steps for a small fragment 'lag' (interfragmentary compression) screw is as follows.

Select the single most appropriate answer.

A. Reduce fracture anatomically, 3.5 mm drill for pilot hole, 2.5 mm drill for gliding hole, countersink, measure, tap, screw
B. Reduce fracture anatomically, 3.5 mm drill for gliding hole, 2.5 mm drill for pilot hole, countersink, measure, tap, screw
C. Reduce fracture anatomically, 2.5 mm drill for pilot hole, 3.5 mm drill for gliding hole countersink, measure, tap, screw
D. Reduce fracture anatomically, 3.5 mm drill for gliding hole, 2.5 mm drill for pilot hole, countersink, tap, measure, screw
E. Reduce fracture anatomically, 3.5 mm drill for gliding hole, 2.5 mm drill for pilot hole, measure, tap, countersink, screw

12. Which of the following is not true regarding locked screws?

Select the single most appropriate answer.

A. The working length of a monocortical locked screw is the amount of screw in contact with the cortex
B. The working length of a monocortical locked screw is the distance between the undersurface of the plate and the bone
C. The working length of a monocortical locked screw is shorter in osteoporotic bone
D. The working length of a monocortical locked screw is not dependent on the distance of the plate from the bone, nor the diameter of the screw
E. The working length of a monocortical locked screw is independent of the number of screws and is the same for self-tapped and self-drilling and tapping screws

13. When comparing the screws used for a locking plate with those used with conventional plates which of the following best describes the differences?

Select the single most appropriate answer.

A. The locking screws have a relatively smaller core diameter
B. The locking screws have a relatively greater core diameter
C. The locking screws have a greater difference between the core diameter and the inner diameter
D. The locking screws have a greater pitch
E. The locking screws need to be made from more flexible material

14. Comparing a solid 9 mm intramedullary (IM) nail with a hollow IM nail of the same material with 9 mm outer diameter and 6 mm inner diameter, the hollow nail is:

Select the single most appropriate answer.

A. Less stiff in proportion to the fourth power of the inner radius
B. Less stiff in proportion to the third power of the inner radius
C. Less strong in proportion to the fourth power of the outer radius
D. Stiffer in proportion to the fourth power of the inner radius
E. Stronger in proportion to the fourth power of the inner radius

15. With regard to wound healing following amputation, which of the following most accurately relates to a malnourished patient?

Select the single most appropriate answer.

A. Albumin below 3.5 g/dl
B. Body mass index (BMI) under 21 kg/m^2
C. Recurrent skin ulceration
D. Serum haemoglobin below 12 g/dl
E. Waist size within two standard deviations of normal for height

16. Which of the following is the gold standard for measurement of vascular inflow?

Select the single most appropriate answer.

A. Ankle–brachial pressure index
B. Capillary refill time
C. Distal pulse Doppler and skin temperature assessment
D. Percutaneous oxygen saturation
E. Percutaneous oxygen tension

17. What is the ischaemic index?

Select the single most appropriate answer.

A. A comparative measure of capillary refill time between an affected lower limb and the normal unaffected upper limb
B. A quantity that relates to the comparative oxygen saturation in the distal tissue of a limb
C. A quantity that should be less than 0.3 to achieve wound healing
D. The ratio of Doppler pressure at the level being tested to the brachial systolic pressure
E. The ratio of oxygen tension between the same level of an affected compared with an unaffected limb

18. A 76-year-old post-menopausal woman presents to the fracture clinic. She was walking her poodle and tripped over its lead, sustaining a distal radial fracture which is minimally displaced. She has previously fractured her lumbar spine (falling off a bar stool) and her ankle (she tripped in very high heels). What treatment would you suggest?

What treatment would you suggest?

Select the single most appropriate answer.

A. 6 weeks in plaster/splint and review in fracture clinic
B. 6 weeks in plaster/splint, review in fracture clinic, modification of lifestyle, and reduction of alcohol intake
C. 6 weeks in plaster/splint, review in fracture clinic, and referral for falls prevention assessment
D. 6 weeks in plaster/splint, review in fracture clinic, and referral for a DEXA (bone density) scan
E. 6 weeks in plaster/splint, review in fracture clinic, start alendronate, and refer to the fracture liaison service

19. A 36-year-old woman is treated for a minimally displaced fractured ankle with 6 weeks in a full cast then 4 weeks of physiotherapy. At final review her foot is painful, red, and swollen. Which imaging modality is specific for diagnosing complex regional pain syndrome (CRPS type I)?

Select the single most appropriate answer.

A. Conventional magnetic resonance imaging (MRI)
B. Conventional plain radiography
C. Gadolinium-enhanced MRI
D. Nuclear medicine bone scan and leucoscan
E. None of the above

chapter

1

BASIC SCIENCE OF ORTHOPAEDIC TRAUMA

Answers

1. D. Formation of granulation tissue

For contact healing to occur a fracture must be anatomically reduced and be absolutely stable. This occurs through the use of devices, which cause interfragmentary compression resulting in strain environments often far less than 2%. Granulation tissue is not observed in this type of healing. It is formed in high strain of up to 100% and its formation occurs in the initial phases of secondary bone healing.

Bates P, Ramachandran M (2006). Bone injury, healing and grafting. In: M Ramachandran (ed.) *Basic Orthopaedic Sciences—the Stanmore Guide*, 1st edn, pp.123–134. CRC/Taylor and Francis, London.

2. D. Remodelling

Primary bone healing occurs through the simultaneous resorption of bone by osteoclasts and production of bone by osteoblasts. This process also occurs as the woven bone formed in secondary bone healing matures to lamellar bone in the remodelling phase.

Bates P, Ramachandran M (2006). Bone injury, healing and grafting. In: M Ramachandran (ed.) *Basic Orthopaedic Sciences—the Stanmore Guide*, 1st edn, pp.123–134. CRC/Taylor and Francis, London.

3. B. They form bridging osteons that mature into lamellar bone by direct remodelling

Primary healing of fractures can occur either through contact healing or by gap healing. Both processes involve an attempt to directly re-establish an anatomically correct and biomechanically competent lamellar bone structure. Direct bone healing can only occur when an anatomical restoration of the fracture fragments is achieved and rigid fixation is provided, resulting in a substantial decrease in interfragmentary strain. Bone on one side of the cortex must unite with bone on the other side of the cortex to re-establish mechanical continuity. If the gap between bone ends is less than 0.01 mm and interfragmentary strain is less than 2% the fracture unites by so-called contact healing. Under these conditions, cutting cones are formed at the ends of the osteons closest to the fracture site. The tips of the cutting cones consist of osteoclasts that cross the fracture line, generating longitudinal cavities at a rate of 50–100 μm/day. These cavities are later filled by bone produced by osteoblasts residing at the rear of the cutting cone. This results in the simultaneous (*not* sequential) generation of a bony union and the restoration of Haversian systems formed in an axial direction. The re-established Haversian systems allow for penetration of blood vessels carrying osteoblastic precursors. The bridging osteons later mature by direct remodelling into lamellar bone, resulting in fracture healing without the formation of periosteal callus.

Marsell R, Einhorn TA (2011). Biology of fracture healing. *Injury*, 42, 551–555.

4. D. Simultaneous generation of a bony union and the restoration of Haversian systems

Gap healing differs from contact healing in that bony union and Haversian remodelling do not occur simultaneously. Gap healing occurs if stable conditions and an anatomical reduction are achieved, although the gap must be less than 800 μm to 1 mm. In this process the fracture site is primarily filled by lamellar bone (akin to intramembranous ossification) oriented perpendicular to the long axis, requiring a secondary osteonal reconstruction unlike the process of contact healing. The primary bone structure is then gradually replaced by longitudinal revascularized osteons carrying osteoprogenitor cells that differentiate into osteoblasts and produce lamellar bone on each surface of the gap. This lamellar bone, however, is laid down perpendicular to the long axis and is mechanically weak. This initial process takes approximately 3 to 8 weeks, after which a secondary remodelling resembling the contact healing cascade with cutting cones takes place. Although not as extensive as endochondral remodelling, this phase is necessary in order to fully restore the anatomical and biomechanical properties of the bone.

Marsell R, Einhorn TA (2011). Biology of fracture healing. *Injury*, 42, 551–555.

5. E. Less than 2%

Granulation tissue will form in strain environments up to 100%; fibrous connective tissue will form up to 17%, fibrocartilage in the range 2–10%, and lamellar bone at less than 2%.

Bates P, Ramachandran M (2006). Bone injury, healing and grafting. In: M Ramachandran (ed.) *Basic Orthopaedic Sciences—the Stanmore Guide*, 1st edn, pp.123–134. CRC/Taylor and Francis, London.

6. D. Periosteal callus

Periosteal callus is formed by the same mechanism as intramembranous ossification (the method through which increases in the diameter of the bone are achieved). Periosteum has an inner loose vascular osteogenic (cambium) layer which contains pluripotent cells. Following trauma, provided that relative stability is present and the periosteum has not been extensively stripped, the pluripotent cells become osteoprogenitor cells which in turn become osteoblasts and bone is laid down without first forming cartilage.

Bates P, Ramachandran M (2006). Bone injury, healing and grafting. In: M Ramachandran (ed.) *Basic Orthopaedic Sciences—the Stanmore Guide*, 1st edn, pp.123–134. CRC/Taylor and Francis, London.

Marsell R, Einhorn TA (2011). Biology of fracture healing. *Injury*, 42, 551–555.

Perren S (2002). Evolution of the internal fixation of long bone fractures the scientific basis of biological internal fixation: choosing a new balance between stability and biology. *J Bone Joint Surg Br*, 84, 1093–1110.

7. D. IL-1 (interleukin 1)

The TGF-β superfamily is a group of structurally related cell regulatory proteins named after its first member TGF-β1—a secreted protein that controls cell growth, cell proliferation, cell differentiation, and apoptosis. BMPs 2–7 and 9 are members of the TGF-β superfamily and play key roles in the differentiation of osteoblasts from osteoprogenitor cells: BMP3 antagonizes these BMPs, BMP4 is vital in fracture repair as it promotes endochondral bone formation, BMP5 is essential to cartilage development, and BMP6 plays a role in joint integrity in adults. GDF2 (also known as BMP9) is one of the most potent inducers of bone formation. It is a member of the TGF-β superfamily. Activin enhances the synthesis and secretion of follicle-stimulating hormone (FSH). It is a member of the TGF-β superfamily but is not involved in fracture healing or bone formation.

IL-1 is a pro-inflammatory cytokine, intensely produced by macrophages, monocytes, and fibroblasts. It is a vital part of the initial haematoma and inflammation stages of callus formation. It promotes angiogenesis and causes osteoblasts to secrete IL-6, which in turn causes further differentiation of osteoblasts and osteoclasts. It also increases the expression of adhesion factors on endothelial cells, facilitating migration of immunocompetent cells. It is also a pyrogen, causes vasodilatation and hypotension, and increases pain sensitivity. It is seen at all sites of inflammation and infection. However, it is not a member of the TGF-β superfamily.

Bates P, Ramachandran M (2006). Bone injury, healing and grafting. In: M Ramachandran (ed.) *Basic Orthopaedic Sciences—the Stanmore Guide*, 1st edn, pp.123–134. CRC/Taylor and Francis, London.

Marsell R, Einhorn TA (2011). Biology of fracture healing. *Injury*, 42, 551–555.

Perren S (2002). Evolution of the internal fixation of long bone fractures the scientific basis of biological internal fixation: choosing a new balance between stability and biology. *J Bone Joint Surg Br*, 84, 1093–1110.

8. D. 2–10%

Soft callus is primarily endochondral callus. It may also be referred to as bridging external callus. It is formed when pluripotent cells within granulation tissue differentiate into chondrocytes and fibroblasts and start to produce fibrous/chondroid elements of the matrix onto which type collagen II is then deposited. Calcification of the matrix results in calcified fibrocartilage. At high strain up to 100% granulation tissue will form, between 10% and 17% fibrous connective tissue will form. In order to get fibrocartilage formation the strain must be between 2% and 10%. Below 2% strain bone formation can occur.

Bates P, Ramachandran M (2006). Bone injury, healing and grafting. In: M Ramachandran (ed.) *Basic Orthopaedic Sciences—the Stanmore Guide*, 1st edn, pp.123–134. CRC/Taylor and Francis, London.

Marsell R, Einhorn TA (2011). Biology of fracture healing. *Injury*, 42, 551–555.

Perren S (2002). Evolution of the internal fixation of long bone fractures the scientific basis of biological internal fixation: choosing a new balance between stability and biology. *J Bone Joint Surg Br*, 84, 1093–1110.

9. A. Angiopoetin-12 is a regulator of vascular regeneration and neoangiogenesis

Endochondral callus formation can only occur if mesenchymal stem cells can be recruited to the fracture site, where they proliferate and differentiate into osteogenic cells. Revascularization is also fundamental to callus formation. Mesenchymal stem cells are sourced from both local tissues and remote haemopoietic sites. Revascularization and neoangiogenesis are highly dependent on the VEGF pathway initiated by expression of VEGF by osteoblasts and hypertrophic chondrocytes. Angiopoetin-1 and angiopoetin-2 are involved in the early in-growth of existing vessels in the periosteum. Angiopoetin-12 does not exist.

Bates P, Ramachandran M (2006). Bone injury, healing and grafting. In: M Ramachandran (ed.) *Basic Orthopaedic Sciences—the Stanmore Guide*, 1st edn, pp.123–134. CRC/Taylor and Francis, London.

Marsell R, Einhorn TA (2011). Biology of fracture healing. *Injury*, 42, 551–555.

Perren S (2002). Evolution of the internal fixation of long bone fractures the scientific basis of biological internal fixation: choosing a new balance between stability and biology. *J Bone Joint Surg Br*, 84, 1093–1110.

10. D. Osteoclast apoptosis

During the replacement of soft cartilaginous callus by hard woven bone all the steps shown occur with the exception of osteoclast apoptosis.

Bates P, Ramachandran M (2006). Bone injury, healing and grafting. In: M Ramachandran (ed.) *Basic Orthopaedic Sciences—the Stanmore Guide*, 1st edn, pp.123–134. CRC/Taylor and Francis, London.

Marsell R, Einhorn TA (2011). Biology of fracture healing. *Injury*, 42, 551–555.

Perren S (2002). Evolution of the internal fixation of long bone fractures the scientific basis of biological internal fixation: choosing a new balance between stability and biology. *J Bone Joint Surg Br*, 84, 1093–1110.

11. B. Reduce fracture anatomically, 3.5 mm drill for gliding hole, 2.5 mm drill for pilot hole, countersink, measure, tap, screw

An interfragmentary compression, or lag, screw has several crucial steps that must not be performed out of sequence.

AO Foundation—lag screw fixation: https://www2.aofoundation.org/wps/portal/!ut/p/c0/04_SB8K8xLLM9MSSzPy8xBz9CP0os3hng7BARydDRwN3QwMDA08zTzdvvxBjIwN_I_2CbEdFADiM_QM!/?segment=Mandible&bone=CMF&showPage=A&contentUrl=srg/popup/additional_material/91/X80_lag_screw_fix.jsp

12. B. The working length of a monocortical locked screw is the distance between the undersurface of the plate and the bone

The working length of a monocortical locked screw is the length of screw seated in the cortex of the bone. It is thus dependent on the thickness of the cortex, and is as a result greatly reduced in osteoporotic bone. The number of screws, screw diameter, and type of screw are independent of the working length in monocortical locking.

Gautier E, Sommer C (2003). Guidelines for the clinical application of the LCP. *Injury*, 34(Suppl. 2), B63–B76.

13. B. The locking screws have a relatively greater core diameter

The screws used with conventional plates are designed to compress the plate onto the bone to increase friction. A key feature of a conventional screw is therefore its pull-out strength. The screws used with locking plates function as a unified fixed angle device; as they act together their absolute and individual pull-out strengths are less important than their ability to resist bending forces. It follows, therefore, that their core diameter should be relatively large (bending stiffness being proportional to the fourth power of the radius) whilst their threads do not need to be as wide.

Gautier E, Sommer C (2003). Guidelines for the clinical application of the LCP. *Injury*, 34(Suppl. 2), B63–B76.

14. A. Less stiff in proportion to the fourth power of the inner radius

This question deals with the concept of the second moment of area. For an extruded shape of circular cross-section the bending stiffness and the torsional stiffness are both proportional to the fourth power of the radius. For a hollow cylindrical shape the second moment of area is proportional to the fourth power of the outer radius minus the fourth power of the inner radius. Thus, for two cylinders of the same outer diameter the solid one will be stiffer. The 'strength' is proportional to the third power of the radius. The overall stiffness depends on the elastic modulus of the material, the second moment of area of the device, and the working length.

Ramachandran M (ed.) (2006). *Basic Orthopaedic Sciences—the Stanmore Guide*, 1st edn. CRC/Taylor and Francis, London.

15. A. Albumin below 3.5 g/dl

Serum albumin represents the most accurate means of assessing someone's nutritional status. Low BMI, waist size, and haemoglobin may determine wound-healing capacity but only indirectly reflect nutritional status.

Kram HB, Appel PL, Shoemaker WC (1989). Prediction of below-knee amputation wound healing using noninvasive laser Doppler velocimetry. *Am J Surg*, 158, 29–31.

Mulder GD, Brazinsky K, Harding KG (1998). Factors influencing wound healing. In: Leaper D, Harding KG (eds) *Wounds: Biology and Management*, Oxford University Press, Oxford.

16. E. Percutaneous oxygen tension

Percutaneous oxygen tension is the gold standard for measuring vascular inflow. The other measurements are crude tests of limb perfusion.

Wütschert R, Bounameaux H (1997). Determination of amputation level in ischemic limbs. Reappraisal of the measurement of TcPo2. *Diabetes Care*, 20, 1315–1318.

17. D. The ratio of Doppler pressure at the level being tested to the brachial systolic pressure

The ratio of Doppler pressure at the level being tested to the brachial systolic pressure defines the ischaemic index of the limb.

Kram HB, Appel PL, Shoemaker WC (1989). Prediction of below-knee amputation wound healing using noninvasive laser Doppler velocimetry. *Am J Surg*, 158, 29–31.

Mulder GD, Brazinsky K, Harding KG (1998). Factors influencing wound healing. In: Leaper D, Harding KG (eds) *Wounds: Biology and Management*, Oxford University Press, Oxford.

18. E. 6 weeks in plaster/splint, review in fracture clinic, start alendronate, and refer to the fracture liaison service

Suspected osteoporosis in the over 75s may not need a DEXA scan for diagnosis according to NICE guidelines. A post-menopausal woman with a fracture is offered treatment for osteoporosis depending on her risk factors. Alendronate is recommended in post-menopausal women who have had a diagnosis of osteoporosis as a first-line treatment for preventing further fractures. If alendronate is not tolerated alternatives include risendronate, etidronate, strontium ranelate, raloxifene, and teriparatide. Teriparatide is also recommended if a woman has another fracture and her bone density has fallen whilst taking alendronate, risendronate, or etidronate. Fracture liaison services should be provided in all orthopaedic clinics—they will address all required aspects of the management of osteoporosis outlined in options B–E.

FRAX. WHO fracture risk assessment tool. http://www.shef.ac.uk/FRAX/

Giger, EV, Castagner B, Leroux JC (2013). Biomedical applications of bisphosphonates. *J Control Release*, 167, 175–188.

National Institute for Health and Care Excellence (NICE). NICE technology appraisal guidance TA161. Alendronate, etidronate, risedronate, raloxifene, strontium ranelate and teriparatide for the secondary prevention of osteoporotic fragility fractures in postmenopausal women (amended). http://www.nice.org.uk/guidance/TA161

19. E. None of the above

CRPS type I can develop following a fracture in 10% of subjects. It is characterized by pain, abnormal regulation of blood flow, sweating, and trophic changes divided into three phases. Phase 1: vasomotor response, swelling and vasodilatation, less than 3 months from injury. Phase 2: dystrophic phase, vasoconstriction, increased stiffness, 3 months to a year from injury. Phase 3: atrophic phase, fibrosis, contracture, a year from injury. CRPS affects both the central and peripheral nervous systems but the cause is still unknown. Various hypotheses, including distal degeneration of nerve fibres, autoimmune involvement, and an association with angiotensin-converting-enzyme (ACE) inhibitors, have been postulated. Imaging modalities are not specific for the diagnosis of CRPS but functional MRI (fMRI) has recently shown promising results. Treatment focuses on tricyclic antidepressants, opioids, and selective neural blockade such as guanethidine blocks, but conventional therapies produce an unpredictable outcome.

Hsu ES (2009). Practical management of complex regional pain syndrome. *Am J Ther*, 16, 147–154.

Maihofner C, Handwerker HO, Birklein F(2006). Functional imaging of allodynia in complex regional pain syndrome. *Neurology*, 66, 711–717.

Schumann M, Zaspel J, Lohr P, et al. (2007). Imaging in early posttraumatic complex regional pain syndrome: a comparison of diagnostic methods. *Clin J Pain*, 23, 449–457.

chapter 2

ADVANCED TRAUMA LIFE SUPPORT (ATLS), POLYTRAUMA, LIMB SALVAGE, AND UK TRAUMA GUIDELINES

Questions

1. A 29-year-old soldier steps on a landmine on the battlefield. He starts to bleed profusely from a mangled left leg. What is the initial treatment?

Select the single most appropriate answer.

A. A battlefield tourniquet should be applied to the limb
B. A clean dressing with a military pressure bandage
C. A haemostatic dressing should be applied immediately
D. Application of a pneumatic tourniquet
E. Immediate evacuation from the battlefield

2. Which of these statements is incorrect with regard to ATLS teaching on head trauma?

Select the single most appropriate answer.

A. Epidural haematomas occur in 2% of patients with traumatic brain injury who are comatose
B. Epidural haematomas typically become biconvex or lenticular in shape as they push the adherent dura away from the inner table of the skull
C. Epidural haematomas are most often located in the temporal or temporoparietal regions
D. Epidural haematomas often result from a tear of the middle meningeal artery as the result of a fracture
E. Epidural haematomas classically present with a lucid interval between time of injury and neurological deterioration

3. Which of the following is not a principle of the ATLS management of severe head injury?

Select the single most appropriate answer.

A. Evacuate haematomas that increase intracranial volume
B. Maintain a low mean arterial blood pressure
C. Maintain normal intravascular volume
D. Reduce elevated intracranial pressure
E. Restore normal oxygenation and normocapnia

4. Which of these statements is not found in the ATLS management of paediatric shock?

Select the single most appropriate answer.

A. Fluid resuscitation in children should start with an isotonic fluid bolus of 50 ml/kg
B. Hypotension occurs late in paediatric hypovolaemic shock and represents a state of decompensated shock
C. If the child deteriorates during fluid resuscitation consideration must be given to the early use of 10 ml/kg of packed red blood cells
D. The mean normal systolic blood pressure in a child is approximately 90 mmHg plus twice the child's age in years
E. The weight of a child in kilograms can be estimated using the formula (2 × age in years) + 10

5. Which of the following is not a conclusion of the multicentre prospective observational Lower Extremity Assessment Project (LEAP)?

Select the single most appropriate answer.

A. Initial plantar sensation is prognostic of long-term functional outcome and should be a component of a limb-salvage decision algorithm
B. More attention to the psychological as well as the physical health of patients who sustain a limb-threatening injury may be needed to ensure an optimal recovery
C. Patients with severe, bilateral lower extremity injuries should be counselled that, regardless of treatment combinations, the function of each limb is similar at 2 and 7 years
D. Severity of soft tissue injury has the greatest impact on decision-making regarding limb salvage versus amputation
E. Smoking places the patient at risk for increased time to union and complications

6. The LEAP study identified a number of early predictors of chronic pain. Which of these is not predictive of chronic pain after limb-threatening trauma?

Select the single most appropriate answer.

A. Evidence of depression and anxiety at 3 months post-discharge
B. High average alcohol consumption at baseline
C. High levels of sleep dysfunction
D. Lack of higher education
E. Treatment with narcotic medication during the first 3 months

7. The LEAP study included a subset of 268 unilateral open tibial fractures. The study group reported on the effect of smoking in this group. Which of the following statements is incorrect?

Select the single most appropriate answer.

A. Current smokers are 37% less likely to achieve union than non-smokers
B. Current smokers are approximately 3.5 times more likely to develop osteomyelitis than non-smokers
C. Current smokers are approximately five times more likely to develop an infection than non-smokers
D. Previous smokers are 32% less likely to achieve union than non-smokers
E. Previous smokers are approximately three times more likely to develop osteomyelitis than non-smokers

8. A motorcyclist is involved in a road traffic accident (RTA) where he hits a stationary object at approximately 50 m.p.h. At the scene he has a pulse rate of 100 b.p.m. and a blood pressure of 140/80. He is taken to the nearest major trauma centre with a hard collar on a spinal board. On arrival he has a primary survey. His pelvic radiograph shows an anteroposterior compression type II pelvic fracture. Which of the following should be avoided?

Select the single most appropriate answer.

A. Application of a pelvic binder if one has not already been applied by paramedics
B. Continue close monitoring with a low threshold for initiation of a massive transfusion protocol
C. Examination of the perineum
D. Log roll the patient to examine the spine for associated injuries
E. Perform a trauma series CT with contrast as early as possible

9. What is the Injury Severity Score (ISS) for a patient with a penetrating chest wound (Abbreviated Injury Scale, AIS = 4), liver laceration (AIS = 4), open tibial shaft fracture (AIS = 3), distal radius fracture (AIS = 2), and a large scalp laceration (AIS = 1)?

Select the single most appropriate answer.

A. 11
B. 14
C. 32
D. 41
E. 46

10. What is the Modified Injury Severity Score (MISS) for a child with a Glasgow Coma Scale (GCS) score of 14, severe but not life-threatening femoral fracture (3 points), moderate abdominal injury (2 points), and severe but probably survivable neck injury (4 points)?

Select the single most appropriate answer.

A. 9
B. 10
C. 29
D. 30
E. 39

11. Which of the following would not be an indication for initial temporary fixation of a femoral shaft fracture?

Select the single most appropriate answer.

A. Closed head injury
B. Contralateral femoral shaft fracture
C. Flail chest and underlying lung contusion
D. Ipsilateral tibial fracture
E. Lactate of –5.0 mmol/L

12. A 91-year-old woman with Alzheimer's is found on the floor of her nursing home bathroom. She presents with a displaced intracapsular femoral neck fracture. She is dehydrated, confused, and has a urinary tract infection. She has chronic obstructive pulmonary disease (COPD) and atrial fibrillation (warfarin), and had a coronary artery bypass graft (CABG) 10 years ago. After optimization (including warfarin reversal) she remains frail with poor cardiorespiratory reserve. What treatment should be suggested?

Select the single most appropriate answer.

A. Cemented hemiarthroplasty on the next routine trauma list
B. Cemented taper slip design total hip arthroplasty
C. Non-operative management with analgesia
D. Open reduction and internal fixation with cannulated screws
E. Uncemented (Thompson/Austin Moore) hemiarthroplasty on the next routine trauma list

13. The incidence of unstable spine injuries in unconscious patients with significant blunt trauma is . . . ?

Select the single most appropriate answer.

A. Up to 11%
B. Up to 34%
C. Up to 23%
D. Up to 29%
E. Over 41%

14. According to the British Orthopaedic Association Standards for Trauma (BOAST), spinal immobilization is recommended for . . . ?

Select the single most appropriate answer.

A. As long as is necessary
B. Less than 12 hours
C. Not more than 48 hours
D. Not more than 24 hours
E. None of above

15. Which of the following is the urgent investigation of choice for a spinal cord injury?

Select the single most appropriate answer.

A. Anteroposterior and lateral radiograph of entire spine
B. MRI
C. Positron emission tomography (PET)-CT scan
D. 2–3 mm fine-slice helical computed tomography (CT) scan
E. < 5 mm helical CT scans

16. A 38-year-old man is involved in a RTA and sustains a posterior dislocation of his right hip, with a small posterior acetabular wall fracture. It is an isolated injury with no neurological deficit, he is otherwise well, and is haemodynamically stable. What is the most appropriate next step in his treatment?

Select the single most appropriate answer.

A. CT scan the next day
B. Open reduction and internal fixation of the posterior wall fracture
C. Open reduction of the dislocation and excision of the bony fragment
D. Skin traction and transfer to an acetabular reconstruction expert
E. Urgent closed reduction and assessment of hip stability post-reduction

17. What is the maximum acceptable time delay for vascular reconstruction if confirmed vascular impairment exists in a lower limb?

Select the single most appropriate answer.

A. 8 hours of cold ischaemia
B. 6 hours of warm ischaemia
C. 3–4 hours of warm ischaemia
D. It depends on coexisting soft/bone tissue injury
E. Not defined

18. Following initial wound excision, which antibiotics should be administered for an open fracture?

Select the single most appropriate answer.

A. Amoxicillin and meropenem
B. Cefuroxime and metronidazole
C. Clindamycin
D. Co-amoxiclav and gentamicin
E. Tobramycin and cefuroxime

19. In an open fracture, following wound, soft tissue, and bone excision, for what duration should antibiotics be given?

Select the single most appropriate answer.

A. 5 days
B. 10–14 days
C. 72 hours or until definitive wound closure (whichever is sooner)
D. Indefinitely
E. It depends on microbiology advice

20. Which of the following scores is not a risk factor for venous thromboembolism (VTE)?

Select the single most appropriate answer.

A. Acute stroke
B. Admission to critical care
C. A first-degree relative with a history of VTE
D. Obesity (BMI > 30 kg/m^2)
E. Varicose veins

chapter

2

ADVANCED TRAUMA LIFE SUPPORT (ATLS), POLYTRAUMA, LIMB SALVAGE, AND UK TRAUMA GUIDELINES

Answers

1. A. A battlefield tourniquet should be applied to the limb

Early use of a tourniquet in combat situations has led to a reduction in morbidity from haemorrhagic limb injuries.

Kragh JF Jr (2010). Use of tourniquets and their effects on limb function in the modern combat environment. *Foot Ankle Clin*, 15, 23–40.

Richey SL (2009). Tourniquets for the control of traumatic haemorrhage: a review of the literature. *J Spec Operations Med*, 9, 56–64.

2. A. Epidural haematomas occur in 2% of patients with traumatic brain injury who are comatose

Though relatively uncommon overall (0.5% of all brain injuries), epidural haematomas occur in 9% of comatose patients with traumatic brain injury. The other statements are all correct.

American College of Surgeons (2012). *Advanced Trauma Life Support (ATLS) Student Course Manual*, 9th edn, Chapter 6. American College of Surgeons,

3. B. Maintain a low mean arterial blood pressure

Maintenance of normal mean arterial blood pressure (MAP) is necessary. The primary goal of treatment for patients with suspected traumatic brain injury is to prevent secondary brain injury. Providing adequate oxygenation and maintaining blood pressure at a level that is sufficient to perfuse the brain are the most important ways to limit secondary brain damage.

Cerebral perfusion pressure (CPP) = MAP – intracranial pressure (ICP)

Elevation of ICP can reduce cerebral perfusion and cause or exacerbate ischaemia, especially where MAP is reduced. The normal ICP in the resting state is approximately 10 mmHg. Pressures greater than 20 mmHg, particularly if sustained and refractory to treatment, are associated with poor outcomes.

American College of Surgeons (2012). *Advanced Trauma Life Support (ATLS) Student Course Manual*, 9th edn, Chapter 6. American College of Surgeons,

4. A. Fluid resuscitation in children should start with an isotonic fluid bolus of 50 ml/kg

The current (ninth) edition of the ATLS Manual recommends that fluid resuscitation be commenced with an isotonic fluid bolus of 20 ml/kg. A diminution in circulating blood volume of up to 30% may be required to manifest a decrease in the child's systolic blood pressure. Tachycardia and poor skin perfusion are often the only keys to early recognition of hypovolaemia. Although a child's primary response to hypovolaemia is tachycardia, this sign also may be caused by pain, fear, or psychological stress. A decrease in blood pressure and other indices of inadequate organ perfusion, such as urinary output, should be monitored closely, but generally develop later.

American College of Surgeons (2012). *Advanced Trauma Life Support (ATLS) Student Course Manual*, 9th edn, Chapter 10. American College of Surgeons,

5. A. Initial plantar sensation is prognostic of long-term functional outcome and should be a component of a limb-salvage decision algorithm

Five hundred and twenty-seven eligible patients between the ages of 16 and 69 with Gustilo-type IIIB and IIIC tibial fractures, avascular limbs resulting from trauma, type IIIB ankle fractures, or severe open midfoot or hindfoot injuries were included in the LEAP study. This study included a subset of 55 patients with an insensate foot at presentation. Twenty-nine of these patients underwent limb salvage. More than half of this group ultimately regained sensation by 2 years. The LEAP Study Group concluded that initial plantar sensation is *not* prognostic of long-term plantar sensory status or functional outcomes and should not be a component of a limb-salvage decision algorithm. Options B–E are all conclusions of the various publications of LEAP study groups.

Bosse MJ, McCarthy ML, Jones AL, et al. (2005). Lower Extremity Assessment Project (LEAP) Study Group. The insensate foot following severe lower extremity trauma: an indication for amputation? *J Bone Joint Surg Am*, 87, 2601–2608.

6. E. Treatment with narcotic medication during the first 3 months

Chronic pain is significantly more common following severe lower extremity trauma than in the general population. The LEAP Study Group identified that less than a high school education and low self-efficacy for return to usual major activities were significant risk factors for developing chronic pain. The LEAP Study Group suggested that these high-risk patients may benefit from early referral to pain management, as patients treated with narcotic medication during the first 3 months post-discharge had lower levels of chronic pain at 7 months. They may also benefit from psychological evaluation and treatment.

Castillo RC, MacKenzie EJ, Wegener ST, Bosse MJ; LEAP Study Group (2006). Prevalence of chronic pain seven years following limb threatening lower extremity trauma. *Pain*, 124, 321–329.

7. C. Current smokers are approximately five times more likely to develop an infection than non-smokers

Patients in the current smokers group were twice as likely to develop an infection and 3.7 times more likely to develop osteomyelitis than non-smokers. Previous smokers were at no greater risk of other infections but were still 2.8 times more likely to develop osteomyelitis than non-smokers.

Castillo RC, Bosse MJ, MacKenzie EJ, Patterson BM; LEAP Study Group (2005). Impact of smoking on fracture healing and risk of complications in limb-threatening open tibia fractures. *J Orthop Trauma*, 19, 151–157.

8. D. Log roll the patient to examine the spine for associated injuries

Log rolling a patient with a potentially unstable pelvic ring injury is contraindicated. This risks mechanical disturbance to the clot that has formed in the retroperitoneum. This clot will contain a large proportion of the body's clotting factors and platelets, meaning there is low reserve for the formation of a further clot. A retrograde urethrogram would not be considered in the primary survey; however, an examination of the perineum for open injuries and ecchymosis must be carried out and documented.

American College of Surgeons (2012). *Advanced Trauma Life Support (ATLS) Student Course Manual*, 9th edn, Chapter ?. American College of Surgeons,

9. D. 41

The ISS is a system that provides an overall score for patients with multiple injuries. Each injury is assigned an AIS score from 1 (minor) to 6 (not survivable) and is allocated to one of six body regions (head, face, chest, abdomen, extremities and pelvis, external). Only the single highest AIS score in each body region is used. The three most severely injured body regions have their score squared and added together to produce the ISS score. Scores range from 0 to 75 ($5^2 + 5^2 + 5^2$), but if any body region has an AIS of 6 (not survivable) then the ISS is automatically given as 75. Major trauma is usually defined as an ISS of greater than 15. In this case the three most severely injured regions are the chest, abdomen, and extremities, giving an ISS of $4^2 + 4^2 + 3^2 = 41$.

Baker SP, O'Neill B, Haddon W Jr, Long WB (1974). The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*, 14, 187–196.

10. C. 29

The MISS is a trauma scoring system for paediatric patients. It operates along similar lines to the ISS but with five body regions (neurological, face and neck, chest, abdomen and pelvic contents, extremities and pelvic girdle) scored from 1 (minor) to 5 (critical with uncertain survival). As with the ISS, the total score is the sum of the squares of the three most severely injured body regions. For MISS scores greater than 40 mortality is 50%, and for scores greater than 50 mortality is 75%. In this case a GCS of 14 would give a neurological score of just 1, so the three most severely injured regions are face and neck, extremities, and abdomen, giving a MISS of $4^2 + 3^2 + 2^2 = 29$.

Mayer T, Matlak ME, Johnson DG, Walker ML (1980). The modified injury severity scale in pediatric multiple trauma patients. *J Pediatr Surg*, 15, 719–726.

11. D. Ipsilateral tibial fracture

Early stabilization of long bone fractures is beneficial, but in certain situations damage control surgery with external fixation and later conversion to intramedullary nailing might be indicated. This may be considered in situations where both femurs are fractured or where the patient's physiology is clearly impaired, as demonstrated by an altered base excess or lactate. It should also be considered if other injuries are present that might be impacted by intramedullary nailing, such as head and chest injuries. An ipsilateral tibial fracture as an isolated finding would not necessarily require temporising fixation, but may be a relative indication for a retrograde femoral nail.

Brumback RJ, Virkus WW (2000). Intramedullary nailing of the femur: reamed versus nonreamed. *J Am Acad Orthop Surg*, 8, 83–90.

Canadian Orthopaedic Trauma Society (2003). Nonunion following intramedullary nailing of the femur with and without reaming. Results of a multicenter randomized clinical trial. *J Bone Joint Surg Am*, 85-A, 2093–2096.

12. A. Cemented hemiarthroplasty on the next routine trauma list

Non-operative management is associated with high morbidity and a low chance of regaining independent mobility. A recent trial in nonagenarians found similar mortality in both groups, but better function in those who received surgery. Surgery should be the default option, even if only for palliation of pain. NICE guidance recommends arthroplasty for displaced intracapsular fractures in elderly patients. As this patient has a low level of functional demand, total hip arthroplasty is inappropriate. NICE further recommends that, when considering arthroplasty, implants should be cemented. Uncemented (e.g. an Austin Moore prosthesis) designs have a higher rate of pain, loosening, and need for revision. There is no increase in 30-day mortality with the use of cemented implants and functional outcomes are better with cemented systems.

Handoll HHG, Parker MJ (2008). Conservative versus operative treatment for hip fractures in adults. *Cochrane Database Syst Rev*, 3: CD000337.

National Institute for Health and Care Excellence (NICE) (2011). Hip fracture: the management of hip fracture in adults. *NICE Guideline CG124*. https://www.nice.org.uk/guidance/cg124

Ooi LH1, Wong TH, Toh CL, Wong HP (2005). Hip fractures in nonagenarians—a study on operative and non-operative management. *Injury*, 36, 142–147.

Parker MI1, Pryor G, Gurusamy K (2010). Cemented versus uncemented hemiarthroplasty for intracapsular hip fractures: a randomised controlled trial in 400 patients. *J Bone Joint Surg Br*, 92, 116–122.

13. B. Up to 34%

The incidence of unstable spine injuries in unconscious patients with significant blunt trauma is 34%. The British Orthopaedic Association has issued guidance on spinal clearance in the trauma patient (BOAST 2).

British Orthopaedic Association (2008). BOAST 2: Spinal clearance in the trauma patient. https://www.boa.ac.uk/wp-content/uploads/2014/05/BOAST-2-Spinal-clearance-in-the-Trauma-Patient.pdf

14. C. Not more than 48 hours

The spine should not be immobilised for more than 48 hours; by this time three-point stabilisation should be removed and a definitive management plan actioned. The British Orthopaedic Association has issued guidance on spinal clearance in the trauma patient (BOAST 2).

British Orthopaedic Association (2008). BOAST 2: Spinal clearance in the trauma patient. https://www.boa.ac.uk/wp-content/uploads/2014/05/BOAST-2-Spinal-clearance-in-the-Trauma-Patient.pdf

15. B. MRI

MRI is the imaging technique of choice in all patients with suspected spinal cord injury. The British Orthopaedic Association has issued guidance on spinal clearance in the trauma patient (BOAST 2).

British Orthopaedic Association (2008). BOAST 2: Spinal clearance in the trauma patient. https://www.boa.ac.uk/wp-content/uploads/2014/05/BOAST-2-Spinal-clearance-in-the-Trauma-Patient.pdf

16. E. Urgent closed reduction and assessment of hip stability post-reduction

Hip dislocations must be reduced urgently and then an assessment of stability recorded. The neurovascular status before and after reduction must be documented. Skeletal traction should then be applied. If the hip remains irreducible or unstable, then urgent advice should be sought from a specialist in acetabular reconstruction and immediate transfer should be considered. Following reduction a CT scan must be done within 24 hours to exclude bony entrapment and to assess hip congruence and the extent of any fracture. If the hip is stable and the joint is congruent then surgery may not be required. The British Orthopaedic Association has issued guidance on the management of patients with pelvic and acetabular fractures (BOAST 3).

British Orthopaedic Association (2008). BOAST 3: pelvic and acetabular fracture management. https://www.boa.ac.uk/wp-content/uploads/2014/12/BOAST-3.pdf

Grimshaw CS, Moed BR (2010). Outcomes of posterior wall fractures of the acetabulum treated nonoperatively after diagnostic screening with dynamic stress examination under anesthesia. *J Bone Joint Surg Am*, 92, 2792–2800.

17. B. 6 hours of warm ischaemia

Six hours of warm ischaemia represents the amount of time it takes for irreversible ischaemic damage to occur in muscle tissue. The British Orthopaedic Association has issued guidance on the management of severe open lower limb fractures (BOAST 4).

British Orthopaedic Association (2009). BOAST 4: the management of severe open lower limb fractures. https://www.boa.ac.uk/wp-content/uploads/2014/12/BOAST-4.pdf

18. D. Co-amoxiclav and gentamicin

Augmentin plus gentamicin should be administered at the time of debridement. Vancomycin should be given at skeletal stabilization. The British Orthopaedic Association has issued guidance on the management of severe open lower limb fractures (BOAST 4).

British Orthopaedic Association (2009). BOAST 4: the management of severe open lower limb fractures. https://www.boa.ac.uk/wp-content/uploads/2014/12/BOAST-4.pdf

19. C. 72 hours or until definitive wound closure (whichever is sooner)

Antibiotics can be stopped once the wound is closed: 72 hours is the alternative but wounds should be covered (thus closed) by this time. The British Orthopaedic Association has issued guidance on the management of severe open lower limb fractures (BOAST 4).

British Orthopaedic Association (2009). BOAST 4: the management of severe open lower limb fractures. https://www.boa.ac.uk/wp-content/uploads/2014/12/BOAST-4.pdf

20. A. Acute stroke

NICE has issued clinical guidelines (CG92) and quality standards (QS3) on VTE. These detail the preventative measures against VTE for all adults on hospital admission.

National Institute for Health and Care Excellence (NICE) (2010). Venous thromboembolism: reducing the risk of venous thromboembolism (deep vein thrombosis and pulmonary embolism) in patients admitted to hospital. *NICE Guideline CG92*. https://www.nice.org.uk/guidance/cg92

National Institute for Health and Care Excellence (NICE) (2010). Venous thromboembolism prevention quality standard. *NICE Quality Standard QS3*. https://www.nice.org.uk/guidance/qs3

chapter

3

SPINAL TRAUMA

Questions

1. A 44-year-old electrician falls from a ladder and suffers an isolated L4 fracture. There is anterior wedging of the vertebral body with 40% loss of vertebral height. Which of these associated features would be an indication for operative stabilization?

Select the single most appropriate answer.

A. Injury to the posterior ligamentous complex on MRI
B. Kyphosis of 15°
C. Left leg radiculopathy since the injury
D. Middle column fracture
E. Retropulsion of a vertebral body fragment reducing the spinal canal by 35% with no neurological deficit

2. A 57-year-old woman falls from a stepladder and lands on her head suffering an isolated Anderson type II (Jefferson) C1 burst fracture. Which of the following is the maximum combined lateral displacement of the lateral masses on an open mouth radiograph or CT before it is deemed unstable?

Select the single most appropriate answer.

A. 2.9 mm
B. 4.9 mm
C. 6.9 mm
D. 8.9 mm
E. 10.9 mm

3. A 25-year-old male motorcyclist is involved in a crash. He has amnesia, a GCS of 14, and neck pain. He is appropriately resuscitated and immobilized using ATLS protocols. He is moving all four limbs and is haemodynamically stable with no other obvious injuries. His C-spine CT scan is reported as normal. What chance is there of a missed C-spine injury?

Select the single most appropriate answer.

A. 0.07%
B. 0.7%
C. 1.7%
D. 2.7%
E. 7%

4. A 26-year-old restrained male driver is involved in a high-speed car crash. He complains of back pain and is extricated from the vehicle with full spinal precautions. Plain radiographs and CT reveal an anterior column fracture of L1. He is haemodynamically stable with no other injuries. Examination reveals boggy tenderness around the thoracolumbar junction. Neurological examination is normal. Which of the following is the most appropriate next management step?

Select the single most appropriate answer.

A. Flexion and extension radiographs of the thoracolumbar spine
B. Long segment posterior stabilization
C. Mobilization in a brace
D. MRI
E. Repeat CT after mobilizing

5. Which of the following is the most important initial management step to minimize secondary damage following spinal cord injury?

Select the single most appropriate answer.

A. Administration of methylprednisolone
B. Administration of tirilazad mesylate
C. Maintenance of MAP over 70 mmHg
D. Maintenance of MAP over 90 mmHg
E. Surgical decompression and stabilization within 48 hours

6. A patient who sustained injuries in a motorcycle accident 30 minutes ago has significant motor and sensory deficits corresponding to a C6 level of injury. A lateral radiograph obtained during the initial on-scene evaluation reveals bilateral jumped facets at C5-C6; this appears to be an isolated injury. The patient is awake and alert. Which of the following should be the next step in management of the dislocation?

Select the single most appropriate answer.

A. Immediate anterior discectomy and fusion
B. Immediate posterior surgical reduction and stabilization
C. MRI
D. Reduction in Gardner–Wells tongs with serial traction
E. Rigid collar immobilization until spinal shock resolves

7. According to current evidence, which of the following is the most appropriate initial treatment for 75-year-old with a minimally displaced type II odontoid peg fracture?

Select the single most appropriate answer.

A. Anterior screw fixation
B. Halo vest application
C. Occipitocervical fusion
D. Padded rigid cervical orthosis (hard collar)
E. Posterior C1/2 fusion

8. When treating thoracolumbar spine fractures, which of the following is considered the major advantage of using a thoracolumbosacral orthosis (TLSO) compared with a three-point fixation brace (Jewett)?

Select the single most appropriate answer.

A. Cost
B. Greater flexion and extension control
C. Greater rotational control
D. Less force on the lumbosacral junction
E. Patient compliance

chapter 3

SPINAL TRAUMA

Answers

1. A. Injury to the posterior ligamentous complex on MRI

Thoracolumbar fractures can be classified according to Denis' three-column theory in combination with the mechanism of injury. Although a two-column injury burst fracture does not necessitate operative stabilization (even with retropulsed fragments), it has been shown that disruption of the posterior ligamentous complex has a high risk of progressing to a late kyphosis with a poor outcome. Neurological deficit, height loss of more than 50%, and kyphosis greater than 20° are predictors of instability which require surgical intervention. However, more recent studies have shown that, in addition, the posterior ligamentous complex (PLC) is vital in determining the stability of these types of fractures and whether patients are likely to develop post-traumatic kyphosis with poor outcomes including neurological deficits. Absolute indications for surgical intervention in thoracolumbar burst fractures are progressive neurological deficit, cauda equina syndrome, and significant spinal instability despite bracing.

Alaney A, Yazici M, Acaroglu E, Turhan E, Cila A, Surat A (2004). Course of nonsurgical management of burst fractures with intact posterior ligamentous complex: an MRI study. *Spine*, 29, 2425–2431.

Dai LY, Wang XY, Jiang LS (2007). Neurologic recovery from thoracolumbar burst fractures: Is it predicted by the amount of initial canal encroachment and kyphotic deformity? *Surg Neurol*, 67, 232–238.

Hashimoto T, Kaneda K, Abumi K (1988). Relationship between traumatic spinal canal stenosis and neurologic deficits in thoracolumbar burst fractures. *Spine*, 13, 1268–1272.

Oner FC, van Gils AP, Dhert WJ, Verbout AJ (1999). MRI findings of thoracolumbar spine fractures: a categorisation based on MRI examinations of 100 fractures. *Skeletal Radiol*, 28, 433–443.

Weninger P, Schultz A, Hertz H (2009). Conservative management of thoracolumbar and lumbar spine compression and burst fractures: functional and radiographic outcomes in 136 cases treated by closed reduction and casting. *Arch Orthop Trauma Surg*, 129, 207–219.

Wood K, Butterman G, Mehbod A, et al. (2003). Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit: A prospective, randomized study. *J Bone Joint Surg Am*, 85-A, 773–781.

2. C. 6.9 mm

The transverse ligament confers stability to the C1/2 articulation. It attaches to the medial aspects of the lateral masses of C1 and prevents posterior displacement of the C2 odontoid peg relative to the anterior arch of C1. During a type II injury, it is progressively tensioned until failure. Biomechanical studies have found that once a combined lateral displacement of 7 mm or more occurs there will be further lateral displacement despite immobilization as the transverse ligament has ruptured. These unstable injuries cause long-term quality-of-life problems for patients, especially those with significant displacement or associated injuries.

Bransford R, Falicov A, Nguyen Q, Chapman J (2009). Unilateral C1 lateral mass sagittal split fracture: an unstable Jefferson fracture variant. *J Neurosurg Spine*, 10, 466–473.

Dvorak MF, Johnson MG, Boyd M, Johnson G, Kwon BK, Fisher CG (2005). Long-term health related quality of life outcomes following Jefferson type burst fractures of the atlas. *J Neurosurg Spine*, 2, 411–417.

Gehweiler JA, Duff DE, Martinez S, et al. (1976). Fractures of the atlas vertebra. *Skeletal Radiol*, 1, 97–102.

Koller H, Kammermeier V, Ulbricht D, et al. (2006). Anterior retropharyngeal fixation C1/2 for stabilisation of atlantoaxial instabilities: Study of feasibility, technical description and preliminary results. *Eur Spine J*, 15, 1326–1338.

Kontautas E, Ambrozaitis KV, Kalesinkas RJ, Spakauskas B (2005). Management of acute traumatic atlas fractures. *J Spinal Disord Tech*, 18, 402–405.

Spence KF Jr, Decker S, Sell KW (1970). Bursting atlantal fractures associated with rupture of the transverse ligament. *J Bone Joint Surg Am*, 52, 543–549.

3. B. 0.7%

Although MRI has a 100% negative predictive value and has a sensitivity and specificity of 97.2% and 98.5%, respectively, its use in the acute trauma setting is limited due to concerns over incompatibility of resuscitation kit, risks of haemodynamic instability whilst being imaged, other stabilization devices (in polytrauma), access, and availability. The role of CT is now well established in the acute trauma setting, and even though 0.7% of injuries may be missed these required no or minimal treatment. Should clinical suspicion warrant an MRI, then it may be performed at a later more appropriate time.

Anderson PA, Gugala Z, Lindsey RW, Schoenfeld AJ, Harris MB (2010). Clearing the cervical spine in the blunt trauma patient. *J Am Acad Orthop Surg*, 18, 149–159.

British Orthopaedic Association (2008). BOAST 2: Spinal clearance in the trauma patient. https://www.boa.ac.uk/wp-content/uploads/2014/05/BOAST-2-Spinal-clearance-in-the-Trauma-Patient.pdf

Brown CV, Antevil JL, Sise MJ, Sack DI (2005). Spiral computed tomography for the diagnosis of cervical, thoracic and lumbar spine fractures: its time has come. *J Trauma*, 58, 890–896.

Holmes JF, Akkinepalli R (2005). Computed tomography versus plain radiography to screen for cervical spine injury: a meta-analysis. *J Trauma*, 58, 902–905.

Muchow RD, Resnick DK, Abdel MP, Munoz A, Anderson PA (2008). Magnetic resonance imaging (MRI) in the clearance of the cervical spine in blunt trauma: a meta-analysis. *J Trauma*, 64, 179–189.

4. D. MRI

Flexion–distraction injuries of the thoracolumbar junction are associated with a 25% chance of neurological injury and 30% chance of associated abdominal injury. The axis of rotation with this mechanism of injury is anterior to the vertebral body. This can cause a distraction injury to the middle and posterior elements. In particular, the posterior ligamentous complex may be disrupted allowing dislocation of the facets with instability and the risk of significant neurological damage. Although CT and radiographs may show increased an interspinous space, MRI is the most sensitive and most specific technique and has the best negative predictive value in ascertaining whether these injuries are unstable.

Chapman JR, Agel J, Jurkovich GJ, Bellabarba C (2008). Thoracolumbar flexion-distraction injuries: associated morbidity and neurological outcomes. *Spine*, 33, 648–657.

Lee HM, Kim HS, Kim DJ, Suk KS, Park JO, Kim NH (2000). Reliability of magnetic resonance imaging in detecting posterior ligament complex injury in thoracolumbar spinal fractures. *Spine*, 25, 2079–2084.

Tezer M, Ozturk C, Aydogan M, Mirzanli C, Talu U, Hamzaoglu A (2005). Surgical outcome of thoracolumbar burst fractures with flexion–distraction injury of the posterior elements. *Int Orthop*, 29, 347–350.

5. D. Maintenance of MAP over 90 mmHg

Although many chemical, cytological, and immunological factors are being and have been investigated, the most important factor in minimizing secondary spinal cord injury is maintaining MAP above 90 mmHg. Spinal cord perfusion is related to MAP and intrathecal (cerebrospinal fluid, CSF) pressure. The National Acute Spinal Cord Injury Study (NASCIS) trials showed no overall benefit from steroids. Although early studies have shown the potential of stem cells and olfactory ensheathing cells (OECs), there is currently not enough evidence to support their use. It should also be noted that the recent Surgical Treatment of Acute Spinal Cord Injury Study (STASCIS) showed benefit of acute decompression within 24 hours in most subsets of patients. Previous theories had suggested that decompressing the cervical spine could be adding a further secondary injury to the spinal cord. Decompression should be supplemented with stabilization.

Bracken MB, Shepard MJ, Hellenbrand KG, et al. (1985). Methylprednisolone and neurologic function 1 year after spinal cord injury: results of the National Acute Spinal Cord Injury Study [NASCIS I]. *J Neurosurg*, 63, 704–713.

Bracken MB, Shepard MJ, Collins WF Jr, et al. (1992). Methylprednisolone or naloxone treatment after acute spinal cord injury: 1 year follow up data. Results of the second National Acute Spinal Cord Injury Study [NASCIS II]. *J Neurosurg*, 76, 23–31.

Bracken MB, Shepard MJ, Holford TR, et al. (1997). Administration of methylprednisolone for 24 or 48 hours or tirizalad mesylate for 48 hours in the treatment of acute spinal cord injury: results of the Third National Acute Spinal Cord Injury Randomized Controlled Trial [NASCIS III]. *J Am Med Assoc*. 277, 1597–1604.

Fehlings MG, Vaccaro A, Wilson JR, et al. (2012). Early versus delayed decompression for traumatic cervical spinal cord injury: results of the surgical Timing in Acute Spinal Cord Injury Study (STASCIS). *PLoS One*, 7, e32037. doi:10.1371/journal.pone.0032037

Lenehan B, Fisher CG, Vaccaro A, Fehlings M, Aarabi B, Dvorak MF (2010). The urgency of surgical decompression in acute central cord injuries with spondylosis and without instability. *Spine*, 35(21, Suppl.), S180–S186.

Rowland JW, Hawryluk GW, Kwon B, Fehlings MG (2008). Current status of acute spinal cord injury pathophysiology and emerging therapies: promise on the horizon. *Neurosurg Focus*, 25, E2.

Vaccaro AR, Daugherty RJ, Sheehan TP, et al. (1997). Neurological outcome of early versus late surgery for cervical spinal cord injury. *Spine*, 22, 2609–2613.

6. D. Reduction in Gardner–Wells tongs with serial traction

Surgical open reduction may increase the neurological deficit if a disc herniation exists. Evidence from animal studies suggests that rapid decompression of the spinal cord may improve recovery. Serially increasing traction weight to reduce the dislocation has been shown to be safe when used in patients who are awake. Indications for MRI include patients who are unable to cooperate with serial examinations, the need for open reduction, and progression of deficit during awake reduction.

Delamarter RB, Sherman J, Carr JB (1995). Pathophysiology of spinal cord injury: recovery after immediate and delayed decompression. *J Bone Joint Surg Am*, 77, 1042–1049.

Eismont FJ, Arena MJ, Green BA (1991). Extrusion of an intervertebral disc associated with traumatic subluxation or dislocation of cervical facets: case report. *J Bone Joint Surg Am*, 73, 1555–1560.

Star AM, Jones AA, Cotler JM, Balderston RA, Sinha R (1990). Immediate closed reduction of cervical spine dislocations using traction. *Spine*, 15, 1068–1072.

7. D. Padded rigid cervical orthosis (hard collar)

Although there is evidence that in many young patients surgery is the most appropriate form of treatment, it has is also been found that the morbidity and mortality associated with surgery in the *elderly* outweighs the potential risks of non-union, including late-onset myelopathy and subsequent falls causing catastrophic fatal spinal cord injury. Elderly patients with type II odontoid peg fractures should initially be immobilized in an appropriate padded hard collar. Radiographs should be performed within a few days to ensure that significant displacement of the fragment (>50%) does not occur. Should this happen, then other options should be discussed with the patient, including occipitocervical fusion.

Anderson LD, D'Alonzo RT (1974). Fractures of the odontoid process of the axis. *J Bone Joint Surg Am*, 56, 1663–1674.

Bednar DA, Parikh J, Hummel J (1995). Management of type II odontoid process fractures in geriatric patients: a prospective study of sequential cohorts with attention to survivorship. *J Spinal Disord*, 8, 166–169.

Chapman J, Bransford R (2007). Geriatric spine fractures: an emerging healthcare crisis. *J Trauma*, 62(6, Suppl.), S61–S62.

Grauer JN, Shafi B, Hilibrand AS, et al. (2005). Proposal of a modified treatment-oriented classification of odontoid fractures. *Spine J*, 5, 123–129.

Julien TD, Frankel B, Traynelis VC, Ryken TC (2000). Evidence based analysis of odontoid fracture management. *Neurosurg Focus*, 8(6), e1.

Koivikko MP, Kiuru MJ, Koskinen SK, Myllynen P, Santavirta S, Kivisaari L (2004). Factors associated with non-union in conservatively treated type II fractures of the odontoid process. *J Bone Joint Surg Br*, 86, 1146–1151.

Nourbakhsh A, Shi R, Vannemreddy P, Nanda A (2009). Operative versus nonoperative management of acute odontoid type II fractures: a meta-analysis. *J Neurosurg Spine*, 11, 651–658.

8. C. Greater rotational control

When treating thoracolumbar spine fractures, the major advantage of using the TLSO is greater rotational control.

Chapman JR, Agel J, Jurkovich GJ, Bellabarba C (2008). Thoracolumbar flexion-distraction injuries: associated morbidity and neurological outcomes. *Spine*, 33, 648–657.

Weninger P, Schultz A, Hertz H (2009). Conservative management of thoracolumbar and lumbar spine compression and burst fractures: functional and radiographic outcomes in 136 cases treated by closed reduction and casting. *Arch Orthop Trauma Surg*, 129, 207–219.

Wood K, Butterman G, Mehbod A, et al. (2003). Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit: a prospective, randomized study. *J Bone Joint Surg Am*, 85-A, 773–781.

chapter 4

UPPER LIMB—SHOULDER, HUMERUS, AND ELBOW

Questions

1. Which of the following features is associated with humeral head ischaemia after a proximal humerus fracture?

Select the single most appropriate answer.

A. Dislocation of the glenohumeral joint
B. Greater tuberosity displacement > 2 cm
C. Length of metaphyseal head extension < 8 mm
D. Maintenance of the medial periosteal hinge
E. Valgus impaction of the humeral head

2. Which of the following is not an indication for fixation of a humeral shaft fracture?

Select the single most appropriate answer.

A. A patient with large breasts
B. Distal third fractures
C. Floating elbow
D. Open fracture
E. Rotator cuff injury

3. A 60-year-old woman slips, sustaining a comminuted intra-articular distal humeral fracture. Which of the following represents the best fixation construct?

Select the single most appropriate answer.

A. Open reduction internal fixation with perpendicular third tubular plates
B. Open reduction internal fixation with plating and an independent lag screw
C. Open reduction internal fixation with plating and a lag screw through the plate
D. Percutaneous lag screw fixation of major fragments
E. Percutaneous wire fixation of major fragments

4. A 35-year-old man falls whilst playing basketball. He sustains a closed fracture dislocation of his right elbow. The elbow is reduced in the emergency department. Radiographs and CT scan demonstrate a type II coronoid fracture and a two-part Mason 4 radial head fracture. Which of the following is the most appropriate management for the radial head element of this injury?

Select the single most appropriate answer.

A. Open reduction and internal fixation with buried compression screws ± a low-profile plate onto the radial neck in the safe zone
B. Radial head arthroplasty using a modular metal press-fit design with care not to over-stuff the joint.
C. Radial head excision and medial ulna collateral ligament repair
D. Radial head excision and silicon interposition (Swanson) arthroplasty
E. Trans-capitellar wire fixation of the radial head to the neck and immobilization in a cast for 4 weeks

5. Which of the following manoeuvres is most important when treating a Monteggia fracture dislocation of the proximal forearm?

Select the single most appropriate answer.

A. Application of a dynamic external brace to allow for early range of movement exercises
B. Obtaining a CT scan to identify the cause of the dislocation
C. Open reduction and internal fixation of the proximal ulna fracture
D. Reduction of the radius and temporary fixation with a K-wire
E. Use of an unlocked nail to fix the ulna fracture

6. What would a fracture of the ulna with lateral dislocation of the radial head be classified as?

Select the single most appropriate answer.

A. Bado type I
B. Bado type IIa
C. Bado type IIb
D. Bado type III
E. Bado type IV

7. Which of the following is not a relative indication for the surgical management of glenoid and scapula fractures?

Select the single most appropriate answer.

A. Angular deformity of the scapula body in the scapular Y view > 45°
B. Displaced double disruption of the 'superior shoulder suspensory complex' (SSSC)
C. Intra-articular step-off > 4 mm
D. Medial displacement of the of the lateral border > 25 mm
E. Reduction of the glenopolar angle to < 40°

8. A 25-year-old rugby player injures his right shoulder during a tackle. A deformity is noticed at his acromioclavicular joint (ACJ). He is taken to accident and emergency (A&E) and diagnosed with a Rockwood type V ACJ dislocation. Which of the following structures has/have been injured?

Select the single most appropriate answer.

A. Acromioclavicular ligament
B. Conoid coracoclavicular ligament
C. Deltotrapezial fascia
D. Trapezoid ligament
E. All of the above

9. Which of the following tests suggests a significant anterior bony lesion causing instability?

Select the single most appropriate answer.

A. Apprehension at 90° abduction and 90° external rotation
B. Apprehension at 90° abduction and 45° external rotation
C. Apprehension at 45° abduction and 45° external rotation
D. Apprehension at 90° Forward flexion and 45° internal rotation
E. Apprehension at 90° abduction and 45° internal rotation

chapter 4

UPPER LIMB—SHOULDER, HUMERUS, AND ELBOW

Answers

1. C. Length of metaphyseal head extension < 8 mm

Hertel evaluated predictors of fracture-induced humeral head ischaemia. One hundred intracapsular fractures of the proximal humerus treated by open surgery were classified using Codman's parts and perfusion was assessed intra-operatively by observation of backflow after a borehole was drilled into the central part of the head. Good predictors of ischaemia were metaphyseal head extension > 8 mm, the integrity of the medial hinge, and the basic fracture pattern. Moderate and poor predictors of ischaemia were fractures consisting of four fragments or more, angular displacement of the head, the amount of displacement of the tuberosities, glenohumeral dislocation, and head-split components.

Hertel R, Hempfing A, Stiehler M, Leunig M (2004). Predictors of humeral head ischemia after intracapsular fracture of the proximal humerus. *J Shoulder Elbow Surg*, 13, 427–433.

2. E. Rotator cuff injury

Indications for fixation include open humeral shaft fractures, fractures associated with certain radial nerve lesions, floating elbow injuries, patients with polytrauma, and patients with large breasts in whom varus deformity with closed management is commonplace. Even certain fracture patterns such as segmental injuries, as well as proximal and distal third fractures, are thought by some to be problematic with functional bracing and should therefore be treated with operative fixation.

Cole PA, Wijdicks CA (2007). The operative treatment of diaphyseal humeral shaft fractures. *Hand Clin*, 23, 437–448.

3. C. Open reduction internal fixation with plating and a lag screw through the plate

The use of screws or wires in isolation and also third tubular plates is generally considered to be insufficient to allow early active motion. Parallel plating is generally found to be the most stable construct in biomechanical and clinical studies.

Korner J, Diederichs G, Arzdorf M, et al. (2004). A biomechanical evaluation of methods of distal humerus fracture fixation using locking compression plates versus conventional reconstruction plates. *J Orthop Trauma*, 18, 286–293.

Stoffel K, Cunneen S, Morgan R, Nicholls R, Stachowiak G (2008). Comparative stability of perpendicular versus parallel double-locking plating systems in osteoporotic comminuted distal humeral fractures. *J Orthop Res*, 26, 778–784.

4. A. Open reduction and internal fixation with buried compression screws ± a low-profile plate onto the radial neck in the safe zone

Surgery is recommended in terrible triad injuries. It aims to restore the bony anatomy and then repair/reconstruct the ligaments in order to achieve an elbow that is stable enough for early movement to be initiated. Excision alone of the radial head is contraindicated in the presence of elbow instability, as the radial head is an important secondary stabilizer to valgus stress. Silicon spacers are rarely used due to synovitis complications. Ring and Jupiter's series demonstrated favourable outcomes of internal fixation of the radial head where the head fragment was in three pieces or fewer. Beyond this degree of comminution, outcomes of fixation were poor and replacement is advocated. Good short-term outcomes have been achieved with metal-head implants. Overstuffing is common and should be avoided.

McKee MD, Pugh DM, Wild LM, Schemitsch EH, King GJ (2005). Standard surgical protocol to treat elbow dislocations with radial head and coronoid fractures. Surgical technique. *J Bone Joint Surg Am*, 87(Suppl. 1, Pt 1), 22–32.

Moro JK, Werier J, MacDermid JC, Patterson SD, King GJ (2001). Arthroplasty with a metal radial head for unreconstructable fractures of the radial head. *J Bone Joint Surg Am*, 83-A, 1201–1211.

Ring D, Quintero J, Jupiter JB (2002). Open reduction and internal fixation of fractures of the radial head. *J Bone Joint Surg Am*, 84-A, 1811–1815.

5. C. Open reduction and internal fixation of the proximal ulna fracture

Anatomical reduction with internal fixation is crucial for this injury. In the majority of cases, if this has been performed correctly, the radial head should readily reduce and remain stable. If the radial head does not reduce after fixing the ulna, the most common cause is inadequate reduction of the ulna.

McKee MD, Pugh DM, Wild LM, Schemitsch EH, King GJ (2005). Standard surgical protocol to treat elbow dislocations with radial head and coronoid fractures. Surgical technique. *J Bone Joint Surg Am*, 87(Suppl. 1, Pt 1), 22–32.

Moro JK, Werier J, MacDermid JC, Patterson SD, King GJ (2001). Arthroplasty with a metal radial head for unreconstructable fractures of the radial head. *J Bone Joint Surg Am*, 83-A, 1201–1211.

Ring D, Quintero J, Jupiter JB (2002). Open reduction and internal fixation of fractures of the radial head. *J Bone Joint Surg Am*, 84-A, 1811–1815.

6. D. Bado type III

Bado originally classified Monteggia fracture dislocations. Type I is anterior dislocation of the radial head with apex anterior angulation of the ulna fracture. Type II is posterior dislocation of the radial head with apex posterior angulation of the ulna fracture. Type III is posterolateral dislocation of the radial head. Type IV is posterolateral dislocation of the radial head with a concurrent radial shaft fracture. Type II has been subdivided by Jupiter according to the location of the ulna fracture: IIa is at the level of the coronoid, IIb at the meta-diaphyseal junction, and IIc in the diaphysis.

Court-Brown CM, Heckman JD, McQueen MM, Ricci WM, Tornetta P III (eds) (2014). *Rockwood and Green's Fractures in Adults*, 8th edn. Wolters Kluwer, Philadelphia, PA.

Ring D, Jupiter J, Simpson S (1998). Monteggia fractures in adults. *J Bone Joint Surg Am*, 80-A, 1733–1744.

7. E. Reduction of the glenopolar angle to < 40°

With the exception of unstable or displaced glenoid fossa fractures, all surgical interventions should be considered relative given the lack of definitive proof regarding the benefits of surgery. The most recent explicit relative indications for surgical intervention in scapula fractures include medial displacement of the lateral border > 25 mm, angular deformity of the body > 45°, intra-articular step-off > 4 mm, and a double disruption of the SSSC. The glenopolar angle is the angle created at the intersection of a line drawn from the inferior glenoid fossa to the superior apex of the glenoid fossa and a line drawn from the superior apex of the glenoid fossa to the inferior angle of the scapula.

A reduction of the glenopolar angle to < 20° would be a relative indication for surgical intervention. Goss described the term the 'superior shoulder suspensory complex' to describe the osseoligamentous ring made up of the glenoid, coracoid, clavicle, and the acromion process as well as the connecting soft tissues between these structures: the coracoclavicular ligament and the acromioclavicular joint capsule.

Cole P, Gauger E, Schroder L (2012). Management of scapular fractures. *J Am Acad Orthop Surg*, 20, 130–141.

Goss T (1993). Double disruption of the superior shoulder suspensory complex. *J Orthop Trauma*, 7, 99–106.

Ideberg R, Grevsten S, Larsson S (1995). Epidemiology of scapular fractures. Incidence and classification of 338 fractures. *Acta Orthop Scand*, 66, 395–397.

Jones C, Cornelius J, Sietsema D, Ringler J, Endres T (2008). Modified Judet approach and minifragment fixation of scapular body and glenoid neck fractures. *J Orthop Trauma*, 22, 558–564.

8. E. All of the above

ACJ dislocations are classified based on both clinical examination and the axillary radiographs. The degree of damage to the acromioclavicular and the coracoclavicular ligaments as well as the deltoid and trapezius attachments are also considered. The most common classification is the Rockwood modification of the Allman and Tossy classification.

Rockwood CA, Williams GR, Youg DC (1998). Disorders of the acromioclavicular joint. In: CA Rockwood, FA Masten II (eds) *The Shoulder*, pp.483–553. Saunders, Philadelphia, PA.

9. C. Apprehension at 45° abduction and 45° external rotation

This is also known as the 'bony apprehension test'. Herring and colleagues performed a prospective study using this test. They found that the test was more sensitive than plain radiographs at predicting significant osseous lesions in those with anterior shoulder instability (sensitivity of 100%, specificity of 86%, positive predictive value of 73%, and negative predictive value of 100% for the test versus a sensitivity of 50%, specificity of 100%, positive predictive value of 100%, and negative predictive value of 84% for plain radiographs).

Bushnell BD1, Creighton RA, Herring MM (2008). The bony apprehension test for instability of the shoulder: a prospective pilot analysis. *Arthroscopy*, 24, 974–982.

chapter

5

UPPER LIMB—FOREARM, WRIST, AND HAND

Questions

1. When judging rotational alignment of the radius on an anteroposterior radiograph the radial tuberosity should lie in which orientation in relation to the radial styloid?

Select the single most appropriate answer.

A. Facing anteriorly
B. Facing away from the ulna
C. Facing posteriorly
D. Facing the ulna
E. There is wide variation between individuals

2. When judging rotational alignment of the ulna on a lateral radiograph, which of the following is the correct orientation of the ulnar styloid?

Select the single most appropriate answer.

A. 180° to the coronoid
B. 90° lateral to the coronoid
C. 90° medial to the coronoid
D. There is wide variation between individuals
E. The same orientation as the coronoid

3. In a Galeazzi fracture, at a maximum of what distance from the lunate fossa of the distal radius does the radius tends to fracture?

Select the single most appropriate answer.

A. 2.5 cm
B. 5 cm
C. 7.5 cm
D. 10 cm
E. 12.5 cm

4. In the ‘normal’ wrist what is the relative transfer of load between the distal radius and distal ulna?

Select the single most appropriate answer.

A. 80%:20%
B. 90%:10%
C. 70%:30%
D. 60%:40%
E. 50%:50%

5. Which structure is the chief stabilizer against longitudinal radioulnar migration after resection or multifragmentary fracture of the radial head?

Select the single most appropriate answer.

A. Annular ligament
B. Central band of the interosseous ligament
C. Distal radioulnar joint
D. Ulnohumeral articulation
E. Volar radiocarpal ligaments

6. Which of the following has been shown to be the most common complication after a Colles’ fracture?

Select the single most appropriate answer.

A. CRPS
B. Extensor pollicis longus (EPL) tendon rupture
C. Flexor pollicis longus (FPL) tendon rupture
D. Median nerve dysfunction
E. Volkmann’s ischaemic contracture

7. A 24-year-old man falls playing football and injures his wrist. He plays on, but the pain increases during the next 48 hours and he attends A&E. Radiographs show an undisplaced fracture of the waist of the scaphoid. He is to be referred to the fracture clinic, but what is the most appropriate initial treatment?

Select the single most appropriate answer.

A. Immobilization in a Futuro type splint with thumb extension
B. Immobilization in a simple forearm cast
C. Immobilization in a scaphoid cast (thumb included)
D. Immobilization in an above elbow cast
E. Immobilization in a basic Futuro type splint

8. Which of the following is not typical of a perilunate dislocation?

Select the single most appropriate answer.

A. Caused by falling 5 m from a ladder
B. Dorsal intercalated segment instability (DISI)
C. Median nerve compression symptoms
D. Swelling and loss of normal bony landmarks
E. Widening of the scapholunate gap

9. A 38-year-old car mechanic has sustained an open fracture of the shaft of the fifth metacarpal of his dominant hand. He has no comorbidities. Which of the following would be the most common cause of infection?

Select the single most appropriate answer.

A. Closure under tension
B. Early closure
C. Extensive soft tissue dissection
D. Failure to debride adequately
E. Use of a blunt wire or repeated passing of wire

10. A 25-year-old barman sustains a fracture of the neck of his fifth metacarpal. He has an angulation of 50° on a lateral view but you decide to manage it non-operatively. Which of the following statements best describes the rationale behind this approach?

Select the single most appropriate answer.

A. Malunion will be compensated by the relatively mobile fifth carpometacarpal joint
B. The patient will compensate with movement at the proximal interphalangeal (PIP) joint
C. These fractures have a good potential to remodel
D. There will be compensation at the metacarpophalangeal (MCP) joint of the index and middle fingers
E. There will be compensation at the wrist joint

11. Which of the following carpal bones can be harvested for a PIP joint reconstruction?

Select the single most appropriate answer.

A. Capitate
B. Hamate
C. Scaphoid pole
D. Trapezium
E. Triquetral

12. Which finger is most commonly involved in fingertip injuries?

Select the single most appropriate answer.

A. Index
B. Little
C. Middle
D. Ring
E. Thumb

13. Which of the following is an indication for removal of the nail for nail bed injuries?

Select the single most appropriate answer.

A. Haematoma of 20% of the nail bed
B. Haematoma of 30% of the nail bed
C. Haematoma of 40% of the nail bed
D. Haematoma of 50% of the nail bed
E. Haematoma of 70% of the nail bed

chapter

5

UPPER LIMB—FOREARM, WRIST, AND HAND

Answers

1. D. Facing the ulna

The radial tuberosity should face the ulna on the anteroposterior projection of the forearm.

Wheeless' Textbook of Orthopaedics. AP view of the wrist: http://www.wheelessonline.com/ortho/ap_view_of_the_wrist

Wheeless' Textbook of Orthopaedics. Posterior anterior view of the wrist: http://www.wheelessonline.com/ortho/posterior_anterior_view_of_the_wrist

2. A. 180° to the coronoid

On the lateral projection of the forearm the ulnar styloid faces the in opposite direction to the coronoid process.

Wheeless' Textbook of Orthopaedics. AP view of the wrist: http://www.wheelessonline.com/ortho/ap_view_of_the_wrist

Wheeless' Textbook of Orthopaedics. Posterior anterior view of the wrist: http://www.wheelessonline.com/ortho/posterior_anterior_view_of_the_wrist

3. C. 7.5 cm

This is known as the 7.5 cm rule. While not exclusive it tends to be true that fractures more proximal than the distal 7.5 cm of the radius do not result in distal radioulnar joint (DRUJ) instability. This is because some of the distal portion of the interosseous membrane remains intact, thus limiting the shortening necessary for DRUJ dislocation.

Moore TM, Lester DK, Sarmiento A (1985). The stabilizing effect of soft-tissue constraints in artificial Galeazzi fractures. *Clin Orthop Relat Res*, 194, 189–194.

Rettig ME, Raskin KB (2001). Galeazzi fracture-dislocation: A new treatment oriented classification. *J Hand Surg Am*, 26, 228–235.

4. A. 80%:20%

The radius normally carries 80% of the load of the forearm at the level of the wrist.

Kijima Y, Viegas S (2009). Wrist anatomy and biomechanics. *J Hand Surg*, 34, 1555–1563.

5. B. Central band of the interosseous ligament

The intraosseous membrane controls motion between the radius and the ulna.

Rozental TD, Beredjiklian PK, Bozentka DJ (2003). Longitudinal radioulnar dissociation. *J Am Acad Orthop Surg*, 11, 68–73.

6. D. Median nerve dysfunction

All these complications can occur, but median nerve dysfunction is extremely common.

Chen N, Jupiter J (2007). Management of distal radius fractures. *J Bone Joint Surg Am*, 89, 2051–2062.

7. B. Immobilization in a simple forearm cast

Stable undisplaced fractures are suitable for non-operative treatment. A Colles' type cast has been shown to be as effective as a scaphoid cast in achieving union with less morbidity and less inconvenience to the patient.

Clay NR, Dias JJ, Costigan PS, Gregg PJ, Barton NJ (1991). Need the thumb be immobilised in scaphoid fractures? A randomised prospective trial. *J Bone Joint Surg Br*, 73, 828–832.

8. B. Dorsal intercalated segment instability (DISI)

Perilunate dislocation is usually associated with high-energy trauma onto an outstretched hand. Swelling and bony deformity are common. Median nerve contusion or compression is common. The scapholunate is normally widened on radiographs as the scapholunate ligament is torn as the bones separate. The 'spilled teacup' sign refers to the volar tilt of the lunate seen on a lateral radiograph of a perilunate dislocation, so DISI is not usually associated with this injury.

Kozin S (1998). Perilunate injuries—diagnosis and treatment. *J Am Acad Orthop Surg*, 6, 114–120.

9. D. Failure to debride adequately

The risk of infection following open fractures with simple wounds is 1.4%. With crushing and contamination this increases to 14%. Several of the factors mentioned are related to an increased risk of infection but the most important factor is the failure to debride adequately.

Day C, Stern P (2011). Fractures of metacarpals and phalanges. In: SW Wolfe, WC Pederson, RN Hotchkiss, SH Kozin (eds) *Green's Operative Hand Surgery*, 6th edn, Vol. 1, pp.239–290. Churchill Livingstone,

10. A. Malunion will be compensated by the relatively mobile fifth carpometacarpal joint

The ring and small finger carpometacarpal (CMC) joints have 20–30° of mobility in the sagittal plane, whereas the index and middle CMC joints have less mobility. Hence angulation can be better compensated for in the ring and small fingers.

Day C, Stern P (2011). Fractures of metacarpals and phalanges. In: SW Wolfe, WC Pederson, RN Hotchkiss, SH Kozin (eds) *Green's Operative Hand Surgery*, 6th edn, Vol. 1, pp.239–290. Churchill Livingstone,

11. B. Hamate

The hamate can be harvested if needed.

Day C, Stern P (2011). Fractures of metacarpals and phalanges. In: SW Wolfe, WC Pederson, RN Hotchkiss, SH Kozin (eds) *Green's Operative Hand Surgery*, 6th edn, Vol. 1, pp.239–290. Churchill Livingstone,

12. C. Middle

Because the middle finger is the longest it has the highest incidence of nail tip injuries.

Sommer N, Brown R (2011). The perionychium. In: SW Wolfe, WC Pederson, RN Hotchkiss, SH Kozin (eds) *Green's Operative Hand Surgery*, 6th edn, Vol. 1, pp.339–350. Churchill Livingstone,

13. D. Haematoma of 50% of the nail bed

The indication for removal of a nail for nail bed injuries is a broken nail with disrupted edges or a haematoma affecting over 50% of the nail bed.

Sommer N, Brown R (2011). The perionychium. In: SW Wolfe, WC Pederson, RN Hotchkiss, SH Kozin (eds) *Green's Operative Hand Surgery*, 6th edn, Vol. 1, pp.339–350. Churchill Livingstone,

chapter 6

LOWER LIMB—PELVIS, HIP, FEMUR, KNEE, AND TIBIA

Questions

1. Disruption of the iliopectineal line on an anteroposterior radiograph suggests a fracture of which of the following structures of the acetabulum?

Select the single most appropriate answer.

A. Anterior column
B. Anterior wall
C. Posterior column
D. Posterior wall
E. Quadrilateral plate

2. Which of the following would be the preferred approach for a posterior column acetabular fracture?

Select the single most appropriate answer.

A. Extended iliofemoral
B. Ilioinguinal
C. Modified Moore (Southern)
D. Stoppa
E. Triradiate

3. A 45-year-old woman suffering from schizophrenia jumps from a motorway bridge approximately 20 m high. Her primary survey radiographs show a fracture dislocation of her right hip. After stabilization and a trauma series contrast CT, which of the following should be performed next?

Select the single most appropriate answer.

A. Application of skin traction from the end of the bed
B. Open reduction and internal fixation of the injuries on the next available list
C. Primary total hip replacement on the next available list
D. Urgent reduction and insertion of traction pin through the distal femur
E. Urgent reduction and insertion of a traction pin through the proximal tibia

4. Which of the following options represents the recommended tip to apex distance (TAD) and position of the lag screw in fixation of a pertrochanteric fracture of the proximal femur?

Select the single most appropriate answer.

A. Central and posterior, TAD < 25 mm
B. Central in both planes, TAD < 20 mm
C. Central in both planes, TAD < 25 mm
D. Inferior and central, TAD < 25 mm
E. Inferior and posterior, TAD < 20 mm

5. An 80-year-old woman who lives independently and walks with a stick falls and sustains a minimally displaced intracapsular fracture to the neck of her femur. How should she be treated?

Select the single most appropriate answer.

A. Closed reduction and internal fixation on the next available trauma list (>6 hours)
B. Hemiarthroplasty
C. Immediate closed reduction and internal fixation (<6 hours)
D. Mobilization as pain allows, with physical therapy and walking aids
E. Total hip replacement

6. Which of the following is not a risk factor for the development of avascular necrosis (AVN) after internal fixation of a fracture of the neck of the femur in a young patient?

Select the single most appropriate answer.

A. Age less than 60 years
B. Delayed time from injury to surgery
C. Female sex
D. Garden IV fracture
E. Near anatomical reduction prior to fixation

7. A 45-year-old woman was knocked over whilst shopping, sustaining a displaced intracapsular fracture to the neck of her femur. She has no known comorbidities, but is a smoker. Which of the following is the most likely cause of her fracture?

Select the single most appropriate answer.

A. Osteoporosis
B. Pathological—benign lesion
C. Pathological—malignant lesion
D. Stress fracture
E. Traumatic

8. Which of the following is not true for reamed femoral nails compared with unreamed nails?

Select the single most appropriate answer.

A. Decreased time to union
B. Higher rates of pulmonary complications
C. Higher rates of union
D. Increased intra-operative blood loss
E. Lower rates of malunion

9. Which of the following statements about the treatment of distal femoral fractures is accurate?

Select the single most appropriate answer.

A. If it occurs around a total knee replacement (TKR), treatment with a retrograde nail is easier in the presence of a cruciate-substituting design
B. Locked plates may improve construct stability in the presence of osteoporotic bone
C. Operative treatment generally results in high rates of successful union
D. Restoration of the distal femoral anatomical axis to 5–7° of varus leads to improved long-term outcomes
E. There is an increased incidence post-TKR in patients with excessive distal femoral resection

10. A patient sustains a fracture around a stable, previously well fixed femoral component of a total hip arthroplasty. The bone quality observed on initial radiographs appears to be adequate. How would you classify this fracture?

Select the single most appropriate answer.

A. A_G
B. B1
C. B2
D. B3
E. C

11. A 73-year-old woman falls and sustains a supracondylar fracture of her distal femur. Five years prior to her fall she had undergone a TKR on the ipsilateral side. Lewis and Rorabeck described a classification system for periprosthetic fractures of the knee: assuming this woman has a displaced periprosthetic fracture around a well-fixed, well-functioning arthroplasty how would her fracture be classified?

Select the single most appropriate answer.

A. A
B. B1
C. C
D. I
E. II

12. All the following statements about ligaments of the knee are true except which?

Select the single most appropriate answer.

A. The anterior cruciate ligament has two bundles: an anteromedial bundle that is tight in extension and a posterolateral bundle that is tight in flexion
B. The meniscofemoral ligaments run from the posterior horn of the lateral meniscus and either anterior (ligament of Humphrey) or posterior (ligament of Wrisberg) to the posterior cruciate ligament (PCL) before attaching to the medial femoral condyle
C. The PCL has two bundles: a posteromedial bundle that is tight in extension and an anterolateral bundle that is tight in flexion
D. The posterolateral corner consists of the lateral collateral ligament, the popliteal tendon complex, the popliteofibular ligament, and the posterolateral capsule
E. The superficial medial collateral ligament provides the primary restraint to a valgus force in 30° of knee flexion

13. The blood supply to the anterior cruciate ligament is derived from which vessel?

Select the single most appropriate answer.

A. Descending geniculate artery
B. Inferior geniculate artery
C. Middle geniculate artery
D. Recurrent branch of the anterior tibial artery
E. Superior geniculate artery

chapter

6

LOWER LIMB—PELVIS, HIP, FEMUR, KNEE, AND TIBIA

Answers

1. A. Anterior column

The iliopectineal line represents the anterior column and the ilioischial line the posterior column. Anterior and posterior wall lines are visible. The medial aspect of the acetabulum is represented by the teardrop and the weightbearing dome by the sourcil.

Matta JM (2003). Surgical treatment of acetabular fractures. In: BD Browner, JB Jupiter, AM Levine, PG Trafton (eds) *Skeletal Trauma: Basic Science, Management and Reconstruction*, 3rd edn. Elsevier Publishing, Amsterdam

2. C. Modified Moore (Southern)

The modified Moore (Southern) approach is also known as the Kocher–Langenbach approach and allows access to the posterior wall and posterior column of the acetabulum. Whilst in theory the extended iliofemoral and triradiate approaches would also allow access, they are much larger, with significant morbidity and complications. The ilioinguinal and stoppa approaches are anterior approaches.

Hoppenfeld S, Deboer P, Buckley R (2009). *Surgical Exposures in Orthopaedics: the Anatomic Approach*, 4th revised edn. Lippincott Williams and Wilkins, Philadelphia, PA.

3. D. Urgent reduction and insertion of traction pin through the distal femur

Urgent manipulation and reduction of the hip is necessary to avoid pressure on the sciatic nerve and reduce the chances of AVN as the capsular vessels remain kinked in the dislocated position. The traction pin through the distal femur is preferred to avoid ligamentotaxis on the knee ligaments.

British Orthopaedic Association (2008). BOAST 3: pelvic and acetabular fracture management. https://www.boa.ac.uk/wp-content/uploads/2014/12/BOAST-3.pdf

Matta JM (2003). Surgical treatment of acetabular fractures. In: BD Browner, JB Jupiter, AM Levine, PG Trafton (eds) *Skeletal Trauma: Basic Science, Management and Reconstruction*, 3rd edn. Elsevier Publishing, Amsterdam

4. D. Inferior and central, TAD < 25 mm

Accurate placement of the lag screw during fixation of proximal femoral fractures with a fixed angle sliding hip screw device is important to avoid failure and cut-out of the screw from the femoral head.

The TAD is the sum of the distance from the tip of the lag screw to the apex of the femoral head on the anteroposterior and lateral views. This distance was first described in 1995 by Baumgaertner and colleagues. No hip with a TAD of less than 25 mm cut out. Further work showed an average TAD of 20 mm had no failures when compared with those with a TAD > 25 mm. For this reason many trauma surgeons aim for a TAD of 20 mm even though the 'magic number' is 25 mm. The position of the screw within the head is recommended to be inferior and central.

Baumgaertner MR, Curtin SL, Lindskog DM, Keggi JM (1995). The value of the tip–apex distance in predicting failure of fixation of peritrochanteric fractures of the hip. *J Bone Joint Surg Am*, 77, 1058–1064.

Baumgaertner MR, Solberg BD (1997). Awareness of tip-apex distance reduces failure of fixation of trochanteric fractures of the hip. *J Bone Joint Surg Br*, 79, 969–971.

Haidukewych GJ (2010). Intertrochanteric fractures: ten tips to improve results. *Instr Course Lect*, 59, 503–509.

5. B. Hemiarthroplasty

This woman should be treated with a hip hemiarthroplasty with a proven implant other than an Austin Moore or Thompsons. A meta-analysis of 106 patients by Lu-Yao et al. showed a non-union rate associated with open reduction and internal fixation of 33% and an AVN rate of 16%. Parker et al. found that the need for further surgical intervention after fixation was significantly higher when compared with a similar group of patients treated with hemiarthroplasty (30% to 50% versus 6% to 18%). Total hip replacement should be reserved for patients who are younger than 75 years of age, who walk independently outside with no more than a stick, who are not cognitively impaired, and who are medically fit for anaesthesia and the procedure.

Chesser TJS, Handley R (2011). New NICE guideline to improve outcomes for hip fracture patients. *Injury*, 42, 727–729.

Lu-Yao GL, Keller RB, Littenberg B, Wennberg JE (1994). Outcomes after displaced fractures of the femoral neck. A meta-analysis of one hundred and six published reports. *J Bone Joint Surg Am*, 76, 15–25.

Parker MJ, Pryor G, Gurusamy K (2010). Hemiarthroplasty versus internal fixation for displaced intracapsular hip fractures: a long-term follow-up of a randomised trial. *Injury*, 41, 370–373.

6. B. Delayed time from injury to surgery

Loizou and Parker prospectively studied 1023 patients who were treated for an intracapsular fractured neck of the femur with some form of internal fixation. They found an increased risk of AVN with younger age, female sex, and displaced fractures. They found no association between the incidence of AVN and the interval between injury and surgery.

Loizou L, Parker J (2009). Avascular necrosis after internal fixation of intracapsular hip fractures; a study of the outcome for 1023 patients. *Injury*, 40, 1143–1146.

7. C. Pathological—malignant lesion

Karantana et al., in a study looking at hip fractures in women under the age of 65, found that 11% were pathological in origin compared with 1.4% in those aged over 65. The mortality of younger women with hip fracture was 46 times that of the background mortality of the female population. This study also found that a female patient under 65 was almost five times more likely to sustain a hip fracture if she was a smoker.

Karantana A, Boulton C, Bouliotis G, Shu KS, Scammell BE, Moran CG (2011). Epidemiology and outcome of fracture of the hip in women aged 65 years and under: a cohort study. *J Bone Joint Surg Br*, 93, 658–664.

8. B. Higher rates of pulmonary complications

There are no clinical studies demonstrating that reamed nailing results in an increase in pulmonary complications, but the other statements have been clinically demonstrated.

Brumback RJ, Virkus WW (2000). Intramedullary nailing of the femur: reamed versus nonreamed. *J Am Acad Orthop Surg*, 8, 83–90.

Canadian Orthopaedic Trauma Society (2003). Nonunion following intramedullary nailing of the femur with and without reaming. Results of a multicenter randomized clinical trial. *J Bone Joint Surg Am*, 85-A, 2093–2096.

9. B. Locked plates may improve construct stability in the presence of osteoporotic bone

Despite the availability of multiple fixation techniques, union rates are only moderate. Although not all cruciate-retaining TKR designs have helpful femoral notch morphology, cruciate-substituting TKR designs have a box which prevents easy passage of a retrograde femoral nail. The pull-out strength of locked constructs in osteoporotic bone has been shown to be superior to non-locked ones. Locked retrograde nails may be even better biomechanically. The normal distal femoral anatomical axis is 5–7° of valgus. Notching of the femur with a misjudged anterior femoral resection, rather than an excessive distal femoral cut, leads to an increased risk of distal femoral fracture after TKR.

Snow M, Thompson G, Turner PG (2008). A mechanical comparison of the locking compression plate (LCP) and the low contact-dynamic compression plate (DCP) in an osteoporotic bone model. *J Orthop Trauma*, 22, 121–125.

Vallier HA, Immler W (2012). Comparison of the 95-degree angled blade plate and the locking condylar plate for the treatment of distal femoral fractures. *J Orthop Trauma*, 26, 327–332.

10. B. B1.

The Vancouver classification of periprosthetic fractures of the hip was described in order to help with management decisions on the treatment of these fractures. It was recognized that these were '. . . usually difficult, often complex, and always expensive' fractures to treat successfully. Fractures around the trochanter are classified as A with A_G and A_L, referring to involvement of either the greater or lesser trochanteric regions, respectively. Fractures around the stem or extending slightly distal to it are classified as Vancouver B. This group is further divided according to whether the implant is solidly fixed (B1) or loose (B2). If the femoral component is loose and there is severe bone stock loss, whether caused by generalized osteopenia, osteolysis, or severe comminution, the fracture is classified as type B3. Type C fractures occur well below the stem tip.

Brady OH, Garbuz DS, Masri BA, Duncan CP (1999). Classification of the hip. *Orthop Clin North Am*, 30, 215–220.

11. E. II

The Lewis and Rorabeck classification for periprosthetic fractures of the knee divides fractures into three groups. Types I and II describe fractures around a stable well-fixed prosthesis, with type I fractures being undisplaced and type II fractures being displaced. Type III fractures are around a loose prosthesis. This woman has a well-fixed knee with a displaced periprosthetic fracture; therefore, her fracture is a type II.

Lewis PL, Rorabeck CH, Angliss RD (1998). Fractures of the femur, tibia, and patella after total knee arthroplasty: decision making and principles of management. *Instr Course Lect*, 47, 449–458.

Rorabeck CH, Taylor JW (1999). Periprosthetic fractures of the femur complicating total knee arthroplasty. *Orthop Clin North Am*, 30, 265–277.

12. A. The anterior cruciate ligament (ACL) has two bundles: an anteromedial bundle that is tight in extension and a posterolateral bundle that is tight in flexion

The cruciate ligaments each have two main bundles. The ACL has a larger anteromedial bundle that tightens during flexion and is the primary restraint to an anterior force on the tibia. The smaller posterolateral bundle tightens as the knee is extended and has a role in control of tibial rotational laxity. The posterior cruciate ligament (PCL) has a larger anterolateral bundle that is tight in flexion and a smaller posteromedial bundle that is tight in extension. This is hard to remember. One way of remembering for both ligaments is the bundles with 'postero' are tight in extension (so will be loose in flexion) and the bundles with 'antero' are the larger of the two bundles.

Amis AA (2012). The functions of the fibre bundles of the anterior cruciate ligament in anterior drawer, rotational laxity and the pivot shift. *Knee Surg Sports Traumatol Arthrosc*, 20, 613–620.

Papannagari R, DeFrate LE, Nha KW, et al. (2007). Function of posterior cruciate ligament bundles during in vivo knee flexion. *Am J Sports Med*, 35, 1507–1512.

13. C. Middle geniculate artery

The blood supply to the ACL is derived from the middle geniculate (or middle genicular) artery, which is a direct branch arising from the popliteal artery in the popliteal fossa at the level of the joint line. It also supplies the posterior cruciate ligament.

Wheeless' Textbook of Orthopaedics. Anatomy of ACL: http://www.wheelessonline.com/ortho/anatomy_of_acl

chapter 7

LOWER LIMB—DISTAL TIBIA, FOOT, AND ANKLE

Questions

1. In the CT-based description of pilon fractures which of the following is the commonest variety of coronal-based pattern [coronal = parallel to trans-malleolar axis]?

Select the single most appropriate answer.

A. Anterior split
B. Coronal split with die punch
C. Posterior split
D. V type
E. Y type

2. In the Lauge-Hansen classification system which of the following accounts for the majority of fracture types?

Select the single most appropriate answer.

A. Pronation–abduction
B. Pronation–dorsiflexion
C. Pronation–external rotation
D. Supination–adduction
E. Supination–external rotation

3. A Weber C-type fibula fracture, most commonly seen as part of an ankle injury, is classified in the Lauge-Hansen system as what?

Select the single most appropriate answer.

A. Pronation–abduction Stage 2
B. Pronation–adduction Stage 2
C. Pronation–external rotation Stage 4
D. Supination–external rotation Stage 2
E. Supination–external rotation Stage 4

4. What is the classical radiographic feature of a supination–adduction injury to the ankle?

Select the single most appropriate answer.

A. Infracollicular fracture
B. Oblique lateral fracture
C. Transverse lateral fracture above syndesmosis
D. Transverse medial fracture
E. Vertical medial fracture

5. Which of the following is not a feature of a pronation–abduction fracture pattern?

Select the single most appropriate answer.

A. Deltoid rupture
B. Distal medial–proximal lateral fibula facture
C. Distal anterior–proximal posterior fibular fracture
D. Fibula transverse fracture with wedge
E. Medial malleolus transverse fracture

6. Which of the following is the main determinant of AVN after a talus neck fracture?

Select the single most appropriate answer.

A. Delay until open reduction and internal fixation
B. Medial surgical incision and dissection
C. Quality of reduction of the fracture
D. Severity of the injury and degree of displacement
E. Whether the fracture is open or closed

7. Which variety of subtalar dislocation occurs in the majority of cases?

Select the single most appropriate answer.

A. Anterior
B. Lateral
C. Medial
D. Pan-talar
E. Posterior

8. A tongue-type calcaneal fracture always has which of these fragments?

Select the single most appropriate answer.

A. Anterior fragment
B. Lateral fragment
C. Medial fragment
D. Posterior tuberosity fragment
E. Superolateral fragment

9. A 45-year-old woman is walking her dog. She sustains an injury to her right foot by trapping it in a rabbit hole and twisting it. Examination shows significant swelling, a bruised midfoot, and tenderness. Anteroposterior and lateral radiographs of the foot show no obvious fractures or dislocation except for a small fleck of bone avulsion at the base of the second metatarsal. What further investigation should be done?

Select the single most appropriate answer.

A. CT scan
B. MRI scan
C. Standing weight-bearing views of both feet as well as oblique radiographs
D. Ultrasound of the foot
E. X rays of the ankle and further oblique images of the foot

10. Which of the following is the most common orientation for fractures of the navicular?

Select the single most appropriate answer.

A. Comminuted central third
B. Dorsomedial—lateral plantar
C. Dorsolateral—medial plantar
D. Sagittal mid navicular
E. Sagittal lateral navicular

11. A 43-year-old man presents to the fracture clinic after a minor twisting injury to his right foot whilst dancing at a party. Radiographs suggest a simple fracture of the base of the fifth metatarsal, at the junction of metaphysis and diaphysis. What is the diagnosis?

Select the single most appropriate answer.

A. James fracture
B. Jones fracture
C. March fracture
D. Peroneus brevis avulsion fracture
E. Shepherd's fracture

12. A 34-year-old man who enjoys running and cycling presents with a 3-week history of mild ache over the lateral border of his left foot. His symptoms are getting worse and he has had to stop running in the last few days. Examination confirms tenderness over the fifth metatarsal diaphysis. What is the diagnosis?

Select the single most appropriate answer.

A. Jones fracture
B. Non-union of the fifth metatarsal
C. Os vesalianum
D. Peroneus brevis tendinopathy
E. Stress fracture

chapter 7

LOWER LIMB—DISTAL TIBIA, FOOT, AND ANKLE

Answers

1. E. Y type

Coronal splits occurred in 60 out of 96 pilon fractures, with sagittal split in the remainder. Of the coronal fractures, a V-type fracture occurred in 15/60, Y-type in 23/60, anterior split in 8/60, and posterior split in 6/60. Coronal fractures with die punch were not specifically described.

Topliss CJ, Jackson M, Atkins RM (2005). Anatomy of pilon fractures of the distal tibia. *J Bone Joint Surg Br*, 87-B, 692–697.

2. E. Supination–external rotation

Approximately 85% of ankle fractures are of the supination–external rotation type.

Kosuge DD, Mahadevan D, Chandrasenan J, Pugh H (2010). Managing type II and type IV Lauge-Hansen supination external rotation ankle fractures: current orthopaedic practice. *Ann R Coll Surg Engl*, 92, 689–692.

3. C. Pronation–external rotation Stage 4

Pronation–external rotation injuries classically have a high fibula fracture as their final stage.

Lauge-Hansen N (1954). Fractures of the ankle III. Genetic roentgenologic diagnosis of fractures of the ankle. *Am J Roentgenol Radium Ther Nucl Med*, 71, 456–471.

4. E. Vertical medial fracture

Supination–adduction injuries start on lateral side with rupture of ligaments or fibular failing in tension (below the syndesmosis). Therefore oblique lateral and high lateral fractures are not classical. Infracollicular fractures or transverse fractures represent traction injuries that do not occur in supination–adduction. The classical feature is the vertical or oblique fracture line of the medial malleolus as this is pushed off by the talus driven into adduction.

Lauge-Hansen N (1954). Fractures of the ankle III. Genetic roentgenologic diagnosis of fractures of the ankle. *Am J Roentgenol Radium Ther Nucl Med*, 71, 456–471.

5. C. Distal anterior–proximal posterior fibular fracture

Pronation–abduction injuries start with medial side first, either medial malleolar fracture or deltoid rupture. They progress posteriorly then to the lateral side with abduction force producing a medial distal–proximal lateral pattern or bending wedge pattern (transverse with wedge) of the fibula. Distal anterior and proximal posterior oblique-spiral fractures planes are classic signs of supination–external rotation injuries and are most clearly seen on lateral view.

Haraguchi N, Armiger RS (2009). A new interpretation of the mechanism of ankle fracture. *J Bone Joint Surg Am*, 91, 821–829.

Okonobo H, Khurana B, Sheehan S, Duran-Mendicuti A, Arianiam A, Ledbetter S (2012). Simplified diagnostic algorithm for Lauge-Hansen classification of ankle injuries. *RadioGraphics*, 32, E71–E84.

6. D. Severity of the injury and degree of displacement

Whilst it was previously thought that delay to definitive fixation was related to the incidence of AVN this is probably not true. Reduction of dislocated fragments should be carried out emergently if possible to reduce risk of skin necrosis and further complications. However, the risk of AVN is probably determined at the time of injury. Anatomical reduction has a significant impact on functional outcome and should be the aim wherever possible.

Halvorson JJ, Winter SB, Teasdall RD, Scott AT (2013). Talar neck fractures: a systematic review of the literature. *J Foot Ankle Surg*, 52, 56–61.

7. C. Medial

Medial dislocation is found in the majority of cases (80%), with lateral dislocation accounting for 15% and posterior and anterior dislocation occurring rarely (1%).

Monson ST, Ryan JR (1981). Subtalar dislocation. *J Bone Joint Surg Am*, 63, 1156–1158.

8. E. Superolateral fragment

Carr et al. created experimental calcaneal fractures in cadavers and noted that constant primary fracture lines occurred, dividing the calcaneus into medial and lateral portions or anterior and posterior portions. These primary fracture lines resulted in the fracture patterns with which we are familiar, including the joint depression and tongue type. The tongue type represents the superolateral portion attached to the Achilles tendon, as described by Essex-Lopresti.

Carr JB, Hamilton JJ, Bear LS (1989). Experimental intra-articular calcaneal fractures: anatomic basis for a new classification. *Foot Ankle*, 10, 81–87.

Essex-Lopresti P (1952). The mechanism, reduction, technique, and results in fractures of the os calcis. *British J Surg*, 39, 395–419.

9. C. Standing weight-bearing views of both feet as well as oblique radiographs

The suspicion is that this woman has a subtle Lisfranc injury to her midfoot, unless proven otherwise. The next investigation should be weight-bearing radiographs of both feet, including proper lateral views. Often, the mild diastasis between the first and second metatarsal base is better appreciated on weight-bearing views. There may be a small step at the medial cuneiform–second metatarsal base, which should be carefully compared with the contralateral side. Additionally, you should look for any dorsal subluxation of the second metatarsal base and the classic bruise at the base of the second metatarsal (plantar aspect).

Davies MS, Saxby TS (1999). Intercuneiform instability and the ‘gap’ sign. *Foot Ankle Int*, 20, 606–609.

Rankine JJ, Nicholas CM, Wells G, Barron DA (2012). The diagnostic accuracy of radiographs in Lisfranc injury and the potential value of a craniocaudal projection. *Am J Roentgenol*, 198, W365–W369.

Ross G, Cronin R, Hauzenblas J, Juliano P (1986). Plantar ecchymosis sign: a clinical aid to diagnosis of occult Lisfranc tarsometatarsal injuries. *J Orthop Trauma*, 10, 119–122.

10. C. Dorsolateral–medial plantar

The navicula typically fractures along a predictable plane due to the often forceful pull of the tibialis posterior tendon attachment.

Sangeorzan BJ, Benirschke SK, Mosca V, et al. (1989). Displaced intra-articular fractures of the tarsal navicular. *J Bone Joint Surg*, 71-A, 1504–1510.

11. B. Jones fracture

This fits the classic description by Sir Robert Jones, who suffered this type of injury himself while dancing. He presented a series of patients with similar injury in 1902. This should be differentiated from a simple avulsion fracture of the base of the fifth metatarsal. Jones fractures occur at the metaphyseal–diaphyseal junction and are prone for delayed/non-union. The traditional recommendation is for a non-weight-bearing cast for 6 weeks, although internal fixation with a screw can be considered based on the needs of the individual patient.

Jones R (1902). I. Fracture of the base of the fifth metatarsal bone by indirect violence. *Ann Surg*, 35, 697–700.

Lawrence SJ, Bottle MJ (1993). Jones' fractures and related fractures of the proximal fifth metatarsal. *Foot Ankle*, 14, 358–365.

Polzer H, Polzer S, Mutschler W, Prall WC (2012). Acute fractures to the proximal fifth metatarsal bone: development of classification and treatment recommendations based on the current evidence. *Injury*, 43, 1626–1632.

12. E. Stress fracture

Some fractures of the fifth metatarsal occur in diaphysis, often as a result of repetitive stress in runners and athletes. They range from an undisplaced fracture to established fracture with sclerosis at the fracture site and in the cortex. Treatment is often surgical with intramedullary screw fixation ± bone grafting as there is a high rate of non-union in the diaphyseal group.

Jones R (1902). I. Fracture of the base of the fifth metatarsal bone by indirect violence. *Ann Surg*, 35, 697–700.

Lawrence SJ, Bottle MJ (1993). Jones' fractures and related fractures of the proximal fifth metatarsal. *Foot Ankle*, 14, 358–365.

Polzer H, Polzer S, Mutschler W, Prall WC (2012). Acute fractures to the proximal fifth metatarsal bone: development of classification and treatment recommendations based on the current evidence. *Injury*, 43, 1626–1632.

chapter

8

PAEDIATRIC TRAUMA

Questions

1. A 2-year-old girl is brought in to A&E by her parents following a fall from the couch. Her parents are concerned that she does not seem to be moving her right arm as easily as before. Radiographs of her right shoulder show a clavicle in two parts with rounded well-corticated ends and a 1-cm gap in the mid diaphysis. What is the diagnosis?

Select the single most appropriate answer.

A. Acute clavicle fracture
B. Congenital pseudoarthrosis of the clavicle
C. Malunion of a previous clavicle fracture
D. Non-accidental injury with late presentation
E. Non-union of a previous clavicle fracture

2. How much does the proximal humeral physis contribute to overall growth of the humerus?

Select the single most appropriate answer.

A. <10%
B. 20%
C. 50%
D. 80%
E. >90%

3. A 6-year-old child has fallen over a climbing frame, landing heavily on his left arm. He has sustained a distal humeral fracture. Which of the following fractures is most likely to be associated with development of the gunstock deformity?

Select the single most appropriate answer.

A. A distal humeral fracture with lateral sided intra-articular element
B. A Gartland type II fracture with associated impaction of the lateral cortex
C. A Gartland type II fracture with an associated impaction of the medial cortex
D. A Gartland type III fracture with posterolateral displacement of the distal fragment
E. A Gartland type III fracture with posteromedial displacement of the distal fragment

4. Which of the following factors is most likely to cause damage to the ulnar nerve in the treatment of a Gartland type III fracture?

Select the single most appropriate answer.

A. Delay to surgery
B. Insertion of a medial side K-wire before a lateral one
C. Insertion of a medial side K-wire with the elbow in flexion
D. Insertion of a medial side K-wire with the elbow in extension
E. Visualization of the nerve with the elbow in flexion

5. An 11-year-old boy was ice skating with his family over the Christmas holidays. He slid and fell on his outstretched hand. The elbow seemed deformed and dislocated, but after a few minutes it reduced spontaneously while he was walking to the car. On the radiograph a displaced medial epicondyle fracture is detected with no elbow dislocation. What treatment would you suggest?

Select the single most appropriate answer.

A. Closed reduction and internal fixation with two smooth K-wires
B. Immobilization for 4 weeks in a long arm cast with the elbow flexed to 90°
C. Open reduction and internal fixation with a semi-threaded screw
D. Open reduction and internal fixation with two smooth K-wires
E. None of the above

6. An 8-year-old boy gets in to a fight with his sister who pushes him down the stairs. He complains to his mother that his left elbow hurts (and that his sister pushed him). A radiograph reveals a lateral condylar fracture which is displaced by 1 mm. What treatment would you suggest?

Select the single most appropriate answer.

A. Above-elbow plaster with radiographic review in 5–7 days to ensure no displacement occurs
B. Collar and cuff with the elbow flexed to 110°
C. Open reduction and fixation with a percutaneous K-wire
D. Open reduction and internal fixation with a partially threaded screw
E. Percutaneous K wiring

7. What is the most common complication of a lateral condyle fracture?

Select the single most appropriate answer.

A. Cubitus valgus
B. Cubitus varus
C. Lateral spur formation
D. Osteonecrosis
E. Tardy ulnar nerve palsy

8. If a child has sustained a radial neck fracture that is angulated by 30–60° with >50% and <100% of translation at the fracture site, how would this be classified according to the Judet classification of radial neck fractures in children?

Select the single most appropriate answer.

A. I
B. II
C. III
D. IIIa
E. IV

9. Which of the following is not normally associated with a poor outcome in a child who has sustained a radial neck fracture?

Select the single most appropriate answer.

A. A dislocation
B. Anatomical open reduction and fracture fixation
C. An epicondylar apophyseal fracture
D. >100% translation
E. 30–60° angulation

10. Which of these statements is correct with regard to elastic nails for forearm fractures?

Select the single most appropriate answer.

A. At the ulnar proximal entry point the ulnar nerve needs to be under vision for protection
B. Indications include: failed closed reduction, re-fracture, open fracture, ipsilateral humerus fracture, and fractures associated with unstable radioulnar dislocation
C. The appropriate diameter nail for each bone is 30–50% of the diameter of the medullary canal
D. The radial entry point is between the fourth and fifth extensor compartments
E. All of the above

11. A 5-year-old child presents to A&E with a distal radial fracture. The radiographs show 12° of angulation and displacement of less than 50%. Which of the following is the most appropriate treatment for this fracture?

Select the single most appropriate answer.

A. Forearm cast with no manipulation
B. Manipulation and K-wire with a forearm cast
C. Manipulation in theatre and application of a forearm cast
D. No treatment required
E. Open reduction and plate fixation

12. In a displaced paediatric distal radial fracture treated with manipulation and application of a cast, what cast index (CI) value is associated with both a higher average post-operative angulation rate and a higher post-operative displacement rate?

Select the single most appropriate answer.

A. >1.2
B. >3.0
C. >0.8
D. <0.6
E. ≥0.5

13. Which of the following classifications is specifically relevant for proximal femoral fractures in children?

Select the single most appropriate answer.

A. Davis
B. Delbet
C. Judet
D. Pauwels
E. Russel Taylor

14. What is the most common type of hip fracture in skeletally immature patients?

Select the single most appropriate answer.

A. Basicervical
B. Intertrochanteric
C. Osteochondral
D. Subtrochanteric
E. Transcervical

15. Which of the following statements is true with regard to paediatric femoral fractures?

Select the single most appropriate answer.

A. The incidence is over 10% of all children's fractures
B. The incidence is greatest in the children aged under 3 years old
C. They always remodel but often end up short
D. They do not show seasonal variation
E. They have a male predominance of 3:1

16. How much shortening at the fracture site is acceptable in patients aged under 10 years with a femoral fracture?

Select the single most appropriate answer.

A. It is alignment, not shortening, that matters
B. None
C. <1 cm
D. <2 cm
E. 2–5 cm

17. What should the limb position be for a midshaft femoral shaft fracture in a child treated with a hip spica?

Select the single most appropriate answer.

A. Hip and knee in full flexion and with the hip in 45° of abduction and 15° of external rotation
B. Hip and knee in mild flexion and with the hip in 20° of abduction and 15° of external rotation
C. Hip and knee in mild flexion and with the hip in 20° of abduction and 15° of internal rotation
D. Hip and knee in extension and with the hip in 20° of abduction and 15° of external rotation
E. Hip and knee extended and hip in neutral rotation but 45° of abduction

18. Which of the following statements is true regarding growth in the paediatric lower extremity?

Select the single most appropriate answer.

A. Growth is fastest at proximal growth plate of the femur followed by the proximal growth plate of the tibia
B. Growth is fastest at the proximal growth plate of the femur followed by the distal growth plate of the tibia
C. Growth is fastest at the two growth plates around the knee with the femur growing faster than the tibia
D. Growth is fastest at the two growth plates around the knee with the tibia growing faster than the femur
E. Growth is fastest at the two growth plates around the knee with equal contributions from the femur and tibia

19. At what age does the patella ossification centre appear?

Select the single most appropriate answer.

A. *In utero*
B. 1–2 years
C. 2–3 years
D. 3–6 years
E. 6–8 years

20. A 13-year-old boy presents to A&E having fallen off his bicycle, injuring his left knee. At examination he has a large haemarthrosis and is holding the knee in approximately 30° of flexion; there is no neurovascular compromise and no collateral ligament injury. Radiographs show a small, isolated fleck of bone in the centre of the knee joint adjacent to the intercondylar eminence. What would the correct management be?

Select the single most appropriate answer.

A. Admit for further imaging with a view to arthroscopic exploration and arthroscopically assisted reduction and fixation on the next appropriate trauma list

B. Admit for manipulation using fluoroscopic imaging under general anaesthetic, followed by immobilization in a cylinder cast in 10–20° of flexion

C. Admit for urgent open reduction and internal fixation with either screws or sutures on the next appropriate trauma list

D. Cylinder cast or hinged knee brace applied in A&E in 10–20° of flexion, crutches, and fracture clinic review in 1–2 weeks

E. Manipulation in A&E gently into full extension, immobilization in a cylinder cast, and repeat radiograph

21. What must be monitored for when dealing with paediatric tibial shaft fractures?

Select the single most appropriate answer.

A. Varus deformity in isolated comminuted tibial fracture

B. Varus deformity in proximal tibial fractures

C. Varus deformity with tibial shaft fracture and plastic deformity of fibular

D. Varus deformity in tibia and fibular fractures at the middle and distal third junction

E. Varus deformity in isolated midshaft tibial fractures

22. What is the appearance of a typical triplane fracture?

Select the single most appropriate answer.

A. Salter–Harris II on anteroposterior view and Salter–Harris III on lateral

B. Salter–Harris III on anteroposterior view and Salter–Harris II on lateral

C. Salter–Harris III on anteroposterior view and Salter–Harris III on lateral

D. Salter–Harris IV on anteroposterior view and Salter–Harris II on lateral

E. Salter–Harris IV on anteroposterior view and Salter–Harris III on lateral

23. Which of these is not a risk factor for non-accidental injury?

Select the single most appropriate answer.

A. Inner city residence

B. Lower socioeconomic class

C. Pre-term baby

D. Twins

E. Unplanned birth

chapter

8

PAEDIATRIC TRAUMA

Answers

1. B. Congenital pseudoarthrosis of the clavicle

Congenital pseudoarthrosis of the clavicle may be confused with a fracture. The radiographic features in this case are typical of congenital pseudoarthrosis of the clavicle—it is almost always on the right side, in the middle third, with rounded, sclerotic bone ends, and no periosteal reaction. The theory is that vascular pulsations of the adjacent subclavian artery cause failure of the medial and lateral primary centres of ossification to unite. This may explain why congenital pseudoarthrosis of the clavicle occurs on the right in more than 90% of cases (the right subclavian artery is more cephalad as it courses over the first rib), with left pseudoarthrosis occurring more commonly in patients with dextrocardia/situs inversus.

Non-union of paediatric clavicle fractures is extremely rare. Non-accidental injury should always be considered—the odds of clavicle fractures are 4.4 times higher in child abuse than in accidental trauma. Other possible differential diagnoses would include cleidocranial dysplasia and neurofibromatosis.

Bae DS (2008). Upper extremity disorders: pediatrics. In: JS Fischgrund (ed.) *Orthopaedic Knowledge Update 9*, pp.682–683. American Academy of Orthopaedic Surgeons, Rosemont, IL.

Jayakumar P, Barry M, Ramachandran M (2010). Orthopaedic aspects of paediatric non-accidental injury. *J Bone Joint Surg Br*, 92, 189–195.

Pandya NK, Wolfgruber H, Christian CW, Drummond DS, Hosalkar HS (2009). Child abuse and orthopaedic injury patterns: analysis at a level I pediatric trauma center. *J Pediatr Orthop*, 29, 618–625.

2. D. 80%

The proximal humerus comprises three secondary centres of ossification: the humeral head (appears at 6 months), the greater tuberosity (3 years), and the lesser tuberosity (5 years). Eighty per cent of humeral growth comes from the proximal physis. It has the highest difference in proximal:distal ratio (the femur is second, with a proximal:distal ratio of 30:70). This, in addition to the thick periosteum of the proximal humerus, the proximity to the physis, and the near universal motion of the shoulder joint, allows fractures in this region to have enormous potential to heal and remodel. Hence most fractures can be treated non-operatively.

Sarwark JF, King EC, Janicki JA (2010). Proximal humerus, scapula, and clavicle. In: JH Beaty, JR Kasser (eds) *Rockwood and Wilkins' Fractures in Children*, 7th edn, pp.1873–1889. Lippincott, Williams and Wilkins, Philadelphia, PA.

3. C. A Gartland type II fracture with an associated impaction of the medial cortex

The gunstock deformity occurs due to a varus malunion. Correcting Bauman's angle will ensure that the risk of this is reduced.

Omid R, Choi P, Skaggs D (2008). Current concepts review—supracondylar humeral fractures in children. *J Bone Joint Surg Am*, 90, 1121–1132.

4. C. Insertion of a medial side K-wire with the elbow in flexion

Injury to the ulnar nerve is associated with the fact that in some children with flexion past 90° there is a tendency to sublux the ulnar nerve over the medial epicondyle.

Omid R, Choi P, Skaggs D (2008). Current concepts review—supracondylar humeral fractures in children. *J Bone Joint Surg Am*, 90, 1121–1132.

5. B. Immobilization for 4 weeks in a long arm cast with the elbow flexed to 90°

Fractures of the medial epicondyle are common injuries in children and adolescents between the ages of 9 and 14. They account for up to 20% of all elbow fractures in the paediatric population; 60% of cases are associated with elbow dislocation. In non-displaced fractures the physeal line remains intact. Clinically, there may be swelling and local tenderness directly over the medial epicondyle. In significantly displaced fractures (>5 mm), the fragment remains proximal to the true joint surface. These can be associated with elbow dislocations. With entrapment of the fragment in the joint, the elbow may appear to be reduced. The key clinical finding is often a block to elbow motion, specifically extension. Management of most medial epicondyle fractures remain non-surgical, generally consisting of immobilization for 4 weeks in a long arm cast with the elbow flexed to 90°. Documented absolute indications for surgical intervention include open fractures and fractured fragments incarcerated in the joint. Relative surgical indications include ulnar nerve dysfunction and valgus instability of the elbow as well as high-demand upper extremity function.

Dias JJ, Johnson GV, Hoskinson J, Sulaiman K (1987). Management of severely displaced medial epicondyle fractures. *J Orthop Trauma*, 1, 59–62.

Hines RF, Herndon WA, Evans JP (1987). Operative treatment of medial epicondyle fractures in children. *Clin Orthop Relat Res*, 223, 170–174.

Kamath AF, Baldwin K, Horneff J, Hosalkar HS (2009), Operative versus nonoperative management of pediatric medial epicondyle fractures: a systematic review. *J Child Orthop*, 3, 345–357.

Papavasiliou VA (1982). Fracture-separation of the medial epicondylar epiphysis of the elbow joint. *Clin Orthop Relat Res*, 171, 172–174.

Pimpalnerkar AL, Balasubramaniam G, Young SK, Read L (1998). Type four fracture of the medial epicondyle: a true indication for surgical intervention. *Injury*, 29, 751–756.

Wilson NI, Ingram R, Rymaszewski L, Miller JH (1988). Treatment of fractures of the medial epicondyle of the humerus. *Injury*, 19, 342–344.

Wilkins KE (1991). Fractures involving the medial epicondylar apophysis. In: CA Rockwood Jr, KE Wilkins, RE King (eds) *Fractures in Children*, 3rd edn, pp.509–828. Philadelphia, PA, JB Lippincott.

6. A. Above-elbow plaster with radiographic review in 5–7 days to ensure no displacement occurs

Fractures of the lateral condyle commonly occur in children aged 5–10 years. Milch described two types of lateral condyle fractures. In Milch type I, the fracture extends through the ossification centre of the capitellum and enters the joint lateral to the trochlear groove. In Milch type II, the fracture extends medially into the trochlear groove. The most widely used system (not identified by name) identifies three fracture patterns. In a type I fracture, the articular surface is intact and the fracture is non-displaced and stable. In types II and III, the fracture enters the joint. Type II fractures are minimally displaced (2–3 mm); type III fractures are displaced > 4 mm and may be rotated. Type I fractures and type II fractures displaced < 2 mm may be treated by closed means. Closed reduction and percutaneous pinning should be attempted in type II fractures displaced by 2–3 mm; however, if anatomical reduction is not obtained, open reduction and internal fixation is required. Type

II fractures displaced > 2–3 mm and all type III fractures are unstable and should be treated with open reduction and internal fixation.

Milch H (1964). Fractures and fracture dislocations of the humeral condyles. *J Trauma*, 15, 592–607.

Mintzer CM, Waters PM, Brown DJ, Kasser JR (1994). Percutaneous pinning in the treatment of displaced lateral condyle fractures. *J Pediatr Orthop*, 14, 462–465.

Sullivan JA (2006). Fractures of the lateral condyle of the humerus. *Am Acad Orthop Surg*, 14, 58–62.

7. C. Lateral spur formation

Potential complications of lateral condyle fractures include non-union, cubitus varus, osteonecrosis, and protuberance of the lateral condyle. Protuberance of the lateral condyle is the most common of these. The other complications are extremely rare but serious. Clinical series report that up to half of cases of lateral condyle fracture have a lateral protuberance. Although there is no functional disability from the protuberance and no surgical treatment is required, it is disconcerting to parents to see the deformity, so it is best to have warned them pre-operatively.

Foster DE, Sullivan JA, Gross RH (1985). Lateral humeral condylar fractures in children. *J Pediatr Orthop*, 5, 16–22.

Jakob R, Fowles JV, Rang M, Kassab MT (1975). Observations concerning fractures of the lateral humeral condyle in children. *J Bone Joint Surg Br*, 57, 430–436.

8. C. III

The Judet classification of radial neck fractures in children is graded I–IV: grade I, undisplaced fracture; grade II, <30° angulation, <50% radial neck diameter translation; grade III, >30° but <60° angulation with <100% but >50% translation; grade IV, 60° to 90° angulation and >100% translation.

Judet H, Judet J (1974). *Fractures et Orthopédie de l'Enfant*, pp.31–39. Maloine, Paris.

Judet J, Judet R, Lefranc J (1962). Fracture du col radial chez l'enfant. *Ann Chir*, 16, 1377–1385.

Stiefel D, Meuli M, Altermatt S (2001). Fractures of the neck of the radius in children. Early experience with intramedullary pinning. *J Bone Joint Surg Br*, 83, 536–541.

9. E. 30–60° angulation

All of the options A–D have been associated with a poor outcome after radial neck fractures. Klitscher notes that radial neck fractures associated with an elbow dislocation, an olecranon fracture, epicondylar fracture, or classified as a Judet grade IV fracture have a poorer outcome than grade III fractures. Any radial neck fracture that requires an open reduction has a higher risk of a poor outcome even if the reduction is anatomical due to the risk of AVN.

Klitscher D, Richter S, Bodenschatz K, et al. (2009). Evaluation of severely displaced radial neck fractures in children treated with elastic stable intramedullary nailing. *J Pediatr Orthop*, 29, 698–703.

10. B. Indications include: failed closed reduction, re-fracture, open fracture, ipsilateral humerus fracture, fractures associated with unstable radioulnar dislocation

Elastic nail fixations are designed for a long bone diaphyseal fracture with the following indications: fractures that fail closed reduction, fractures associated with unstable proximal or distal radioulnar dislocation, open fractures, fractures associated with compartment syndrome requiring fasciotomy, re-fractures, ipsilateral humerus fracture ('floating elbow'). The entry point for the ulna should be on the lateral side of the olecranon to avoid ulnar nerve injury. The entry point for the radius is between the first and second compartments (extensor pollicis longus and extensor carpi radialis longus tendons) or between the second and third compartment (extensor carpi radialis brevis and extensor pollicis longus tendons). The appropriate nail diameter is 60–80% of the medullary canal diameter.

Flynn JM (2002). Pediatric forearm fractures: decision making, surgical techniques and complications. *Instr Course Lect*, 51, 355–360.

Pring ME, Chambers HG (2011). Forearm fractures: intramedullary rodding. In: MS Kocher, MB Millis (eds) *Operative Techniques: Pediatric Orthopaedic Surgery*, pp.90–101. Saunders, Philadelphia, PA.

11. A. Forearm cast with no manipulation

In children under 10 years of age, a displaced fracture of the distal radius with <15° angulation (<10° otherwise) can be treated closed without manipulation in the expectation of remodelling by 6–9 months. A forearm cast should be applied for pain relief.

Stutz C, Mencio GA (2010). Fractures of the distal radius and ulna: metaphyseal and physeal injuries. *J Pediatr Orthop*, 30, S85–S89.

12. C. >0.8

The cast index (CI) is the ratio of the sagittal to the coronal width from the inside edges of the cast at the fracture site measured on radiographs. It can be used to identify the optimal cast level that reduces the risk of redisplacement of a distal radius fracture after manipulation and cast application.

Kamat AS, Pierse N, Devane P, Mutimer J, Horne G (2012). Redefining the cast index: The optimum technique to reduce redisplacement in pediatric distal forearm fractures. J Pediatr Orthop, 32, 787–791.

Malviya A, Tsintzas D, Mahawar K, Bache CE, Glithero PR (2007). Gap index: a good predictor of failure of plaster cast in distal third radius fractures. J Pediatr Orthop B, 16, 48–52.

13. B. Delbet

The Delbet classification of proximal femoral fractures in children is as follows: type I, transepiphyseal fracture; type II, transcervical fracture; type III, cervicotrochanteric fracture; type IV, intertrochanteric.

Canale ST (2000). Mini-symposium: the difficult neck of femur fracture (v) hip fractures in children. *Curr Orthop*, 14, 108–113.

14. E. Transcervical

Transcervical fractures are the most common hip fracture in skeletally immature patients.

Canale ST (2000). Mini-symposium: the difficult neck of femur fracture (v) hip fractures in children. *Curr Orthop*, 14, 108–113.

15. E. They have a male predominance of 3:1

Most femoral fractures in children occur in boys. The other answers are all false.

Aronson DD, Singer RM, Higgins RF (1987). Skeletal traction for fractures of the femoral shaft in children. A long-term study. *J Bone Joint Surg Am*, 69, 1435–1439.

Kasser JR (1992). Femur fractures in children. *Instr Course Lect*, 44, 403–408.

16. C. <1 cm

Some shortening is acceptable to allow for the predictable overgrowth that can occur.

Aronson DD, Singer RM, Higgins RF (1987). Skeletal traction for fractures of the femoral shaft in children. A long-term study. *J Bone Joint Surg Am*, 69, 1435–1439.

Kasser JR (1992). Femur fractures in children. *Instr Course Lect*, 44, 403–408.

17. B. Hip and knee in mild flexion and with the hip in 20° of abduction and 15° of external rotation

Correct limb positioning in casting is important to prevent complications such as femoral nerve palsy, hip subluxation, and fracture malreduction.

Kasser JR (1992). Femur fractures in children. *Instr Course Lect*, 44, 403–408.

18. C. Growth is fastest at the two growth plates around the knee with the femur growing faster than the tibia

During childhood most growth in the body occurs around the knee. In total the knee adds an average of 42.5 cm (24 cm from the femur and 18.5 cm from the tibia) to the total increase in height in boys and 38.7 cm (22 cm from the femur and 16.7 cm from the tibia) in girls. This illustrates the importance of the recognition, treatment, and surveillance of paediatric fractures around the knee to recognize growth arrest earlier and to try to prevent discrepancy in leg length. Roughly, the lower limb grows about 2 cm/year in childhood with the femoral growth plate 1.2 cm/year) contributing a little more than the tibial (0.9 cm/year).

Dimeglio A (2001). Growth in pediatric orthopaedics. In: RT Morrissey, SL Weinstein (eds) *Lovell and Winter's Pediatric Orthopaedics*, 5th edn, pp.33–63. Lippincott, Philadelphia, PA.

19. D. 3–6 years

The ossification centre of the patella first appears around the age of 3 but can be delayed until 6 in normal knees. It is important to recognize this in the assessment of knee trauma in young children. In radiographs of children aged 6 and under the patella may be completely radiolucent, present, or have multifocal ossification resembling a comminuted fracture. In cases of doubt a contralateral radiograph is recommended for comparison.

Shandsjr AR (1926). An analysis of one hundred X-rays of patellae. *J Bone Joint Surg*, 8, 824–831.

20. A. Admit for further imaging with a view to arthroscopic exploration and arthroscopically assisted reduction and fixation on the next appropriate trauma list

Fractures of the tibial eminence generally occur in children aged 8–14. They should be suspected in all children of this age who present with a knee haemarthrosis. The bony fragment is usually visible on radiographs, but not always. Meyers and McKeever have described three main types. A type I fracture is non-displaced and does not interfere with knee extension. A type II fracture has an intact posterior hinge with the anterior portion being elevated. In this type, knee extension is generally limited and there is a possibility that soft tissue is caught under the anterior fracture fragment. A type III fracture is fully displaced, usually with the knee held in a mildly flexed position. An isolated, fully displaced fracture (type III) cannot be satisfactorily treated with closed reduction and should be treated with arthroscopically assisted reduction and fixation.

LaFrance RM, Giordano B, Goldblatt J, Voloshin I, Maloney M (2010). Pediatric tibial eminence fractures: evaluation and management. *J Am Acad Orthop Surg*, 18, 395–405.

Meyers MH, McKeever FM (1959). Fracture of the intercondylar eminence of the tibia. *J Bone Joint Surg* 41-A, 209–222.

21. E. Varus deformity in isolated midshaft tibial fractures

Varus deformity is uncommon in comminuted tibial fractures but occurs frequently in isolated simple tibial fractures (60%) due to the tendency of the fibula to deform the tibia. Valgus deformity is more common in proximal tibial fractures. Tibial fractures with plastic deformity of the fibular are commonly associated with valgus deformity (60%). Distal fractures of tibia and fibular are prone to drift into valgus due to the pull of lateral and anterior compartment muscles.

Jackson DW, Cozen L (1971). Genu valgum as a complication of proximal tibial metaphyseal fractures in children. *J Bone Joint Surg Am*, 53, 1571–1578.

Jordan SE, Alonso JE, Cook FF (1987). The etiology of valgus angulation after metaphyseal fractures of the tibia in children. *J Pediatr Orthop*, 7, 450–457.

22. B. Salter–Harris III on anteroposterior view and Salter–Harris II on lateral

Triplane fractures occur in many different forms, the common theme being that the fracture is seen in three different planes. The most common is the Salter–Harris III fracture seen on the anteroposterior view, with the Salter–Harris II seen on the lateral. They occur due to the progressive closure of the distal tibial physis.

Cummings RJ, Shea KG (2010). Distal tibial and fibular fractures. In: *Rockwood and Wilkins' Fractures in Children*, 7th edn, pp. 967–1016. Lippincott, Williams and Wilkins, Philadelphia, PA

23. A. Inner city residence

Non-accidental injury must be suspected in all cases of paediatric fractures. All options apart from inner city residence are risk factors.

Jayakumar P, Barry M, Ramachandran M. (2010). Orthopaedic aspects of paediatric non-accidental injury. *J Bone Joint Surg Br*, 92-B, 189–195.

Thomas SA, Rosenfeld NS, Leventhal JM, Markowitz RI (1991). Longbone fractures in young children: distinguishing accidental injuries from child abuse. *Pediatrics*, 88, 471–476.

Part 2 **Extended Matching Questions**

chapter 9

BASIC SCIENCE OF ORTHOPAEDIC TRAUMA

Questions

1. A. Osteoclasts
B. Osteoblasts
C. Osteocytes
D. Osteoprogenitor cells
E. Calcium hydroxyapatite
F. Collagen type I
G. Tropocollagen
H. Electronegative
I. Electropositive
J. Wolff's law
K. Piezoelectric
L. Haversian
M. Volkmann
N. Concentric
O. Canaliculi
P. Lacunae
Q. Circumferential
R. Interstitial
S. Collagen type II
T. Fibronectin
U. Osteopontin
V. Osteonectin
W. Osteocalcin

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which term is used to describe the structure characterized by the deposition of mineralized bone matrix in concentric lamellae around a central vascular channel seen in primary direct healing?
2. Which non-collagenous protein is a cell adhesion molecule involved in the construction of cartilage matrix in fracture callus, and which therefore would not be detected in a fracture healing by pure primary direct healing?
3. Which cell involved in primary direct healing is a multinucleate giant cell formed by the fusion of monocyte precursors and during remodelling is stimulated by an electropositive charge?

2. A. Intramedullary nailing of oblique proximal tibial fracture
B. Haematoma
C. Osteoclast
D. Tumour necrosis factor-alpha (TNF-α)
E. External fixation of a lateral compression type 2 pelvic fracture
F. Inflammation
G. Chondrocyte
H. Platelet-derived growth factor (PDGF)
I. Plaster cast application, paediatric forearm fracture
J. Soft callus formation
K. Osteoblast
L. VEGF
M. Locking plate multifragmentary distal femoral fracture
N. Hard callus formation
O. Fibroblast
P. Macrophage colony-stimulating factor (M-CSF)
Q. Low-contact-dynamic compression plate (LC-DCP) humeral shaft fracture
R. Remodelling
S. Wnt

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which cytokine expressed during haematoma formation results in the migration of inflammatory cells?
2. Which mode of fracture fixation is not intended to promote secondary fracture healing?
3. Which cell is active during both the haematoma and the remodelling phases of secondary fracture healing?
4. Which phase of secondary fracture healing is inhibited in BMP2-knockout mice?

3. A. Below knee
B. Through knee
C. Low transtibial
D. Syme
E. Boyd
F. Chopart
G. Lisfranc
H. Transmetatarsal

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Should be performed in conjunction with a percutaneous Achilles tendon lengthening to prevent late plantar pressure sores.
2. Equinus or equinovarus contractures are late complications of these amputations.
3. Is an ankle disarticulation with removal of the malleoli and metaphyseal flares that requires a patent posterior tibial artery to ensure soft tissue healing.
4. Describes a disarticulation at the tarsometatarsal (TMT) joint.
5. Involves the suturing of the patella tendon to the cruciate ligaments.

4. A. 10%
B. 25%
C. 40%
D. 41%
E. 65%
F. 0–8%

This list of percentages relates to the percentage of energy expenditure *above* normal for ambulation. Which of the figures relates to energy expenditure after the following amputations?

1. Bilateral transtibial
2. Wheelchair bound
3. Short transtibial
4. Long transtibial
5. Average transtibial

5. A. Bone mass
B. Serum calcium
C. Serum phosphate
D. Alkaline phosphatase
E. Urinary calcium
F. Urinary phosphate
G. Vitamin D
H. Trabeculae
I. Cortical bone:cancellous bone ratio
J. Bone turnover

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Osteoporosis is defined by reduced . . .
2. Osteomalacia is defined by elevated . . .
3. Osteopenia is defined by reduced . . .

6. A. Charcot joint
B. Osteomyelitis
C. CRPS
D. Osteoporosis
E. Myeloma
F. Osteosarcoma
G. Deep vein thrombosis (DVT)

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. An 80-year-old rheumatoid arthritis patient with severe hallux valgus, an ulcer over the hallux metatarsophalangeal joint, and a raised CRP.
2. A 32-year-old right-hand-dominant secretary with a red, swollen, painful wrist following 10 weeks in plaster for a fractured waist of scaphoid.
3. A 50-year-old diabetic with a deformed, swollen foot and no history of trauma.
4. A 32-year-old left-hand-dominant artist with a red, swollen, painful wrist 4 weeks after percutaneous screw fixation for fractured waist of scaphoid.

7. A. Decreased muscle endurance
B. Cardiac arrest
C. 300 mmHg
D. 150 mmHg above systolic blood pressure
E. 100 mmHg above systolic blood pressure
F. 250 mmHg
G. The surgeon
H. The theatre sister/operating department practitioner (ODP)
I. The theatre manager

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Lower limb tourniquets in adults should be inflated to a pressure of . . .
2. Prolonged tourniquet use is associated with . . .
3. Upper limb tourniquets in adults are inflated to a pressure of . . .
4. Who is responsible for ensuring the tourniquet is working?

8. A. Creep
B. Passivation layer
C. Notch sensitivity
D. Stress corrosion cracking
E. Transformational toughening
F. Stiffness
G. Hysteresis
H. Hardness
I. Young's modulus relatively close to that of bone

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A potential disadvantage of titanium when used for internal fixation components.
2. A property of cobalt chrome that makes it a good material for bearing surfaces.
3. A potential disadvantage of stainless steel when used for fixation plates.

9. A. Stress at fracture site increased
B. Stress at fracture site decreased
C. Strain at fracture site increased
D. Strain at fracture site decreased
E. Stress on construct increased and strain at fracture site increased
F. Stress on construct decreased and strain at fracture site decreased
G. Stress on construct increased and strain at fracture site decreased
H. Stress on construct decreased and strain at fracture site increased
I. Stress on construct decreased and strain at fracture site not affected

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. The screws in a locking plate are placed closer to the fracture.
2. A second bar is added to a uniaxial external fixator, being placed further away from the bone than the existing bar.
3. Using pins of greater diameter in a uniaxial external fixator.

chapter 9

BASIC SCIENCE OF ORTHOPAEDIC TRAUMA

Answers

1. Answers: 1-L; 2-T; 3-A

1. Cortical bone is arranged in a regular fashion, with repeating individual Haversian units, also known as osteons. Lacunae containing osteocytes are present between the lamellae—these are connected by canaliculi that facilitate cellular signalling and nutrition.
2. All of the non-collagenous proteins listed are mainly involved in secondary healing by callus formation, but fibronectin is the only cell adhesion molecule involved in the construction of cartilage matrix. It is produced by fibroblasts, chondrocytes, and osteoblasts during the early stages of formation of fracture callus. Osteocalcin is produced by osteoblasts and is only detected in hard callus. It attracts osteoclasts and is therefore involved in remodelling and the control of bone density. Osteopontin is a cell-binding protein thought to mediate cellular interaction in bone repair and remodelling. Osteonectin is an intracellular molecule that plays a regulatory role in cell function.
3. Osteoclasts are multinucleate giant cells formed by the fusion of monocyte precursors. They resorb bone by a combination of acidic and proteolytic digestion. Osteoblasts are derived from pluripotent mesenchymal cells, and activated osteoblasts produce collagen type I, proteoglycans, glycoproteins, phospholipids, and phosphoproteins. Osteocytes were previously osteoblasts but are now trapped within the matrix. Osteoprogenitor cells are the mesenchymal cells awaiting activation into osteoblasts. Mechanical stress results in remodelling (Wolff's law) due to differences in piezoelectric charge. The compression side of a bone is electronegative and this preferentially stimulates osteoblasts to form additional bone, whereas the tension side is electropositive stimulating osteoclasts and resorption.

Webb JCJ, Tricker J (2000). A review of fracture healing. *Curr Orthopaedics*, 14, 457–463.

2. Answers: 1-D; 2-Q; 3-C; 4-N

1. PDGF is a growth factor not a cytokine. VEGF causes revascularization and neoangiogenesis. M-CSF is integral to resorption of calcified cartilage. Wnt promotes differentiation of MSCs into osteoblasts.
2. Assuming that the fracture has been anatomically reduced and interfragmentary compression has been achieved, the LC-DCP is a method of producing a very stable construct with very low strain (<2%). The surgeon's intention is that this should result in primary/direct fracture healing without callus formation. All the other modes of fixation achieve relative stability and will therefore heal through callus formation.

3. Fibroblasts and chondrocytes are present during the formation of soft callus and osteoblasts during hard callus formation (and remodelling). Osteoblasts have a role in removing dead bone at the fracture ends in the early days after a fracture, and also in the remodelling phase which may take several years to complete.
4. BMP2 is a necessary component of the signalling cascade that governs fracture repair. Mice lacking the ability to produce BMP2 in their limb bones have spontaneous fractures that do not resolve with time. Other osteogenic stimuli are still present in the limb skeleton of BMP2-deficient mice but they cannot compensate for the absence of BMP2. Further work has established that full fracture healing can still occur in the presence of osteoblasts unable to express BMP2 (with functional chondrocytes) but the cartilage phase is persistent if chondrocytes are unable to express BMP2.

Bates P, Ramachandran M (2006). Bone injury, healing and grafting. In: M Ramachandran (ed.) *Basic Orthopaedic Sciences—the Stanmore Guide*, 1st edn, pp.123–134. CRC/Taylor and Francis, London.

Marsell R, Einhorn TA (2011). Biology of fracture healing. *Injury*, 42, 551–555.

Mi M, Jin H, Wang B, et al. (2013). Chondrocyte BMP2 signalling plays an essential role in bone fracture healing. *Gene*, 512, 211–218.

Tsuji K, Bandyopadhyay A, Harfe BD, et al. (2006). BMP2 activity, although dispensable for bone formation, is required for the initiation of fracture healing. *Nat Genet*, 38, 1424–1429.

Webb JCJ, Tricker J (2000). A review of fracture healing. *Curr Orthopaedics*, 14, 457–463.

3. Answers: 1-H; 2-G and H; 3-D; 4-G; 5-B

Transmetatarsal amputations risk plantar pressure sores if not performed with simultaneous lengthening of the Achilles tendon. All forefoot amputations risk equinus contractures as they likely involve the insertion of tibialis anterior and leave the Achilles and tibialis posterior functioning unopposed.

Jowan G, Penn-Barwell JG (2011). Outcomes in lower limb amputation following trauma: a systematic review and meta-analysis. *Injury*, 42, 1474–1479.

Persson B (2001). Lower limb amputation—Part 1: Amputation methods—a 10 year literature review. *Prosthetics Orthotics Int*, 25, 7–13.

4. Answers: 1-D; 2-F; 3-C; 4-A; 5-B

The more proximal the amputation level, the greater the energy expenditure required for the patient when ambulating. This is an important consideration during pre-operative counselling. Young adult males with traumatic amputations tend to ambulate more readily than older patients with vascular disease, partly due to the energy required.

Jowan G. Penn-Barwell JG (2011). Outcomes in lower limb amputation following trauma: a systematic review and meta-analysis. *Injury*, 42, 1474–1479.

Persson B (2001). Lower limb amputation—Part 1: Amputation methods—a 10 year literature review. *Prosthetics Orthotics Int*, 25, 7–13.

5. Answers: 1-A; 2-D; 3-A

Osteoporosis is by definition a reduction in bone mass—that is to say all elements of the bone are reduced, both organic and inorganic. Osteomalacia is a failure of mineralization of the bone. Osteopenia can be considered to be 'mild' osteoporosis as per the World Health Organization definitions based on the *Z*-scores on bone density testing.

WHO Scientific Group on the assessment of osteoporosis at primary health care level: http://www.who.int/chp/topics/Osteoporosis.pdf

Osteoporosis prevention, diagnosis, and therapy: NIH Consensus Statement: http://consensus.nih.gov/2000/2000Osteoporosis111html.htm

Osteoporosis: assessing the risk of fragility fracture (NICE guidance): http://www.nice.org.uk/guidance/cg146/resources/guidance-osteoporosis-assessing-the-risk-of-fragility-fracture-pdf

6. Answers: 1-B; 2-C; 3-A; 4-C

Complex regional pain syndrome (CRPS), also known as reflex sympathetic dystrophy, often presents in a similar fashion to Charcot and infection. All three need to be excluded and certain tests may be helpful in identifying the cause, such as CRP/erythrocyte sedimentation rate (ESR), bone scan, white cell scan, and MRI.

Lee L, Blume PA, Sumpio, B (2003). Charcot joint disease in diabetes mellitus. *Ann Vasc Surg*, 17, 571–580.

Mouzopoulos G, Kanakaris NK, Kontakis G, et al. (2011). Management of bone infections in adults: the surgeon's and microbiologist's perspectives [review]. *Injury*, 42(Suppl. 5), S18–S23.

Turner-Stokes L, Goebel A (2011). Guideline development group. Complex regional pain syndrome in adults: concise guidance [review]. *Clin Med*, 11, 596–600.

7. Answers: 1-D; 2-A; 3-E; 4-G and H

Tourniquets in the lower limbs are typically inflated to 150 mmHg over the systolic blood pressure, while in the upper limbs the inflation pressure is lower. They should be cleaned regularly and be well maintained.

Fitzgibbons PG, DiGiovanni C, Hares S, Akelman E (2012). Safe tourniquet use: a review of the evidence. *J Am Acad Orthop Surg*, 20, 310–319.

McEwen J, Kelly D, Jardanowski T, Inkpen K (2002). Tourniquet safety in lower leg applications. *Orthop Nurs*, 21, 61–62.

Smith TO, Hing CB (2010). The efficacy of the tourniquet in foot and ankle surgery? A systematic review and meta-analysis. *Foot Ankle Surg*, 16, 3–8.

8. Answers: 1-C; 2-H; 3-D

Titanium has a passivation layer which is made of titanium oxide and is protective. However, it is the notch sensitivity of this layer and the deeper titanium alloy that is a disadvantage, leading to points of focus for fatigue failure. Cobalt chromium has a very hard durable surface making it ideal as a bearing surface. Stainless steel is subject to crevice corrosion.

Beer FP, Johnston ER, DeWolf JT (eds) (2006). *Mechanics of Materials*, 4th edn [Polar moment of area, p.140; Second moment of area, p.217; Moments of area, and inside rear cover for summary of moments of area formulae, Appendix A, pp.736–745]. McGraw Hill, New York.

Budynas RG, Nisbett, JK (eds) (2008). *Shigley's Mechanical Engineering Design*, 8th edn [Second moment of area and bending stresses, pp.86–87]. McGraw Hill, New York.

9. Answers: 1-G; 2-F; 3-F

More bars, thicker bars, bars in more planes, bars closer to the skin, more pins, thicker pins, and pins closer to the fracture all serve to increase the stiffness of an external fixator construct.

Beer FP, Johnston ER, DeWolf JT (eds) (2006). *Mechanics of Materials*, 4th edn [Polar moment of area, p.140; Second moment of area, p.217; Moments of area, and inside rear cover for summary of moments of area formulae, Appendix A, pp.736–745]. McGraw Hill, New York.

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chapter

10

ADVANCED TRAUMA LIFE SUPPORT (ATLS), POLYTRAUMA, LIMB SALVAGE, AND UK TRAUMA GUIDELINES

Questions

1. A. Mechanical instability of the pelvic ring may be tested by manual manipulation of the pelvis

B. 1 in 6

C. Manual manipulation of the pelvis should never be performed

D. Pelvic binder

E. Manipulation of pelvis should not be performed in patients with shock and obvious pelvic fracture

F. Two large cannulae and 2 L of crystalloid

G. Up to 50%

H. Testing for pelvic instability can result in further haemorrhage

I. 1 in 4

J. Longitudinal traction applied through the skin or skeleton

K. Massive transfusion protocol

L. 1 in 10

M. Manual manipulation of the pelvis should only be performed once during physical examination

N. Up to 33%

O. Over 33%

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. What advice on manual manipulation of the pelvis is not included in the ninth edition of the ATLS Student Manual?
2. What is the risk of death following an open pelvic fracture?
3. What is the first-line method recommended in the ATLS Manual for stabilizing the pelvis before transferring the patient from a hospital that does not have the resources to definitively manage the degree of associated haemorrhage seen in a major pelvic disruption?

2. A. Mangled Extremity Severity Score (MESS)
B. Non-union
C. Predictive Salvage Index (PSI)
D. Ganga Hospital limb salvage score
E. Osteomyelitis
F. Limb Salvage Index (LSI)
G. Satisfaction is far higher in the early amputation group than in the reconstruction group
H. Satisfaction of patients with foot and ankle injuries who require free tissue transfer or ankle fusion is significantly better than those with below knee amputation
I. Nerve injury, ischaemia, soft tissue injury, skeletal injury, shock, and age of patient score (NISSA)
J. Late amputation
K. Wound infection
L. None of the above
M. Wound dehiscence
N. Patient satisfaction after treatment of lower extremity injury is predicted more by function, pain, and the presence of depression at 2 years than comorbidities, injury, or treatment

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. According to the findings of the LEAP Study Group, which scoring systems is most predictive of functional outcome following limb reconstruction after severe lower extremity trauma?
2. The LEAP study included 371 patients who had had limb salvage procedures. The study established that this group had more complications and more re-admissions to hospital. Which was the most common complication reported?
3. Which of the statements concerning patient satisfaction is correct with regard to the findings of the LEAP Study Group?

3. A. 11
B. 15
C. 34
D. 36
E. 41
F. 49
G. Injury Severity Score (ISS)
H. New Injury Severity Score (NISS)
I. Modified Injury Severity Score (MISS)

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. The ISS for a patient with an open pelvic fracture (Abbreviated Injury Score, AIS = 4), open femoral shaft fracture (AIS = 3), splenic rupture (AIS = 4), fractured mandible (AIS = 2), and three broken ribs (AIS = 2).
2. The best predictor of mortality in adult orthopaedic blunt trauma.
3. The most appropriate scoring system for paediatric trauma.

4. A. Anatomical reduction (closed or open) and cannulated screw fixation
B. Bipolar cemented hemiarthroplasty
C. Austin Moore uncemented hemiarthroplasty
D. Non-operative management with traction
E. Cephalomedullary nail fixation
F. Dynamic hip screw fixation
G. Total hip arthroplasty
H. Cemented hemiarthroplasty with unipolar head
I. Internal fixation with cannulated screws
J. Reconstruction femoral nail fixation

Select the best treatment from the list for the following scenarios.

1. A 70-year-old woman trips whilst walking her dog before going to work as a volunteer at your hospital. She sustains a displaced intracapsular fracture of the neck of the femur.
2. A 55-year-old man is injured after falling from a ladder at work. He sustains a displaced subcapital fracture of the neck of the femur.
3. A 75-year-old lady woman at home and sustains an intertrochanteric fracture of the femur. She has a history of breast cancer with known skeletal metastases and there is a lytic lesion in the per-trochanteric region.

5. A. 2%
B. 50%
C. 20%
D. Thin-slice (2–3 mm) helical CT
E. Flexion/extension views
F. Pressure sores
G. Plain radiography
H. MRI scanning
I. Pulmonary complications

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which investigation is the urgent investigation of choice for spinal cord injury?
2. Which are associated with spinal immobilization for longer than 48 hours?
3. What percentage of spinal injuries occur at two levels?
4. Which investigation is insensitive for the neck and upper thoracic spine?

6. A. 6 hours
B. 12 hours
C. 24 hours
D. 48 hours
E. 72 hours
F. 5 days
G. 1 week
H. 10 days

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Following an acetabular fracture, chemical thromboprophylaxis should be started within how long after the injury?
2. Following a pelvic ring fracture, images should be transferred to a hospital specializing in pelvic surgery within how long after the injury?
3. Displaced fractures requiring reduction and internal fixation should undergo surgery by an acetabular reconstruction expert within a maximum of how long following injury?

7. A. Contamination with marine, agricultural, or sewage matter
B. Lower limb splinting (including knee and ankle)
C. Intravenous antibiotics
D. Primary surgical treatment (wound excision and fracture stabilization)
E. Saline-soaked gauze dressing, impermeable film
F. Definitive skeletal and soft tissue reconstruction
G. Vacuum dressing
H. Antibiotic beads
I. Definitive soft tissue cover
J. Definitive skeletal stabilization

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which procedures should/can be performed at a non-specialist centre?
2. Which procedures should only be planned and performed by senior plastic and orthopaedic surgeons?
3. For which of the options is urgent debridement (within 6 hours) justified?
4. What should be achieved within 72 hours and should not exceed 7 days?
5. What should *not* be considered as definitive wound management in open fractures?

8. A. Anti-embolism stockings
B. Aspirin
C. Foot impulse devices
D. Low molecular weight heparin
E. 28–35 days
F. 10–14 days
G. Intermittent pneumatic compression devices
H. Inferior Vena Cava Filter

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which of these should be prescribed on admission?
2. What drug and duration of use would be appropriate after an elective hip replacement?
3. Which is/are contraindicated in peripheral vascular disease?

chapter

10

ADVANCED TRAUMA LIFE SUPPORT (ATLS), POLYTRAUMA, LIMB SALVAGE, AND UK TRAUMA GUIDELINES

Answers

1. Answers: 1-C; 2-G; 3-J

1. According to the ATLS (and in contrast to other opinions), manual manipulation of the pelvis in a haemodynamically stable patient can aid the diagnosis of a pelvic fracture. ATLS recognizes that doing so can result in further haemorrhage. However, it is recommended that such manual manipulation is not done in a patient with shock and an obvious pelvic fracture, and that when performed it should only be done once. The argument against manual manipulation is very strong—there is risk of further haemorrhage due to displacement of haematoma. Furthermore, the low specificity (71%) and sensitivity (59%) render physical examination a poorly accurate test.
2. The ATLS Manual states that the overall risk of death is up to 50% for an open pelvic fracture and around 17% for all pelvic fractures. These numbers are high compared with more recent published data—10% for a haemodynamically unstable patient with a pelvic fracture managed in a modern trauma system. It is also important to recognize that associated injuries (particularly brain injury) are better predictors of mortality in these patients.
3. Longitudinal traction applied through the skin or the skeleton is suggested as a first-line method to stabilize the pelvis prior to transfer. The Manual goes on to advise that because these injuries externally rotate the hemipelvis, internal rotation of the lower limbs also reduces the pelvic volume. ATLS describes the use of a pelvic binder as a supplement to these manoeuvres. A sheet, pelvic binder, or other device can apply sufficient stability for the unstable pelvis at the level of the greater trochanters of the femur.

American College of Surgeons (2012). *Advanced Trauma Life Support (ATLS) Student Course Manual*, 9th edn. American College of Surgeons,

Bonner TJ, Eardley WGP, Newell N et al. (2011). Accurate placement of a pelvic binder improves reduction of unstable fractures of the pelvic ring. *J Bone Joint Surg Br*, 93, 1524–1528.

Grant PT (1990). The diagnosis of pelvic fractures by 'springing'. *Arch Emerg Med*, 7, 178–182.

Sathy AK, Starr AJ, Smith WR, et al. (2009). The effect of pelvic fracture on mortality after trauma: an analysis of 63,000 trauma patients. *J Bone Joint Surg Am*, 91-A, 2803–2810.

Sauerland S, Bouillon B, Rixen D, et al. (2004). The reliability of clinical examination in detecting pelvic fractures in blunt trauma patients: a meta-analysis. *Arch Orthop Trauma Surg*, 124, 123–128.

2. Answers: 1-L; 2-B; 3-N

1. The LEAP Study Group assessed functional outcome using the physical and psychosocial domains of the Sickness Impact Profile (SIP) and compared these with a variety of scoring

systems. None of the scores listed predicted functional outcome at 6 months or 2 years to any reasonable degree, and neither did they predict recovery between those two time points.

2. Of the 371 salvaged limbs included in the LEAP study 3.9% had a late amputation, 23.2% had a wound infection, 8.6% developed osteomyelitis, and 31% went on to non-union. Wound dehiscence was more common in the amputation group. Other complications in the amputation group of 149 patients included revision amputation (5.2%) and wound infection (34.2%).

3. Only option N is supported by the LEAP study data. No patient demographic, treatment, or injury characteristics were found to correlate with patient satisfaction. Only measures of physical function, psychological distress, clinical recovery, and return to work correlated with patient satisfaction at 2 years. Five of these outcome measures accounted for >35% of the overall variation in patient satisfaction; these were return to work, depression, the physical functioning component of the SIP, self-selected walking speed, and pain intensity. The absence of major complications and less anxiety were marginally significant.

Harris AM, Althausen PL, Kellam J, et al.; Lower Extremity Assessment Project (LEAP) Study Group (2009). Complications following limb-threatening lower extremity trauma. *J Orthop Trauma*, 23, 1–6.

Ly TV, Travison TG, Castillo RC, et al.; LEAP Study Group (2008). Ability of lower-extremity injury severity scores to predict functional outcome after limb salvage. *J Bone Joint Surg Am*, 90, 1738–1743.

O'Toole RV, Castillo RC, Pollak AN, et al.; LEAP Study Group (2008). Determinants of patient satisfaction after severe lower-extremity injuries. *J Bone Joint Surg Am*, 90, 1206–1211.

Pollak AN, Jones AL, Castillo RC, et al.; LEAP Study Group (2010). The relationship between time to surgical debridement and incidence of infection after open high-energy lower extremity trauma. *J Bone Joint Surg Am*, 92, 7–15.

3. Answers: 1-D; 2-H; 3-I

The ISS takes the three body regions with the highest AIS and squares each number, before adding them together. The maximum is 75, and any patient with an AIS of 6 in any region automatically scores 75. The NISS accounts for bilateral injuries, i.e. bilateral open femur fractures may be scored twice, giving a more accurate reflection of the severity of injury.

Baker SP, O'Neill B, Haddon W Jr, Long WB (1974). The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*, 14, 187–196.

Harwood PJ, Giannoudis PV, Probst C, Van Griensven M, Krettek C, Pape HC; Polytrauma Study Group of the German Trauma Society (2006). Which AIS based scoring system is the best predictor of outcome in orthopaedic blunt trauma patients? *J Trauma*, 60, 334–340.

Mayer T, Matlak ME, Johnson DG, Walker ML (1980). The Modified Injury Severity Scale in pediatric multiple trauma patients. *J Pediatr Surg*, 15, 719–726.

4. Answers: 1-G; 2-A; 3-E

NICE guidance recommends total hip arthroplasty in patients who are able to walk independently out of doors with no more than the use of a stick, are not cognitively impaired, and are medically fit for anaesthesia and the operation. A recent systematic review supports this recommendation. In young patients (under 60) it is preferable to preserve the femoral head. Anatomical reduction optimizes the chance of union (particularly avoiding varus malreduction). Open reduction (Smith–Petersen or Watson–Jones approaches) may be required. Quality of reduction is now thought to be more important than time to surgery. Where excision and replacement is inappropriate, patients with skeletal femoral metastases should have their whole bone stabilized with a long cephalomedullary nail. On-axis fixation is less likely to fail than an off-axis device (e.g. a dynamic hip screw).

The British Orthopaedic Association has issued guidance on hip fractures in the older person (BOAST 1).

British Orthopaedic Association (2012). BOAST 1: Version 2. https://www.boa.ac.uk/wp-content/uploads/2014/12/BOAST-1.pdf

Hopley C, Stengel D, Ekkernkamp A, Wich M (2010). Primary total hip arthroplasty versus hemiarthroplasty for displaced intracapsular hip fractures in older patients: systematic review *Br Med J*, 340, c2332.

Jacofsky DJI, Haidukewych GJJ (2004). Management of pathologic fractures of the proximal femur: state of the art. *J Orthop Trauma*, 18, 459–469.

National Institute for Health and Care Excellence (NICE) (2011). Hip fracture: the management of hip fracture in adults. *NICE Guideline CG 124*. https://www.nice.org.uk/guidance/cg124

5. Answers: 1-H; 2-F and I; 3-C; 4-G

MRI is the investigation of choice in spinal cord injury. Prolonged immobilization risks pressure sores and pulmonary compromise. Up to 20% of spinal injuries involve two levels. Plain radiographs are not adequate for the investigation of spinal injury. The British Orthopaedic Association has issued guidance on spinal clearance in the trauma patient (BOAST 2).

British Orthopaedic Association (2008). BOAST 2: Spinal clearance in the trauma patient. https://www.boa.ac.uk/wp-content/uploads/2014/05/BOAST-2-Spinal-clearance-in-the-Trauma-Patient.pdf

6. Answers: 1-D; 2-C; 3-H

Chemical thromboprophylaxis should be commenced within 48 hours of injury in acetabular fractures. Image transfer for pelvic trauma patients should occur within the first 24 hours, and acetabular reconstruction should be carried out within 10 days. The British Orthopaedic Association has issued guidance on the management of patients with pelvic and acetabular fractures (BOAST 3).

British Orthopaedic Association (2008). BOAST 3: pelvic and acetabular fracture management. https://www.boa.ac.uk/wp-content/uploads/2014/12/BOAST-3.pdf

7. Answers: 1-B, C and E; 2-D, F, G, and H; 3-A; 4-F; 5-G

Open fractures should be managed in a centre with specialist services on site able to deal with complex orthopaedic and plastic surgery reconstruction. This has been shown to improve outcomes. The 6-hour rule only applies to heavily contaminated wounds, although urgent debridement may be conducted as part of damage-control surgery. The British Orthopaedic Association has issued guidance on the management of severe open lower limb fractures (BOAST 4).

British Orthopaedic Association (2009). BOAST 4: the management of severe open lower limb fractures. https://www.boa.ac.uk/wp-content/uploads/2014/12/BOAST-4.pdf

8. Answers: 1-A, C, and G; 2-D and E; 3-A

NICE has issued clinical guidance (CG92) and quality standards (QS3) on VTE. These detail the preventative measures against VTE for all adults on hospital admission.

National Institute for Health and Care Excellence (NICE) (2010). Venous thromboembolism: reducing the risk of venous thromboembolism (deep vein thrombosis and pulmonary embolism) in patients admitted to hospital. *NICE Guideline CG92*. https://www.nice.org.uk/guidance/cg92

National Institute for Health and Care Excellence (NICE) (2010). Venous thromboembolism prevention quality standard. *NICE Quality Standard QS3*. https://www.nice.org.uk/guidance/qs3

chapter 11

SPINAL TRAUMA

Questions

1. A. MRI
B. CT myelography
C. Standing anteroposterior and lateral radiographs without brace
D. CT
E. Brace and radiograph
F. Anterior corpectomy and lumbar interbody fusion
G. Short-segment posterior stabilization (one above and one below)
H. Long-segment posterior stabilization (two above and two below, at least)
I. Bed rest

For each of the following cases select the most appropriate treatment or investigation from the list. Each option may be used once, more than once, or not at all.

1. An isolated T10 anterior column fracture in a 45-year-old woman without osteoporosis with 15° kyphosis.
2. An isolated L3 burst fracture with 35% retropulsion into the spinal canal on MRI/CT in a 65-year-old woman with osteoporosis and no neurological deficit.
3. An isolated L1 burst fracture in a healthy 35-year-old man with 20° kyphosis

2. A. Posterior C1/2 fusion
B. Cervical orthosis
C. Internal fixation
D. Halo vest
E. Occipitocervical fusion
F. Cervicothoracic brace
G. Observation
H. Gardner-Wells tong traction
I. Anterior C1/2 fusion

For each of the following cases select the most appropriate treatment option from the list. Each option may be used once, more than once, or not at all.

1. A 45-year-old fit and healthy woman with an undisplaced type IIb odontoid peg fracture.
2. A 75-year-old woman with multiple significant medical comorbidities suffering from an undisplaced type IIb odontoid peg fracture.
3. A 23-year-old male mountain biker who crashed at speed suffering from an undisplaced type I traumatic spondylolisthesis of C2 (hangman's fracture).

3. A. Anterior corpectomy with cage and plate fixation
B. Posterior open reduction and internal fixation
C. Closed (Gardner-Wells) tong reduction
D. Anterior discectomy and decompression with attempted open reduction
E. Halo vest
F. Cervical orthosis
G. Posterior short-segment stabilization (one level above and below injury level)
H. Posterior long-segment stabilization (three levels above and below injury level)
I. Cervicothoracic orthosis

For each of the following cases select the most appropriate treatment option from the list. Each option may be used once, more than once, or not at all.

1. A 39-year-old woman with an isolated C6 burst fracture with no neurological deficit, 2 mm of retropulsion into the spinal canal, and MRI scan showing no cord compression or injury to the posterior ligamentous complex.
2. A 27-year-old man who has fallen from a ladder and suffered a bifacet dislocation of C4/5. He has GCS score of 15 and no neurological deficit. MRI scan shows a moderate sized C4/5 disc prolapse touching, but not compressing, the spinal cord.
3. A 72-year-old man with ankylosing spondylitis who has fallen down the stairs and suffered a fracture at C5.

4. A. MRI
B. CT
C. Standing radiographs
D. Short-segment posterior stabilization
E. Anterior corpectomy, cage and plate fixation
F. Thoracolumbar brace
G. Long-segment posterior stabilization
H. Mobilization with standing radiographs
I. Lumbar disc replacement
J. Plain radiographs of the whole spine
K. Repeat examination at 24 hours

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 28-year-old female pedestrian is hit by a car. She suffers polytrauma and is appropriately resuscitated. She complains of back pain in addition to multiple other injuries. She has a GCS score of 15 and no neurological deficit. Select the most appropriate next step in the management of her back injury.
2. A 42-year-old man suffers a paragliding accident when his canopy collapses and he falls 30 m. He complains of severe thoracolumbar back pain and radicular-type pain into his groin. Following appropriate ATLS-based care he is found to have a T12/L1 disc injury with evidence of injury to the posterior ligamentous complex at this level on MRI. There is no bony injury on MRI or initial CT. Select the most appropriate next step in his management.
3. A 70-year-old man with diffuse idiopathic skeletal hyperostosis (DISH) falls down the stairs and suffers an L1/2 fracture–subluxation. He has no neurological deficit. MRI and CT confirm the presence of a fracture through the body of L1 with an associated pars fracture bilaterally. Select the most appropriate next step in his management.

5. A. T2
B. T6
C. T12
D. Walking, bowel, bladder, sexual function
E. Bladder, walking, sexual function, bowel
F. Bladder, bowel, sexual function, walking
G. 4 hours
H. 12 hours
I. 24 hours

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which functions do patients with a spinal cord injury rank (in order of importance) as being most important in their recovery?
2. Patients with a spinal cord injury must be referred (at consultant to consultant level) to a spinal injuries unit within what time to determine the most appropriate management plan (unless a local Trauma Network protocol states otherwise)?
3. Cardiac blood flow, contractility, and arrhythmias including bradycardia can pose significant problems for patients and clinicians when the injury is above which level?

6. A. A fall from a standing or sitting height
B. A RTA
C. A gunshot
D. DISH
E. Ankylosing spondylitis
F. Previous VTE
G. Incomplete spinal cord injury
H. Contact sports
I. Assault

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 30-year-old is most likely to suffer a cervical spine injury as a result of which of these factors?
2. A 69-year-old is most likely to suffer a cervical spine injury as a result of which of these factors?
3. Whether young or old, patients with which diagnosis and a cervical spine injury should have urgent surgical decompression and stabilization to maximize their chance of recovery and minimize morbidity and mortality?

7. A. 20%
B. 30%
C. 40%
D. 50%
E. 20°
F. 10°
G. 2 mm
H. 3.5 mm
I. 5 mm

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. How much loss of vertebral body height is an indicator of instability requiring surgical intervention?
2. Up to how much canal compromise can be tolerated at T12/L1 before persistent neurological deficit can be expected once fracture healing has occurred?
3. How much translation between adjacent vertebrae is predictive of a posterior ligamentous complex injury?

chapter 11

SPINAL TRAUMA

Answers

1. Answers: 1-C; 2-E; 3-H

Kyphosis greater than 20°, significant canal compromise (>50%), or neurological deficit are indications for fixation.

Alaney A, Yazici M, Acaroglu E, Turhan E, Cila A, Surat A (2004). Course of nonsurgical management of burst fractures with intact posterior ligamentous complex: an MRI study. *Spine*, 29, 2425–2431.

Dai LY, Wang XY, Jiang LS (2007). Neurologic recovery from thoracolumbar burst fractures: is it predicted by the amount of initial canal encroachment and kyphotic deformity? *Surg Neurol*, 67, 232–238.

Hashimoto T, Kaneda K, Abumi K (1988). Relationship between traumatic spinal canal stenosis and neurologic deficits in thoracolumbar burst fractures. *Spine*, 13, 1268–1272.

Oner FC, van Gils AP, Dhert WJ, Verbout AJ (1999). MRI findings of thoracolumbar spine fractures: a categorisation based on MRI examinations of 100 fractures. *Skeletal Radiol*, 28, 433–443.

Weninger P, Schultz A, Hertz H (2009). Conservative management of thoracolumbar and lumbar spine compression and burst fractures: functional and radiographic outcomes in 136 cases treated by closed reduction and casting. *Arch Orthop Trauma Surg*, 129, 207–219.

Wood K, Butterman G, Mehbod A, et al. (2003). Operative compared with nonoperative treatment of a thoracolumbar burst fracture without neurological deficit: a prospective, randomized study. *J Bone Joint Surg Am*, 85-A, 773–781.

2. Answers: 1-C; 2-B; 3-B

Unstable fracture patterns, or those which are displaced, require operative intervention if the patient is fit enough. If the fracture is undisplaced, or if stable, a cervical orthosis is sufficient.

Anderson LD, D'Alonzo RT (1974). Fractures of the odontoid process of the axis. *J Bone Joint Surg Am*, 56, 1663–1674.

Bednar DA, Parikh J, Hummel J (1995). Management of type II odontoid process fractures in geriatric patients: a prospective study of sequential cohorts with attention to survivorship. *J Spinal Disord*, 8, 166–169.

Chapman J, Bransford R (2007). Geriatric spine fractures: an emerging healthcare crisis. *J Trauma*, 62(6, Suppl.), S61–S62.

Grauer JN, Shafi B, Hilibrand AS, et al. (2005). Proposal of a modified treatment-oriented classification of odontoid fractures. *Spine J*, 5, 123–129.

[No authors listed]. Isolated fractures of the axis in adults. *Neurosurgery*, 2002, 50(3, Suppl.), S125–S139.

Julien TD, Frankel B, Traynelis VC, Ryken TC (2000). Evidence based analysis of odontoid fracture management. *Neurosurg Focus*, 8, e1.

Koivikko MP, Kiuru MJ, Koskinen SK, Myllynen P, Santavirta S, Kivisaari L (2004). Factors associated with non-union in conservatively treated type II fractures of the odontoid process. *J Bone Joint Surg Br*, 86, 1146–1151.

Li XF, Dai LY, Lu H, Chen XD (2006). A systematic review of management of hangman's fractures. *Eur Spine J*, 15, 257–269.

Nourbakhsh A, Shi R, Vannemreddy P, Nanda A (2009). Operative versus nonoperative management of acute odontoid type II fractures: a meta-analysis. *J Neurosurg Spine*, 11, 651–658.

3. Answers: 1-A; 2-D; 3-H

Cervical fractures involving the posterior longitudinal ligamentous complex are often unstable. The discs provide segment stability and damage to these also confers instability. Ankylosing spondylitis is a relative indication for fixation.

Aebi M, Zuber K, Marchesi D (1991). Treatment of cervical spine injuries with anterior plating: Indications, techniques and results. *Spine*, 16(3, Suppl.), S38–S45.

Caron T, Bransford R, Nguyen Q, Agel J, Chapman J, Bellabarba C (2010). Spine fractures in patients with ankylosing spinal disorders. *Spine*, 35, E458–E464.

Dvorak MF, Fisher CG, Fehlings MG, et al. (2007). The surgical approach to subaxial cervical spine injuries: an evidence-based algorithm based on the SLIC classification system. *Spine*, 32, 2620–2629.

Goffin J, Plets C, Van den Bergh R (1989). Anterior cervical fusion and osteosynthetic stabilisation according to Caspar: a prospective study of 41 patients with fractures and/or dislocations of the cervical spine. *Neurosurgery*, 25, 865–871.

Koivikko MP, Myllynen P, Karjalainen M, Vornanen M, Santavirta S (2000). Conservative and operative treatment in cervical burst fractures. *Arch Orthop Trauma Surg*, 120, 448–451.

Payer M (2005). Immediate open anterior reduction and antero-posterior fixation/fusion for bilateral cervical locked facets. *Acta Neurochir (Wien)*, 147, 509–514.

Razack N, Green BA, Levi AD (2000). The management of traumatic cervical bilateral facet fracture-dislocations with unicortical anterior plates. *J Spinal Disord*, 13, 374–381.

Toh E, Nomura T, Watanabe M, Mochida J (2006). Surgical treatment for injuries of the middle and lower cervical spine. *Int Orthop*, 30, 54–58.

Westerveld LA, Verlaan JJ, Oner FC (2009). Spinal fractures in patients with ankylosing spinal disorders: a systematic review of the literature on treatment, neurological status and complications. *Eur Spine J*, 18, 145–156.

Whang PG, Goldberg G, Lawrence JP, et al. (2009). The management of spinal injuries in patients with ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis: a comparison of treatment methods and clinical outcomes. *J Spinal Disord Tech*, 22, 77–85.

4. Answers: 1-B; 2-D; 3-G

Mechanism of injury alone is enough to trigger the need for a trauma CT scan. The injury to the posterior longitudinal ligament infers instability. Fractures of the pathological spine require long-segment stabilization.

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Gellad FE, Levine AM, Joslyn JN, Edwards CC, Bosse M (1986). Pure thoracolumbar facet dislocation: clinical features and CT appearance. *Radiology*, 161, 505–508.

Lee HM, Kim HS, Kim DJ, Suk KS, Park JO, Kim NH (2000). Reliability of magnetic resonance imaging in detecting posterior ligament complex injury in thoracolumbar spinal fractures. *Spine*, 25, 2079–2084.

Levine AM, Bosse M, Edwards CC (1988). Bilateral facet dislocations in the thoracolumbar spine. *Spine*, 13, 630–640.

Tezer M, Ozturk C, Aydogan M, Mirzanli C, Talu U, Hamzaoglu A (2005). Surgical outcome of thoracolumbar burst fractures with flexion–distraction injury of the posterior elements. *Int Orthop*, 29, 347–350.

5. Answers: 1-F; 2-G; 3-B

Spinal cord injuries are time critical in their initial management. Bladder and bowel function are hugely important for patients in terms of retaining their independence.

Alexander MS, Biering-Sorensen F, Bodner D, et al. (2009). International standards to document remaining autonomic function after spinal cord injury. *Spinal Cord*, 47, 36–43.

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Krassioukov AV, Karlsson AK, Wecht JM, et al. (2007). Assessment of autonomic dysfunction following spinal cord injury: rationale for additions to international standards for neurological assessment. *J Rehabil Res Dev*, 44, 103–112.

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6. Answers: 1-B; 2-A; 3-G

The mechanism of injury can guide you to making the correct diagnosis. Incomplete cord injuries should be treated urgently before they become complete.

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Chapman J, Bransford R (2007). Geriatric spine fractures: an emerging healthcare crisis. *J Trauma*, 62(6, Suppl.), S61–S62.

Fehlings MG, Vaccaro A, Wilson JR, Singh A, Cadotte DW, et al. (2012). early versus delayed decompression for traumatic cervical spinal cord injury: results of the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS). *PLoS One*, 7, e32037. doi:10.1371/journal.pone.0032037

Grauer JN, Shafi B, Hilibrand AS, et al. (2005). Proposal of a modified treatment-oriented classification of odontoid fractures. *Spine J*, 5, 123–129.

Julien TD, Frankel B, Traynelis VC, Ryken TC (2000). Evidence based analysis of odontoid fracture management. *Neurosurg Focus*, 8, e1.

Koivikko MP, Kiuru MJ, Koskinen SK, Myllynen P, Santavirta S, Kivisaari L (2004). Factors associated with non-union in conservatively treated type II fractures of the odontoid process. *J Bone Joint Surg Br*, 86, 1146–1151.

Nourbakhsh A, Shi R, Vannemreddy P, Nanda A (2009). Operative versus nonoperative management of acute odontoid type II fractures: a meta-analysis. *J Neurosurg Spine*, 11, 651–658.

7. Answers: 1-D; 2-D; 3-H

The key figure here is 50%: 50% loss of height or 50% loss of canal volume are indications for surgery.

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Hashimoto T, Kaneda K, Abumi K (1988). Relationship between traumatic spinal canal stenosis and neurologic deficits in thoracolumbar burst fractures. *Spine*, 13, 1268–1272.

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Radcliff K, Su BW, Kepler CK, et al. (2012). Correlation of posterior ligamentous complex injury and neurological injury to loss of vertebral height, kyphosis and canal compromise. *Spine*, 37, 1142–1150.

chapter

12

UPPER LIMB—SHOULDER, HUMERUS, AND ELBOW

Questions

1. A. Anterior band inferior glenohumeral ligament
B. Middle glenohumeral ligament
C. Superior glenohumeral ligament
D. Subscapularis
E. Acromioclavicular ligament
F. Coracoacromio ligament
G. Corococlavicular ligaments
H. Superior labrum
I. Posterior labrum
J. Posterior band inferior glenohumeral ligament

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 26-year-old man sustains a traumatic anterior glenohumeral joint dislocation while playing rugby. He is apprehensive in shoulder abduction and external rotation. Which structure is most likely to have been injured?
2. A 56-year-old man with diabetes presents with increasing pain and stiffness in his right shoulder. He has reduced external rotation on the affected side. Which structure is most likely to have been injured?
3. A 16-year-boy presents with presents with deep-seated shoulder pain following a hand-off whilst playing rugby. Which structure is most likely to have been injured?
4. A 28-year-old mountain biker presents with superior shoulder pain after he landed on his right shoulder following a fall from his mountain bike. There is pain over the acromioclavicular joint but no obvious deformity. Which structure is most likely to have been injured?

2. A. Axillary nerve
B. Lateral antebrachial cutaneous nerve
C. Anterior
D. Musculocutaneous
E. Ulnar nerve
F. Anterolateral
G. Radial nerve
H. Posterolateral

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. During fixation of a humeral shaft fracture using the minimally invasive plate osteosynthesis (MIPO) technique, which nerve can be damaged as it lies between the biceps and brachialis muscles?
2. When applying an external fixator for the treatment of a humeral shaft fracture in a polytrauma patient, pins placed in the midshaft region should be inserted from which approach to avoid injuring the radial nerve?
3. Which nerve is a continuation of the posterior cord of the brachial plexus and passes through the quadrangular space?

3. A. Non-surgical treatment
B. Olecranon osteotomy approach
C. Triceps-sparing approach
D. Triceps-splitting approach
E. Triceps-reflecting approach
F. Percutaneous surgery
G. Total elbow arthroplasty
H. Hemiarthroplasty

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. What treatment or approach would you recommend for an 80-year-old patient with an undisplaced extra-articular fracture of the distal humerus and multiple medical comorbidities?
2. What treatment or approach would you recommend for a 45-year-old patient with severe rheumatoid arthritis who has a multifragmentary fracture of the distal humerus and requests fixation?
3. What treatment or approach would you recommend for a 40-year-old patient with an extra-articular distal humeral fracture?
4. What treatment or approach would you recommend for a 45-year-old patient with a multifragmentary distal humerus fracture and a wound over the distal third of the triceps?

4. A. Obtain CT scan for surgical planning
B. Medial ulnar collateral ligament repair
C. Radial head excision
D. Fragment excision of a Mason II radial head fracture
E. Simple immobilization of the elbow for 6 weeks
F. Radial head replacement with a metallic implant
G. Radial head replacement with a silicon prosthesis (Swanson)
H. Open reduction and internal fixation of the radial head
I. Early active mobilization of the elbow

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 28-year-old man is injured during a skiing accident. He falls onto an outstretched arm. Radiographs demonstrate a comminuted Mason III radial head fracture. There is pain along his forearm and on loading of the DRUJ. What would you recommend?
2. A 40-year-old man falls from the first rung of a ladder and sustains a Mason II radial head fracture, with the fragment comprising 40% of the articular surface. The range of movement is from 15–80° with a clear endpoint, and pronation is restricted to 20°. This range does not improve after aspiration of the joint haematoma. What would you recommend?
3. A 21-year-old woman sustains an isolated Mason I fracture to her radial head after a fall from her bicycle. She is very anxious that her fracture will displace. What would you recommend?

5. A. An associated radial neck fracture is fixed with a plate
B. An associated radial neck fracture is fixed with crossed headless screws
C. The anterior band of the medial collateral ligament (MCL) is over-tensioned
D. An associated coronoid fracture is fixed with a buttress plate
E. A paediatric Monteggia fracture is immobilized for 6 weeks
F. There is failure to recognize a triangular fibrocartilage complex (TFCC) injury
G. Bado type I with a simple fracture of the ulna fixed anatomically using a semi-tubular plate
H. Bado type I with a simple fracture of the ulna fixed anatomically with a locking compression plate
I. Bado type I with a comminuted fracture of the ulna bridged using a locking compression plate
J. Bado type IV fixed anatomically using a Boyd approach
K. Bado type II fixed anatomically using a Kocher approach

The following clinical scenarios are likely to be related to which of these operative treatments of Monteggia and Monteggia variant fractures?

1. Pain-free loss of forearm rotation develops 6 months after surgery.
2. Painful restricted forearm rotation occurs 2 weeks after surgery.
3. Inability to extend the fingers following surgery.

6. A. Non-operative treatment
B. Acute closed reduction and immobilization in external rotation
C. Open reduction
D. Open reduction and transfer of the upper third of the subscapularis
E. Open reduction and the McLaughlin procedure
F. Open reduction and humeral head allograft reconstruction
G. Shoulder arthroplasty
H. Posterior shoulder soft tissue reconstruction

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. What would you recommend for a 28-year-old patient with epilepsy who has an acute posterior glenohumeral joint dislocation with on-going uncontrolled seizures?
2. What would you recommend for a 66-year-old patient with a chronic disabling locked posterior glenohumeral dislocation with a 50% defect in the articular surface?
3. What would you recommend for a 42-year-old patient with a chronic locked posterior dislocation of the humeral head with a 20% defect of the articular surface?

7. A. Ideberg type I
B. Ideberg type II
C. Ideberg type III
D. Ideberg type IV
E. Ideberg type V
F. Double disruption of the superior shoulder suspensory complex
G. Scapulothoracic dissociation
H. Scapula body fracture

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A fracture of the glenoid rim.
2. A fracture of the scapular neck with a concomitant ipsilateral clavicle fracture.
3. A fracture of the superior glenoid fracture extending through base of coracoid.

chapter 12

UPPER LIMB—SHOULDER, HUMERUS, AND ELBOW

Answers

1. Answers: 1-A; 2-B; 3-I; 4-E

This question outlines the major ligamentous structures offering support to the glenohumeral joint. Many are condensations of the capsule. Injuries to different structures will lead to instability in different planes of motion.

Robinson CM, Dobson RJ (2004). Anterior instability of the shoulder after trauma. *J Bone Joint Surg Br*, 86-B, 469–479.

2. Answers: 1-D; 2-F; 3-A

A thorough knowledge of anatomical structures, their course, and variation is essential when performing minimally invasive or percutaneous techniques. Radial nerve injury can be avoided in external fixation by using a mini-open technique for pin placement.

Apivatthakakul T, Patiyasikan S, Luevitoonvechkit S (2010). Danger zone for locking screw placement in minimally invasive plate osteosynthesis (MIPO) of humeral shaft fractures: a cadaveric study. *Injury*, 41, 169–172.

Zlotolow DA, Catalano LW, Barron OA, Glickel SZ (2006). Surgical exposures of the humerus. *J Am Acad Orthop Surg*, 14, 754–765.

3. Answers: 1-A; 2-E; 3-C; 4-B

The indications for non-surgical treatment of distal humeral fractures are very few and include undisplaced fractures and patients who are unwilling to undergo surgery. In rheumatoid arthritis, reflection of triceps takes into account possible progression to a total elbow replacement as it preserves triceps function. Extra-articular and simple articular fractures may be treated by triceps-sparing (paratriceps) approaches, but the lack of an olecranon osteotomy means that an accurate view of the joint is not available. In open fractures, an approach which allows the skin wound to be exploited can be utilized, and multifragmentary intra-articular fractures are best visualized by olecranon osteotomy.

Nauth A, McKee M, Ristevski B, Hall J, Schemitsch E (2011). Current concepts review—distal humeral fractures in adults. *J Bone Joint Surg Am*, 93, 686–700.

O'Driscoll S (2000). The triceps-reflecting anconeus pedicle (TRAP) approach for distal humeral fractures and nonunions. *Orthop Clin North Am*, 31, 91–101.

4. Answers: 1-F; 2-H; 3-I

1. Case 1 implies disruption of the interosseous membrane and the DRUJ (Essex–Lopresti). Radial head excision in this instance risks proximal radial migration and wrist problems. As the fracture is comminuted, arthroplasty is preferred over fixation.
2. Case 2 implies a mechanical block caused by the displaced fragment. While many Mason II fractures can be treated conservatively, this is an indication for fixation. As the fragment comprises more than 25% of the joint surface, fixation is preferred to fragment excision.
3. Case 3 suggests an undisplaced fracture (Mason I). Stiffness is a common problem and early mobilization is key to optimizing functional outcome.

Moro JK, Werier J, MacDermid JC, Patterson SD, King GJ (2001). Arthroplasty with a metal radial head for unreconstructible fractures of the radial head. *J Bone Joint Surg Am*, 83-A, 1201–1211.

Ring D, Quintero J, Jupiter JB (2002). Open reduction and internal fixation of fractures of the radial head. *J Bone Joint Surg Am*, 84-A, 1811–1815.

Sowa DT, Hotchkiss RN, Weiland AJ (1995). Symptomatic proximal translation of the radius following radial head resection. *Clin Orthop*, 317, 106–111.

5. Answers: 1-J; 2-G; 3-A

It is important to appreciate the complications that may arise as a result of inadequate surgical treatment of these injuries. The first patient is most likely to have a radioulnar synostosis, which more commonly occurs when both bones are fractured at the same level and is compounded by an approach that goes through muscle. The second patient is likely to have had a re-subluxation of the radial head resulting in pain and restricted rotation. This is most likely to occur if the ulna is malreduced, short, or fixed with inadequate hardware such as tubular or reconstruction plates. The third patient has a posterior interosseous nerve (PIN) palsy. This is most likely to occur with exposure beyond the radial neck in a lateral approach. Thus the PIN is more at risk when a plate is applied than when crossed screws are used. The Boyd approach is designed to avoid the PIN.

Ring D, Jupiter J, Simpson S. (1998), Monteggia fractures in adults. *J Bone Joint Surg Am*, 80-A, 1733–1744.

6. Answers: 1-A; 2-G; 3-E

Although reduction of posterior dislocations is important, control of the seizures is more important at this time, both for the patient's general health and also as re-dislocation is very likely. Articular loss of over 50% is an indication for replacement, especially in the elderly. Smaller defects can be filled with subscapularis to prevent them engaging with the glenoid and causing instability.

Cicak N (2004). Posterior dislocation of the shoulder. *J Bone Joint Surg Br*, 86-B, 324–332.

7. Answers: 1-A; 2-F; 3-C

Ideberg produced a classification of scapula fractures. Those associated with clavicle fractures are termed 'floating shoulders'.

Cole P, Gauger E, Schroder L (2012). Management of scapular fractures. *J Am Acad Orthop Surg*, 20, 130–141.

Goss T (1993). Double disruption of the superior shoulder suspensory complex. *J Orthop Trauma*, 7, 99–106.

Ideberg R, Grevsten S, Larsson S (1995). Epidemiology of scapular fractures. Incidence and classification of 338 fractures. *Acta Orthop Scand*, 66, 395–397.

Jones C, Cornelius J, Sietsema D, Ringler J, Endres T (2008). Modified Judet approach and minifragment fixation of scapular body and glenoid neck fractures. *J Orthop Trauma*, 22, 558–564.

chapter 13

UPPER LIMB—FOREARM, WRIST, AND HAND

Questions

1. A. Extensor carpi radialis longus and extensor carpi radialis brevis
B. Extensor carpi ulnaris and flexor carpi ulnaris
C. Anconeus and extensor carpi ulnaris
D. Anconeus and extensor digitorum communis
E. Flexor carpi radialis and pronator teres
F. Brachioradialis and extensor carpi radialis brevis
G. Anconeus and flexor carpi ulnaris
H. Extensor pollicis longus and extensor carpi ulnaris
I. Extensor carpi radialis brevis and extensor digitorum communis
J. Supinator and pronator teres
K. Abductor pollicis longus and extensor carpi ulnaris

For each of the following procedures, choose the option giving the most likely intermuscular plane to be used.

1. Fixation/replacement of the radial head.
2. Dorsal plating of the radial diaphysis.
3. Plate fixation of the ulna diaphysis.

2. A. Annular ligament
B. Central band
C. Radiocarpal joint
D. TFCC
E. Pronator teres
F. Accessory band
G. Distal oblique bundle
H. Radial head
I. Ulna head
J. Proximal oblique cord
K. Membranous part of the interosseous membrane

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which is the primary stabilizer against longitudinal forearm instability?
2. Which is the primary stabilizer of the distal radioulnar joint?
3. Which is the thickest part of the interosseous membrane?

3. A. 0 mm
B. –2 mm
C. + 2 mm
D. +5 mm
E. –5 mm
F. 11°
G. 22°
H. 30°
I. 45°
J. 60°
K. 70°

For each of the radiological parameters below chose the most appropriate 'normal' figure from the list.

1. Ulnar variance.
2. Radial inclination.
3. Teardrop angle.

4. A. Fixation and a concurrent Suave–Kapandji procedure
B. Fixation and above-elbow plaster with forearm supinated
C. Urgent fasciotomy of the hand
D. Commencement of intravenous antibiotics
E. Fixation and carpal tunnel release through a separate incision
F. Suave–Kapandji procedure
G. Fixation and carpal tunnel decompression through an incision zig-zagging across the wrist crease
H. Fixation and injection of the carpal tunnel with a steroid
I. Urgent referral to hand therapy
J. Fixation and TFCC reconstruction with a palmaris longus autograft
K. Darrach's procedure
L. Urgent external fixation and commencement of vitamin C
M. Standard fixation

High-energy distal radius fractures have a high complication rate. Select the most appropriate acute treatment from the list for the following problems.

1. Paraesthesia in the index and middle fingers at the time of surgery.
2. A shiny swollen hand with stiff fingers at follow-up.
3. Instability of the DRUJ 1 year post-operatively.

5. A. Futuro splint
B. Colles' cast
C. Scaphoid cast (thumb included)
D. Above-elbow cast
E. Surgical reduction and fixation
F. Screw fixation with cancellous bone graft
G. Screw fixation with corticocancellous bone graft
H. Vascularized bone grafting
I. Wrist fusion

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 24-year-old man has fallen from his mountain bike and presents immediately to A&E. He has sustained a 2-mm displaced and angulated fracture of the waist of the scaphoid. What is the best management option?
2. A 74-year-old man presents with severe pain and restriction of movement in his wrist. He says he injured his wrist at work 20 years ago. Radiographs show scaphoid non-union advanced collapse (SNAC) with severe degenerative changes in the wrist joint. What is the best management option?
3. A 20-year-old student presents to the hand clinic with a history of an injury in the gym 12 months earlier and persisting wrist pain with a decreased range of movement. She was treated in a Futuro-type splint at the time of the original injury. Radiographs show non-union of the scaphoid with a humpback deformity. What is the best management option?

6. A. Triquetral avulsion fracture
B. Scapholunate ligament rupture
C. Fracture of the hook of the hamate
D. Lunotriquetral ligament injury
E. Pisotriquetral osteoarthritis
F. Kienbock's disease
G. Proximal pole scaphoid fracture
H. Carpal tunnel syndrome
I. Lesser arc injury

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 31-year-old motorcyclist involved in a RTA goes over the bonnet of a car and lands on his wrist. He presents with a painful swollen wrist. The duty doctor tells the on-call team that the patient has a 'signet sign' on the anteroposterior radiograph of the wrist, but no fracture is seen. What is the diagnosis?
2. A golfer presents with hypothenar pain, and when he grips the golf club he gets tingling in his little finger. He denies trauma but did beat a ball out of the rough before the pain and tingling started in his hand. What is the diagnosis?
3. A 26-year-old manual worker takes up road cycling following the success of Team GB in the 2012 Olympics. He develops pain on dorsiflexion of the wrist when he is cycling. When he is not cycling he is left with a low-grade constant pain in the wrist. He denies any trauma. What is the diagnosis?

7. A. Wagner's approach
B. Chamay approach
C. Shot-gun approach
D. Lateral approach
E. Farabeauf approach
F. Brunner incision
G. Volar approach
H. Through the floor of the fifth dorsal compartment
I. Fishmouth approach

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 28-year-old piano player presents with a phalangeal fracture. You want the least chance of extensor tendon adhesions following plate fixation. What is your recommended approach?
2. A 45-year-old painter presents with a comminuted fracture of the base of the first metacarpal which you plan to fix with a plate. What is your recommended approach?
3. What approach would you recommend for a dorsal lip fracture affecting the PIPJ in a university student?

8. A. Central slip injury
B. Volar lip fracture
C. Dorsal lip fracture
D. Soft tissue mallet finger
E. Oblique fracture of the proximal phalanx
F. Pilon fracture of the PIPJ
G. Avulsion fracture of the base of the proximal phalanx
H. Metacarpophalangeal joint dislocation
I. Volar avulsion fracture of distal phalanx

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 22-year-old man with a missed injury of his right index finger has developed a boutonniere deformity. What is your diagnosis?
2. A 28-year-old cricketer sustained injury to his right middle finger and has developed a compensatory swan neck deformity. What is your diagnosis?
3. Which of the injuries would be best managed with a dynamic external fixation?

9. A. Composite flap
B. First dorsal metacarpal kite flap
C. Moberg advancement flap
D. Kutler flap
E. Atasoy flap
F. Heterodigital flap
G. Homodigital flap
H. Cross-finger flap
I. Heal by second intention

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which option would you use for soft tissue coverage in a 26-year-old man who has sustained a finger tip injury of less than 1 cm without exposed bone?
2. Which option would you use for soft tissue coverage in a 35-year-old woman with a volar oblique injury to her middle finger with an exposed phalangeal tip?
3. Which option would you use for soft tissue coverage in a 28-year-old carpenter with a volar oblique injury to his thumb with exposure of the underlying phalanx?

chapter 13

UPPER LIMB—FOREARM, WRIST, AND HAND

Answers

1. Answers: 1-C; 2-I; 3-B

Intermuscular and internervous planes are the basis of most surgical exposures in orthopaedics.

Hoppenfeld S, DeBoer P, Buckley R (eds) (2009). *Surgical Exposures in Orthopaedics: the Anatomic Approach*, 4th edn. Lippincott Williams and Wilkins, Philadelphia, PA.

2. Answers: 1-H; 2-D; 3-B

The radial head is the most important structure in resisting longitudinal migration of the radius. That is why acute resection is not recommended in the trauma setting.

Green JB, Zelouf DS (2009). Forearm instability. *J Hand Surg*, 34, 953–961.

Rozental TD, Beredjiklian PK, Bozentka DJ (2003). Longitudinal radioulnar dissociation. *J Am Acad Orthop Surg*, 11, 68–73.

3. Answers: 1-B; 2-G; 3-K

Remember the rule of 11s: palmar tilt = 11°, radial height = 11°, radial inclination = 22° (11 × 2). The teardrop angle refers to the angle between the central axis of the teardrop and the central axis of the radial shaft, which is normally 70°. In fractures, a change in the teardrop angle indicates the degree of impaction of the lunate fossa and is useful for identifying an intra-articular step on the lateral radiograph.

Ng Y, McQueen MM (2011). What are the radiological predictors of functional outcome following fractures of the distal radius? *J Bone Joint Surg Br*, 93-B, 145–150.

4. Answers: 1-M; 2-I; 3-F

The majority of patients with median nerve symptoms at the time of presentation will recover spontaneously. The nerve injury occurs at the level of the fracture and not in the carpal tunnel so a decompression is rarely required if the fracture is reduced adequately and in a timely fashion. Decompression may in fact increase the complication rate. CRPS is a common complication, and despite an increase in the number of pharmacological therapies available, urgent functional therapy to break the cycle of disuse is essential and should form the mainstay of treatment.

Atkins R (2003). Aspects of current management—complex regional pain syndrome. *J Bone Joint Surg Br*, 85-B, 1100–1106.

Carter P, Stuart P (2000). The Sauve–Kapandji procedure for post-traumatic disorders of the distal radio-ulnar joint. *J Bone Joint Surg Br*, 82-B, 1013–1018.

Odumala O, Ayekoloye C, Packer G (2001). Prophylactic carpal tunnel decompression during buttress plating of the distal radius—is it justified? *Injury*, 32, 577–579.

5. Answers: 1-E; 2-I; 3-G

Stable undisplaced fractures are suitable for non-operative treatment. A Colles' type cast has been shown to be as effective as a scaphoid cast in achieving union with less morbidity and less inconvenience to the patient.

Clay NR, Dias JJ, Costigan PS, Gregg PJ, Barton NJ (1991). Need the thumb be immobilised in scaphoid fractures? A randomised prospective trial. *J Bone Joint Surg*, 73B, 828–832.

Davis TRC (1999). The wrist. In: NJ Barton, P Mulligan (eds) *The Upper Limb and Hand*. WB Saunders, London.

Herbert TJ (1990). *The Fractured Scaphoid*. Quality Medical Publishing, St Louis, MO.

6. Answers: 1-B; 2-C; 3-F

These are all classic descriptions of specific injuries and their related injury mechanisms.

Stanbury S, Elfar J (2011). Perilunate dislocation and perilunate fracture-dislocation. *J Am Acad Orthop Surg*, 19, 554–562.

7. Answers: 1-D; 2-A; 3-B

There are numerous different approaches to various parts of the digits, utilized in different clinical settings.

Day C, Stern P (2011). Fractures of metacarpals and phalanges. In: SW Wolfe, WC Pederson, RN Hotchkiss, SH Kozin (eds) *Green's Operative Hand Surgery*, 6th edn, Vol. 1, pp.239–290. Churchill Livingstone, London.

8. Answers: 1-C; 2-D; 3-F

Dynamic external fixation of the digit, such as with a Suzuki fixator, is useful for providing distraction and movement at the same time in phalangeal pilon fractures.

Day C, Stern P (2011). Fractures of metacarpals and phalanges. In: SW Wolfe, WC Pederson, RN Hotchkiss, SH Kozin (eds) *Green's Operative Hand Surgery*, 6th edn, Vol. 1, pp.239–290. Churchill Livingstone, London.

9. Answers: 1-I; 2-H; 3-C

Various options are available for soft tissue coverage in injuries to the hands and digits.

Day C, Stern P (2011). Fractures of metacarpals and phalanges. In: SW Wolfe, WC Pederson, RN Hotchkiss, SH Kozin (eds) *Green's Operative Hand Surgery*, 6th edn, Vol. 1, pp.239–290. Churchill Livingstone, London.

chapter 14

LOWER LIMB—PELVIS, HIP, FEMUR, KNEE, AND TIBIA

Questions

1. A. Ilioinguinal approach
B. Kocher–Langenbach approach
C. Stoppa approach
D. External fixation using supra-acetabular pins
E. Sacroiliac joint screw fixation
F. Extended iliofemoral approach
G. Trochanteric flip/osteotomy
H. Application of skeletal traction through the distal femur
I. C-clamp
J. External fixation using iliac wing pins

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Through which approach or procedure is the lateral femoral cutaneous nerve most at risk?
2. Which procedure or approach relies entirely on good visualization with image intensification in order to be performed safely?
3. Which procedure or approach is best used for reduction and fixation of an anterior column fracture of the acetabulum accompanied with central dislocation of the hip?
4. Which procedure or approach is the immediate treatment for a vertical shear pelvic ring injury prior to referral to a major trauma centre for definitive fixation?

2. A. Anterior column fracture
B. Posterior column fracture
C. Anterior wall fracture
D. Posterior wall fracture
E. Transverse fracture
F. T-type fracture
G. Transverse + posterior wall fracture
H. Posterior column + posterior wall fracture
I. Anterior column + posterior hemitransverse fracture
J. Associated fracture of both columns

Match the best possible fracture pattern to the following cases.

1. A 27-year-old passenger involved in a RTA complains of pain in her right hip. Her leg is short and internally rotated with an apparent foot drop.
2. A 55-year-old man falls 2.5 m from a ladder onto his right-hand side. An anteroposterior radiograph shows disruption of the iliopectineal and ilioischial lines, and there is a spur sign on the obturator oblique film.
3. A 44-year-old man falls heavily onto his right hip when attempting to re-create the winning Olympic vault at his local gym. On his anteroposterior pelvis radiograph there is disruption of the iliopectineal and ilioischial lines. The CT scan demonstrates that the superior articular surface is in contact with the intact ilium.

3. A. Dynamic hip screw
B. <20 mm
C. Proximal femoral nail
D. Total hip replacement
E. <24 mm
F. Cannulated screws
G. <25 mm
H. Hip hemiarthroplasty
I. <10 mm

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 75-year-old woman who lives independently at home and walks with a stick has fallen, sustaining a minimally displaced intracapsular fractured neck of femur. Which of the options would be the most appropriate treatment for her?
2. What is the ideal tip–apex distance when fixing an extracapsular fracture with a dynamic hip screw?
3. Which is the best treatment option for a 65-year-old previously mobile man with a displaced intracapsular fracture?

4. A. Lateral epiphyseal artery
B. Hemiarthroplasty
C. Immediate application of traction
D. Total hip replacement
E. Femoral osteotomy
F. A two-hole dynamic hip screw
G. Lateral femoral circumflex artery
H. Cannulated hip screws
I. Obturator artery
J. Internal fixation

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which is the main terminal vessel providing blood supply to the femoral head?
2. Which vessel provides blood supply to the inferoanterior part of the femoral head?
3. What is the treatment of choice for a young, extremely active patient with a displaced intracapsular fracture to the neck of the femur?

5. A. Reamed anterograde nail
B. External fixation
C. Reamed retrograde nail
D. Ring fixator
E. Periarticular locked plate
F. Dynamic compression plate
G. Unreamed retrograde nail
H. Above knee amputation
I. Skeletal traction
J. Intensive care unit
K. CT angiogram

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 45-year-old motorcyclist crashes, crosses the central reservation, and sustains an open midshaft femoral fracture. Twenty minutes later, on admission to A&E, he has no pulses distal to the fracture and an on-table angiogram 30 minutes after that demonstrates no distal flow from the level of the fracture site. What should be done/used?
2. A 26-year-old man is thrown from a mechanical rodeo bull in a pub and sustains a closed midshaft femoral fracture and an ipsilateral displaced transverse acetabular fracture. What should be done/used?
3. A 55-year-old woman falls off the big red balls whilst auditioning for Total Wipeout and sustains a spiral third femoral fracture exiting distally at the supracondylar ridge. She has a cruciate-substituting TKR on the same side of uncertain provenance. What treatment is required?

6. A. Hoffa fragment
B. Open injury
C. Posterior condylar resection
D. Floating knee
E. Anterior femoral resection
F. Segond fracture
G. Distal femoral resection
H. Vascular injury
I. Mayo fracture
J. Coronal segment

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Errors with which step in TKR may increase the risk of post-operative fracture?
2. What name is given to an associated fracture in the coronal plane?
3. Which associated injury has an incidence of 5–10% with distal femoral fractures?

7. A. Conservative treatment
B. Intramedullary fixation
C. Fixation with a locking plate and screws
D. Proximal femoral replacement
E. Cable plate fixation ± onlay cortical strut graft
F. Long-stem revision prosthesis
G. Cement-on-cement revision
H. Cable fixation

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which should be used for a Vancouver B1 periprosthetic fracture?
2. Which should be used for a Vancouver B3 periprosthetic fracture?
3. Which should be used for a Vancouver C periprosthetic fracture?

8. A. Hinged brace immobilization allowing flexion of 30–90° for 6 weeks followed by staged ACL reconstruction once knee is pain free and mobile

B. Acute* MCL repair and ACL reconstruction in the same procedure

C. Acute posterolateral corner repair only

D. Acute ACL reconstruction only

E. Acute ACL and PCL reconstruction

F. Hinged brace immobilization allowing flexion of 30–90° for 6 weeks followed by staged posterolateral corner reconstruction and ACL/PCL reconstruction

G. Acute open posterolateral corner repair or reconstruction and arthroscopic ACL and PCL reconstruction at the same surgery

H. Long-leg cast immobilization in extension for 6 weeks then clinical assessment for stability before planning any surgery

I. Immobilization with a knee-spanning external fixator in extension for 6 weeks and then clinical assessment for stability before planning further surgery

*Note: In all cases acute would suggest within 2 weeks of injury.

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 26-year-old female water-skier gets her leg entangled in the towrope, which exerts a varus hyperextension force on the knee. On examination she has recurvatum, grade 3+ lateral collateral ligament laxity, and posterior sag with a grade III posterior draw. MRI shows that all lateral structures are torn as well as complete rupture of both ACL and PCL. The MCL is intact. Which treatment option is most appropriate?
2. A 35-year-man was injured in a motocross accident 2 days previously. There is little haemarthrosis, but he has a grade III Lachman test and grade 3+ MCL opening when stressing. MRI scans show a midsubstance ACL rupture and avulsion of the both superficial and deep MCL off the tibia. Which treatment option is most appropriate?
3. A 21-year-old man sustains a valgus injury in a rugby tackle. He hears a ‘pop’. He presents to the fracture clinic 1 week after his injury. On examination he has grade 2 MCL laxity with a firm endpoint. MRI shows a partial midsubstance MCL tear and a complete ACL rupture. Which treatment option is most appropriate?

9. A. No immobilization, crutches, and weight-bearing as tolerated
B. Cylinder cast/brace immobilization in extension, crutches, and weight-bearing as tolerated
C. Hinged-brace immobilization selectively locked allowing 40–90° of flexion
D. Open reduction and internal fixation on the next available trauma list
E. Medial patellofemoral ligament reconstruction with gracilis tendon autograft
F. Tibial tubercle medialization
G. Tibial tubercle anteriorization
H. Patella tendon shortening
I. Patellectomy

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 17-year-old female gymnast suffers a first time lateral patella dislocation that spontaneously reduced in the gymnasium seconds after her fall. On examination there is minimal swelling. What should you do?
2. A 61-year-old man trips and falls heavily onto his right knee. He presents with an inability to straight leg raise and a comminuted patella fracture is seen on radiographs. What should you do?
3. A 48-year-old man is kicked directly on the patella in a veterans football match. Although painful, he can perform a gentle straight leg raise. Radiographs show a simple transverse patella fracture with a 5-mm gap between the fragments. What should you do?

chapter 14

LOWER LIMB—PELVIS, HIP, FEMUR, KNEE, AND TIBIA

Answers

1. Answers: 1-D; 2-E; 3-A; 4-H

A working knowledge of the basics of surgical approaches to the acetabulum and pelvis is required in the FRCS exam, especially the structures at risk.

Hoppenfeld S, Deboer P, Buckley R (eds) (2009). *Surgical Exposures in Orthopaedics: the Anatomic Approach*, 4th revised edn. Lippincott Williams and Wilkins, Philadelphia, PA

Matta JM (2003). Surgical treatment of acetabular fractures. In: BD Browner, JB Jupiter, AM Levine, PG Trafton (eds) *Skeletal Trauma: Basic Science, Management and Reconstruction*, 3rd edn. Elsevier Publishing, Amsterdam.

2. Answers: 1-D; 2-J; 3-E

LeTournel described the classification of acetabular fractures, from the plain radiographs rather than CT.

Matta JM (2003). Surgical treatment of acetabular fractures. In: BD Browner, JB Jupiter, AM Levine, PG Trafton (eds) *Skeletal Trauma: Basic Science, Management and Reconstruction*, 3rd edn. Elsevier Publishing, Amsterdam.

3. Answers: 1-H; 2-G; 3-D

The tip–apex distance must be less than 25 mm on the combined anteroposterior and lateral radiographs.

Baumgaertner MR, Curtin SL, Lindskog DM, Keggi JM (1995). The value of the tip–apex distance in predicting failure of fixation of peritrochanteric fractures of the hip. *J Bone Joint Surg Am*, 77, 1058–1064.

Baumgaertner MR, Solberg BD (1997). Awareness of tip–apex distance reduces failure of fixation of trochanteric fractures of the hip. *J Bone Joint Surg Br*, 79, 969–971.

Chesser TJS, Handley R (2011). New NICE guideline to improve outcomes for hip fracture patients. *Injury*, 42, 727–729.

Haidukewych GJ (2010). Intertrochanteric fractures: ten tips to improve results. *Instr Course Lect*, 59, 503–509.

Lu-Yao GL, Keller RB, Littenberg B, Wennberg JE (1994). Outcomes after displaced fractures of the femoral neck. A meta-analysis of one hundred and six published reports. *J Bone Joint Surg Am*, 76, 15–25.

Parker MJ, Pryor G, Gurusamy K (2010). Hemiarthroplasty versus internal fixation for displaced intracapsular hip fractures: a long-term follow-up of a randomised trial. *Injury*, 41, 370–373.

4. Answers: 1-A; 2-G; 3-J

Femoral head-preserving surgery relies on the blood supply being intact. A knowledge of the anatomy of the blood supply is required for the exam. The arterial anastomosis changes with age.

Ly TV, Swiontkowski MF (2008). Treatment of femoral neck fractures in young adults. *J Bone Joint Surg Am*, 90, 2254–2266.

Trueta J, Harrison MH (1953). The normal vascular anatomy of the femoral head in adult man. *J Bone Joint Surg Br*, 35, 442–461.

5. Answers: 1-B; 2-C; 3-E

Long-bone fractures, especially of the femur, can cause significant physiological compromise to the patient. The era of damage control surgery focused on temporary stabilization of the femur, with definitive fixation once the patient had been stabilized. Reamed, statically locked anterograde nails are the implant of choice in diaphyseal fractures.

Ricci WM, Gallagher B, Haidukewych GJ (2009). Intramedullary nailing of femoral shaft fractures: current concepts. *J Am Acad Orthop Surg*, 17, 296–305.

6. Answers: 1-E; 2-A; 3-B

Notching of the anterior femoral cortex when performing the anterior femoral cut in TKR reduces resistance to bending forces and may increase the risk of post-operative distal femoral fracture. Distal femur fractures may be extra- or intra-articular, but up to 35% have an associated coronal plane fracture, known as a Hoffa fracture. Vascular injuries may be present in around 2% of cases and usually occur when the distal fragment extends under the pull of the gastrocnemius muscle, injuring the popliteal artery. Five to ten per cent of these fractures occur in the setting of an open injury.

Gwathmey FW Jr, Jones-Quaidoo SM, Kahler D, Hurwitz S, Cui Q (2010). Distal femoral fractures: current concepts. *J Am Acad Orthop Surg*, 18, 597–607.

Lesh ML, Schneider DJ, Deol G, Davis B, Jacobs CR, Pellegrini VD Jr (2000). The consequences of anterior femoral notching in total knee arthroplasty. A biomechanical study. *J Bone Joint Surg Am*, 82-A, 1096–1101.

7. Answers: 1-E; 2-D; 3-C

The Vancouver system is used to classify periprosthetic fractures of the femur. The system describes the location of the fracture, the stability of the implant, and the quality of the bone stock.

Campbell P, McWilliams TG (2002). Periprosthetic femoral fractures. *Curr Orthop*, 16, 126–132.

Haddad FS, Masri BA, Garbuz DS, Duncan CP (1999). The prevention of periprosthetic fractures in total hip and knee arthroplasty. *Orthop Clin North Am*, 30, 191–207.

Learmonth ID (2004). The management of periprosthetic fractures around the femoral stem. *J Bone Joint Surg Br*, 86, 13–19.

Rosenberg AG (2006). Managing periprosthetic femoral stem fractures. *J Arthroplasty*, 21, 101–104.

Schmidt AH, Kyle RF (2002). Periprosthetic fractures of the femur. *Orthop Clin North Am*, 33, 143–152, ix.

Tsiridis E, Haddad FS, Gie GA (2003). The management of periprosthetic femoral fractures around hip replacements. *Injury*, 34, 95–105.

8. Answers: 1-G; 2-B; 3-A

The American Medical Association (AMA) classification of ligament injuries is confusing. There are two components: the severity system (grades I, II, and III) and the laxity system (grades 1+, 2+, 3+). Severity refers to damage to the fibres of the ligament: grade I is tenderness but no laxity; grade II is more fibres disrupted, so more tenderness, but no laxity; and grade III indicates complete disruption of fibres in one area and so laxity occurs. The laxity system is the degree of opening: 1+, 3–5 mm; 2+, 6–10 mm; and 3+, >10 mm.

Midsubstance and femoral avulsion MCL injuries can be treated successfully in a brace for 6 weeks in most cases. The ligament is tight in extension so the brace must block extension. If combined with an ACL injury the knee can be re-examined at 6 weeks and then delayed ACL reconstruction can be planned, but only when the knee is mobile. Operating on a stiff knee does not yield good results. Complete tibial avulsion of the MCL should be treated acutely. One of the key features of Question 2 is the absence of haemarthrosis. These injuries usually disrupt the meniscotibial ligaments, and the synovium is thus breached allowing the joint fluid to leak out in the calf. This type of injury may not heal if the ligament flips over the pes anserinus so that the pes lies interposed between the ligament and the tibia (akin to a Stener lesion in the thumb) and/or there is slow leakage of synovial fluid from a breached capsule, which in itself can prevent healing.

Lateral and posterolateral corner injuries should be addressed quickly. It is reasonable in all cases of multiligament injury to elevate and rest the knee for 7–10 days to allow soft tissue swelling to settle. During this time a MRI and/or CT scan can be obtained and surgery planned. The available literature points to improved knee scores if surgical intervention is early (<2–3 weeks) rather than late. In addition, from a purely surgical perspective, identification of the lateral structures, most importantly the common peroneal nerve, is very difficult once healing has begun.

Myamoto RG, Bosco JA, Sherman OH (2009). Treatment of medial collateral ligament injuries. *J Am Acad Orthop Surg*, 17, 152–161.

Pacheco RJ, Ayre CA, Bollen SR (2011). Posterolateral corner injuries of the knee: a serious injury commonly missed. *J Bone Joint Surg Br*, 93-B, 194–197.

Phisitkul P, James SL, Wolf BR, Amendola A (2006). MCL injuries of the knee—current concepts review. *Iowa Orthop J*, 26, 77–90.

9. Answers: 1-C; 2-D; 3-D

First-time lateral patella dislocations in the absence of significant osteochondral fractures are best treated conservatively. Patellectomy was previously a popular procedure for elderly patients with comminuted patella fractures. However, the outcomes of patellectomy are poor and quadriceps muscle power is reduced by approximately 50%. The modern literature thus suggests that an attempt at reduction and fixation in comminuted fractures and/or partial patellectomy salvaging the largest fragment(s) are/is preferable to total patellectomy in the first instance. Transverse patella fractures with articular surface disruption of >2–3 mm or displacement between the fragments of >1–4 mm should be treated operatively. The technique of choice is tension band wiring. Straight-leg raising in children and healthy adults can often be performed despite patella fracture owing to intact retinacular tissue, and although it is an important part of clinical examination it should not indicate non-operative management. If the patient can tolerate it, a more sensitive test is to extend the knee from a flexed position against gravity.

Carpenter JE, Kasman R, Matthews LS (1993). Fractures of the patella. *J Bone Joint Surg Am*, 75, 1550–1561.

Melvin JS, Mehta S (2011). Patellar fractures in adults. *J Am Acad Orthop Surg*, 19, 198–207.

chapter 15

LOWER LIMB—DISTAL TIBIA, FOOT, AND ANKLE

Questions

1. A. ORIF
B. Intramedullary nail and fibula fixation
C. Isolated fibular fixation
D. Fibular fixation and a spanning external fixator
E. Spanning external fixator
F. Anterolateral approach
G. Posterolateral approach
H. Anteromedial approach
I. Anterior approach
J. Lateral approach

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which approach has superior access to a Chaput–Tilleaux fragment in pilon fractures?
2. Which approach has superior visualization of articular fragments?
3. In pilon fractures with an intact lateral column which is the best technique for maintaining position until soft tissues improve?

2. A. Anterior talofibular ligament
B. Anterior–inferior tibiofibular ligament
C. Posterior inferior tibiofibular ligament
D. Interosseous membrane
E. Superficial deltoid
F. Deep deltoid
G. Supination–external rotation (SER) I
H. SER II
I. SER III
J. SER IV
K. Posterior talofibular ligament PTFL

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. What accounts for approximately 40–45% of the strength of the syndesmosis?
2. SER I injury is confined to which structure?
3. A positive gravity/external rotation stress view represents which type of injury?

3. A. Deltoid ligament
B. Fibular tip
C. Fibula—Weber B level
D. Interosseous membrane
E. Subtalar joint
F. Anterior inferior tibiofibular ligament
G. Posterior inferior tibiofibular ligament
H. Anterior talofibular ligament
I. Fibula—above syndesomosis

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 26-year-old soccer player sustains a twisting injury to his ankle. Radiographs show an increased medial clear space and widened syndesmosis. Which lateral structure do you suspect was first to be injured?
2. In a pronation–external rotation (PER) injury (stage III) of the ankle, which structure is the last to be injured?
3. In a PER injury (stage III) which structure remains intact?

4. A. Anterior talofibular ligament
B. Anterior inferior tibiofibular ligament
C. Shear
D. Calcaneofibular ligament
E. Torsional
F. Anterolateral approach
G. Tension
H. Anteromedial approach
I. Anterior approach

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A vertical medial malleolus fracture with joint comminution is best approached with which incision?
2. Injury to what structure occurs in a stage 1 ligamentous supination–adduction injury?
3. When fixing the medial side in supination–adduction injuries the construct must primarily withstand what force?

5. A. Non-operative
B. Lateral malleolus/fibula
C. Posterior malleolus
D. Medial malleolus
E. High fibula fracture
F. Weber A
G. Weber B
H. Weber C
I. SER III
J. SER IV

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. What must be addressed first to achieve accurate restoration of fibula length in pronation–abduction injuries, with a comminuted fibula and ligamentous posterior injury?
2. The involvement of which structure represents the difference in pronation–abduction type I and type II injuries?
3. Which fracture pattern has the best long-term outcome?

6. A. Periarticular osteopenia
B. Narrowing of the subtalar joint space
C. Relative sclerosis of the talar body
D. Flattening of the talar dome
E. Osteophytes at the medial malleolus
F. Ankle and subtalar joint arthrosis
G. Subchondral sclerosis
H. Talar tilt
I. Trabeculations across the fracture line
J. Callus formation
K. Subchondral radiodense line

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Eight weeks after fixation of a talar neck fracture, which feature on radiographs is considered encouraging?
2. Four months after internal fixation of a talar neck fracture in a 45-year-old labourer, which feature would suggest avascular necrosis?
3. One year after operative treatment of a talar body fracture a 32-year-old soldier presents with hindfoot stiffness

7. A. Medial dislocation
B. Lateral dislocation
C. Posterior dislocation
D. Anterior dislocation
E. Medial dislocation with tibialis posterior blocking reduction
F. Lateral dislocation with tibialis posterior blocking reduction
G. Medial dislocation with peroneal tendons blocking reduction
H. Lateral dislocation with peroneal tendons blocking reduction
I. Extensor tendons and extensor retinaculum
J. Deep peroneal nerve or artery

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which of these subtalar injuries is also described as 'acquired clubfoot'?
2. Which is the most likely pattern of subtalar dislocation following a high-speed injury that cannot be reduced closed?
3. Which subtalar injury occurs with excessive plantar flexion?

8. A. ORIF
B. Primary fusion and ORIF
C. External fixation with a plate
D. Primary fusion with a bone graft
E. Non-operative treatment
F. Brodén view
G. Mortise view
H. Lateral view
I. Harris view
J. Canale view

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which radiographic view is best for visualizing the posterior facet of the calcaneus?
2. Which is the superior surgical option for Sanders type IV fractures?
3. Which view is best for identifying medial wall penetration by screws?

9. A. Lisfranc fracture
B. Stress fracture
C. Jones fracture
D. Fracture of the base of the fifth metatarsal
E. Multiple metatarsal fractures
F. Talonavicular dislocation
G. Cuboid avulsion fracture
H. Nutcracker fracture

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 36-year-old woman fell from a horse but her foot was trapped and twisted in the stirrup as she fell. Examination shows bruising over the midfoot and plantar ecchymosis. What is your diagnosis?
2. A 26-year-old man has been training for the London Marathon. He recently completed a half marathon as part of his training but since then has been unable to run due to a painful right foot. What is your diagnosis?
3. A 34-old-year-old woman twisted her right ankle on the way to a Christmas party. She was wearing a new pair of high heels. Examination shows normal ankle movement. What is your diagnosis?

10. A. Plantar direction
B. Dorsal direction
C. Medial direction
D. Lateral direction
E. Tibialis anterior
F. Tibialis posterior
G. Peroneus longus
H. Peroneus brevis
I. Cervical ligament
J. Bifurcate ligament
K. Spring ligament
L. Lisfranc ligament

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. In disruptions between the medial and intermediate cuneiform what structure is likely to block closed reduction?
2. Which static structure stabilizes the calcaneocuboid joint?
3. In which direction are cuneiform dislocations more common?

11. A. Jones fracture
B. Base of metatarsal fracture (tuberosity)
C. Diaphyseal (shaft) fracture
D. Stress fracture
E. Os versalianum
F. Non-union

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 34-year-old man who enjoys running presents with a 3-week history of aching over the lateral border of his left foot. His symptoms are getting worse, and have forced him to stop running recently. What is your diagnosis?
2. A 14-year-old boy attends the fracture clinic after a minor injury. His parents are very concerned as a doctor in A&E told them there was a fracture. The radiograph shows a thin sliver of sclerotic bone at the base of the fifth metatarsal. What is your diagnosis?
3. A 26-year-old woman inverted her ankle at a party while wearing high heels. Radiographs show an undisplaced fracture of the base of the fifth metatarsal, not extending beyond the articulation between the fourth and fifth metatarsophalangeal joints. What is your diagnosis?

chapter 15

LOWER LIMB—DISTAL TIBIA, FOOT, AND ANKLE

Answers

1. Answers: 1-F; 2-I; 3-E

The Chaput–Tilleaux fragment represents the fragment avulsed from the tibia by the anterior inferior tibiofibula ligament and is therefore best visualized with an anterior lateral approach. The anterior approach would give the best access to medial and lateral articular fracture fragments. External fixation should be considered for all pilon fractures as a staged process until soft tissues are recovered sufficiently to allow for definitive fixation.

Topliss C, Jackson M, Atkins RM (2005). Anatomy of pilon fractures of the distal tibia. *J Bone Jonit Surg Br*, 87-B, 692–697.

2. Answers: 1-C; 2-B; 3-J

The posterior inferior tibiofibular ligament confers 50% of the strength to the syndesmosis. It is the most important stabilizing structure of this joint.

Lauge-Hansen N (1954). Fractures of the ankle III. Genetic roentgenologic diagnosis of fractures of the ankle. *Am J Roentgenol Radium Ther Nucl Med*, 71, 456–471.

Ogilvie-Harris DJ, Reed SC, Hedman TP (1994). Disruption of the ankle syndesmosis: biomechanical study of the ligamentous restraints. *Arthroscopy*, 10, 558–560.

3. Answers: 1-F; 2-D and I; 3-G

In the first question, it is likely that the soccer player has suffered a SER injury as these account for the majority of fractures. The injury commences at the anterior inferior tibiofibula ligament and rotates laterally about the ankle mortise. PER injuries start medially and rotate laterally—stage III is the fibula fracture above the level of the syndesmosis and/or a disruption of the interosseous membrane. In stage III PER injuries, the posterior inferior tibiofibular ligament remains intact.

Lauge-Hansen N (1954). Fractures of the ankle III. Genetic roentgenologic diagnosis of fractures of the ankle. *Am J Roentgenol Radium Ther Nucl Med*, 71, 456–471.

4. Answers: 1-H; 2-A; 3-C

With a medial malleolus push-off fracture and joint comminution a purely medial approach does not allow visualization of the articular surface. Therefore an anteromedial or even an anterior approach allows greater visualization of the joint. The anterior talofibular ligament fails in ligamentous supination–adduction injury initially, followed by the calcaneofibular ligament. The medial malleolus is then pushed off; fixation of this fragment must primarily withstand shear forces.

Lauge-Hansen N (1954). Fractures of the ankle III. Genetic roentgenologic diagnosis of fractures of the ankle. *Am J Roentgenol Radium Ther Nucl Med*, 71, 456–471.

5. Answers: 1-D; 2-C; 3-G

In comminuted fibula fractures of the pronation–abduction mechanism, accurate length and rotation of the fibula is key. One technique is to accurately reduce and stabilize the medial column first, which will reduce the talus and thus help guide accurate restoration of the fibula length. The difference in pronation–abduction injury stage I and stage II is the posterior injury. The injury starts on the medial side with fracture or deltoid ligament rupture and then progresses around posteriorly (and anteriorly simultaneously) and finishes on the lateral side. Stage II PAB injuries are either ligamentous or bony posterior injuries. Weber A fractures were thought to have better outcomes than Weber B or C injuries, but a recent meta-analysis has identified that this is not the case. It has been suggested that the associated chondral damage remains problematic. Weber C fractures represent higher-energy injuries with syndesmotic disruption and are therefore recognized to be associated with worse outcomes.

Stufkens SA, van den Bekerom MP, Kerkhoffs GM, Hintermann B, van Dijk CN (2011). Long-term outcome after 1822 operatively treated ankle fractures: A systematic review of the literature. *Injury*, 42, 119–127.

6. Answers: 1-A; 2-C; 3-B

The incidence of AVN increases with the severity of injury. The more displaced the fracture the greater the damage to the blood supply, especially when parts of the talus dislocate completely. A Hawkin's sign is seen with revascularization of the talar body, represented by subchondral lucency indicating osteoclastic activity returning at between 6 and 8 weeks after surgery.

McBride DJ, Ramamurthy C, Laing P (2005). The hindfoot: calcaneal and talar fractures and dislocations—Part II: Fracture and dislocations of the talus. *Curr Orthop*, 19, 101–107.

7. Answers: 1-A; 2-F; 3-C

Medial subtalar dislocations are described as acquired club foot due to the similarity of their appearance to congenital club foot. Posterior subtalar dislocations occur with plantar flexion and anterior with dorsiflexion. Lateral subtalar dislocations are more often associated with high-energy mechanisms, whilst medial dislocations are lower-energy injuries. With medial dislocations the talar head rests dorsally and reduction can be blocked by extensor tendons, the deep peroneal nerve, or the talonavicular capsule. Reduction of lateral dislocations can be blocked by the tibialis posterior, the joint capsule, or flexor tendons.

Monson ST, Ryan JR (1981). Subtalar dislocation. *J Bone Joint Surg Am*, 63, 1156–1158.

8. Answers: 1-F; 2-B; 3-I

The Brodén view is performed with the foot internally rotated and in neutral flexion. The beam is centred on the lateral malleolus and then angled through 10°, 20°, 30°, and 40° toward the patient's head. The image starts with the posterior part of the facet and then moves anteriorly. The Harris axial view can be taken with the image intensifier in a vertical orientation and the heel placed on the receiver and the forefoot dorsiflexed by 10–20°. This view clearly demonstrates the medial wall, the sustentaculum, and screw penetration. Sanders type IV fractures have superior outcomes with reconstruction and primary fusion.

Sanders R, Fortin P. DiPasquale T, Walling A (1993). Operative treatment in 120 displaced intraarticular calcaneal fractures. Results using a prognostic CT scan classification. *Clin Orthop Relat Res*, 290, 87–95.

9. Answers: 1-A; 2-B; 3-D

Plantar ecchymosis is pathognomonic for Lisfranc injuries.

Coetzee JC, Ly TV (2007). Treatment of primarily ligamentous Lisfranc joint injuries: primary arthrodesis compared with open reduction and internal fixation. *J Bone Joint Surg Am*, 89(Suppl. 2, Pt 1), 122–127.

Deamond EA, Chou LB (2006). Current concepts review: Lisfranc injuries. *Foot Ankle Int*, 27, 653–660.

Egol K, Walsh M, Rosenblatt K, Capla E, Koval KJ (2007). Avulsion fractures of the 5th metatarsal base: a prospective outcome study. *Foot Ankle Int*, 28, 581–583.

10. Answers: 1-A; 2-J; 3-B

The tibialis anterior is attached to the base of the first metatarsal. This is the most likely structure blocking reduction of a medial and intermediate cuneiform disruption. The bifurcate ligament runs from the calcaneus to the cuboid and the navicular and is a static stabilizer. The peroneii are dynamic stabilizers of the calcaneocuboid joint. Due to the shape of the cuneiform bones (smaller plantar, wider dorsally) dislocation here is most often dorsal.

Kelikian AS, Sarrafian SK (eds) (2011). *Sarrafian's Anatomy of the Foot and Ankle: Descriptive, Topographic, Functional*. Lippincott Williams and Wilkins. Philadelphia, PA.

11. Answers: 1-D; 2-E; 3-B

Stress fractures of the foot are common, especially in athletes. An accessory ossicle at the base of the fifth metatarsal is common. Tuberosity fractures do not extend beyond the fourth/fifth metatarsal joint.

Nunley JA (2001). Fractures of the base of the fifth metatarsal. *Orthop Clin North Am*, 32, 171–180.

chapter

16

PAEDIATRIC TRAUMA

Questions

1. A. Sling immobilization
B. Open reduction and plate fixation
C. Closed reduction and intramedullary fixation with elastic nail
D. Intramedullary fixation with a Rockwood pin
E. Closed reduction and immobilization
F. Open reduction and stabilization with an elastic nail
G. Open reduction and soft tissue stabilization
H. Coracoclavicular ligament repair
I. Hook plate fixation

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 7-year-old boy falls from a climbing frame and sustains an isolated, closed midshaft clavicle fracture. It is 100% displaced but the skin is not tented and he is neurovascularly intact. What should you do now?
2. A 16-year-old boy is injured during a rugby tackle whereby he sustained an axial compression to his shoulder. He complains that he is finding it difficult to swallow and breathe. A CT scan confirms the diagnosis. What should you do now?
3. A 13-year-old boy is injured during a football tackle. He has a 100% displaced distal clavicle fracture. This is a closed injury and he is neurovascularly intact. What should you do now?

2. A. Bone scan
B. MRI
C. Ultrasound
D. CT
E. Nerve conduction study
F. Sling immobilization
G. Open reduction and fixation
H. Closed reduction and sling immobilization
I. Shoulder spica cast
J. Closed reduction and percutaneous fixation

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A newborn baby was delivered by traumatic vaginal delivery and the midwife is concerned that her right arm is not moving spontaneously. The paediatric team has performed a radiograph, which is unremarkable, and is seeking your advice on what to do next. Which investigation would be most useful?
2. A 7-year-old boy fell out of tree onto his left outstretched arm and sustained an isolated closed Salter–Harris type II fracture of his proximal humerus. It is angulated 50° into varus and translated half the width of the humeral shaft. How should this be managed?
3. A 15-year-old boy was involved in a RTA and has fractured his femur as well as his proximal humerus. The humeral fracture is closed, angulated 50° into varus, and translated half the width of the humeral shaft. How should his proximal humeral injury be managed?

3. A. Often associated with elbow dislocation
B. Clinically diagnosed as a block to elbow motion
C. The physeal line is intact
D. Absolute indication for surgery
E. The medial epicondyle is not a true epiphysis
F. Is also known as a medial condyle fracture
G. Is often pathological

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which statement applies to a non-displaced medial epicondyle fracture?
2. Which statement applies to a displaced medial epicondyle fracture?
3. Which statement applies to an incarcerated medial epicondyle fracture?

4. A. The fracture line extends medially into the trochlear groove
B. The fracture is displaced with capitellar rotation
C. The fracture line passes through the ossification centre of the capitellum
D. None of the above
E. This fracture pattern is rare
F. The fracture is displaced with trochlear comminution
G. Is associated with ulnar nerve injury

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which statement applies to a Milch type I fracture?
2. Which statement applies to a Milch type II fracture?
3. Which statement applies to an unstable elbow?

5. A. Grade I
B. Avascular necrosis
C. Posterior interosseous nerve injury
D. Grade II
E. Grade III
F. Non-union
G. Anterior interosseous nerve injury
H. Radial nerve injury
I. Ulnar nerve injury

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which nerve injury is most commonly associated with a paediatric radial neck fracture?
2. What is the most common complication associated with open reduction of a radial neck fracture?
3. What is the Judet classification of a radial neck fracture that is angulated $<30°$ and has less than 50% radial diameter translation at the fracture site?

6. A. I
B. Salter–Harris
C. II
D. Thurston Holland
E. Fracture angulation of 30°
F. III
G. Holstein–Lewis
H. Complete displacement of initial injury
I. Isolated distal radial fracture (intact ulna)
J. Watson-Jones
K. IV
L. V
M. Cast index
N. Volkmann
O. Both bones fractured

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. What is the most common grade of Salter–Harris injury seen in fractures of the distal radius?
2. Which metaphyseal fragment is sometimes seen in paediatric distal radial fractures?
3. What is the most significant risk facture for fracture re-displacement after manipulation?

7. A. Gallows traction
B. Spica cast
C. Longitudinal traction
D. Monolateral external fixator
E. Rigid intramedullary nail
F. Flexible nailing
G. Plate fixation
H. Hamilton Russell traction
I. Multiple individual lag screws
J. Circular fixator

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A suitable method for managing femoral fractures in children aged under 18 months.
2. Suitable methods for managing femoral fractures in children aged 2–5 years.
3. Suitable methods for managing femoral fractures in children aged 5–10 years.
4. Suitable methods for managing femoral fractures in children aged 10–15 years.
5. Suitable methods for managing femoral fractures in children aged over 15 years.

8. A. Long-leg cast immobilization and careful observation with serial radiographs
B. Ipsilateral hemiepiphysiodesis
C. Ipsilateral hemiepiphysiodesis and corrective femoral osteotomy
D. Open reduction and internal fixation with partially threaded cancellous screws
E. Closed reduction and percutaneous fixation with partially threaded cannulated screws
F. Contralateral femoral diaphyseal shortening and intramedullary fixation at the conclusion of growth
G. Appropriately timed contralateral distal femoral epiphysiodesis
H. Ipsilateral leg lengthening by distraction osteogenesis
I. Physeal bar resection and interposition of fat

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. A 15-year-old girl presents to A&E after falling from her horse. Radiographs reveal open growth plates and a displaced Salter–Harris type III fracture of the distal femoral epiphysis. Which procedure is most appropriate?
2. A 13-year-old girl sustains a forced hyperextension injury to the knee during netball when another girl lands on her straightened leg. Radiographs reveal a displaced Salter–Harris type II fracture of the distal femoral physis. Which procedure is most appropriate?
3. A 13-year-old boy sustains a displaced Salter–Harris type II fracture of the distal femur that is managed conservatively. Radiography and tomography 9 months later reveal that the fracture has healed without angular deformity but 90% of the distal femoral physis has closed. When measured on a scanogram, the injured extremity is 1 cm shorter than the uninjured one, with all of the discrepancy in the femur. After determination of the patient's skeletal age, the total discrepancy is predicted to be 3.0 cm. Which procedure is most appropriate?

9. A. Patella dislocation
B. Tibial eminence avulsion fracture
C. Tibial tubercle avulsion fracture
D. Medial collateral ligament injury
E. Anterior cruciate ligament rupture
F. Patella tendonitis
G. Patella fracture
H. Posterolateral corner injury
I. Quadriceps tendon rupture

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. An 11-year-old boy falls off his bicycle and presents with a large haemarthrosis but no palpable point bony tenderness. You notice a small bony fragment on the radiographs. What is the diagnosis?
2. When playing football a 14-year-old boy kicks the ground instead of the ball, sustaining a knee injury. He has a moderate haemarthrosis and the range of moment is limited to 20–90°. He is unable to straight leg raise. What is the diagnosis?
3. A 15-year-old girl sustains an injury to her knee whilst changing direction in a netball match. Her mother reports hearing a loud pop from the side-line. What is the diagnosis?

10. A. Varus
B. Valgus
C. Procurvatum
D. Recurvatum
E. Valgus and recurvatum
F. Valgus and procurvatum
G. Varus and recurvatum
H. Varus and procurvatum

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Which is the classic deformity of a non-operatively treated proximal metaphyseal tibial fracture?
2. Which deformity that would be expected with isolated fracture of the tibia at midshaft level?
3. Which deformity would be expected in distal tibia and fibula fracture?

11. A. Tillaux
B. Lateral two-part triplane
C. Medial three-part triplane
D. Lateral three-part triplane
E. Medial two-part triplane
F. Pronation–eversion external rotation
G. Supination–plantar flexion
H. Supination–inversion
I. Supination–adduction

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. Minimal swelling and deformity but pain and tenderness over anterolateral tibia are found with injury mechanism?
2. A Salter–Harris type I distal fibula and Salter–Harris type IV distal tibia are most likely with which mechanism?
3. Which is the commonest variety of triplane?

12. A. 4–10 days
B. 10–14 days
C. 15–21 days
D. 22–28 days
E. Mid clavicle fracture
F. Lateral clavicle fracture
G. Linear skull fracture
H. Rib fractures
I. Metaphyseal corner fracture
J. Spiral femoral shaft fracture
K. Spiral humeral fracture
L. Spiral tibial fracture

For each of the following scenarios select the most appropriate option from the list. Each option may be used once, more than once, or not at all.

1. You are asked for an opinion on the date of a possible non-accidental injury (NAI) in a 1-month-old child. The radiograph demonstrates loss of fracture line and abundant callus, so what is the likely age of this injury?
2. Which fracture has highest specificity for NAI?
3. Which fracture is commonly associated with non-accidental twisting injury?

chapter 16

PAEDIATRIC TRAUMA

Answers

1. Answers: 1-A; 2-G; 3-A

The majority of clavicle fractures in children can be treated non-operatively. The 16-year-old in Question 2, with difficulty swallowing and breathing, has sustained a sternoclavicular joint injury—either a dislocation or more likely at physeal separation. These can often be treated conservatively, but in the case of impingement on midline structures they require reduction and stabilization.

Lenza M, Belloti, JC, Andriolo RB, Gomes dos Santos JB, Faloppa F (2009). Conservative interventions for treating middle third clavicle fractures in adolescents and adults. *Cochrane Database Syst Rev*, (2):CD007121.

Nenopoulos SP, Gigis IP, Chytas AA, Beslikas TA, Nenopoulos AS, Christoforidis JE (2011). Outcome of distal clavicular fracture separations and dislocations in immature skeleton. *Injury*, 42,376–380.

Sarwark JF, King EC, Janicki JA (2010). Proximal humerus, scapula, and clavicle. In: JH Beaty, JR Kasser (eds) *Rockwood and Wilkins' Fractures in Children*, 7th edn, pp.1873–1889. Lippincott, Williams and Wilkins, Philadelphia, PA.

2. Answers: 1-C; 2-F; 3-G

Common injuries to the newborn as a result of traumatic delivery include humeral and clavicle fractures, as well as humeral–physeal separations—best seen on ultrasound. Humeral fractures in children are well tolerated, but relative indications for fixation include increasing age and polytrauma.

Pahlavan S, Baldwin KD, Pandya NK, Namdari S, Hosalkar H (2011). Proximal humerus fractures in the pediatric population: a systemic review. *J Child Orthop*, 5, 187–194.

Pandya NK, Behrends D, Hosalkar HS (2012). Open reduction of proximal humerus fractures in the adolescent population. *J Child Orthop*, 6, 111–118.

Sarwark JF, King EC, Janicki JA (2010). Proximal humerus, scapula, and clavicle. In: JH Beaty, JR Kasser (eds) *Rockwood and Wilkins' Fractures in Children*, 7th edn, pp.1873–1889. Lippincott, Williams and Wilkins, Philadelphia, PA.

3. Answers: 1-C; 2-A; 3-A, B, and D

Medial epicondyle fractures are common injuries in children and adolescents between the ages of 9 and 14. They account for up to 20% of all elbow fractures in the paediatric population and 60% of cases associated with elbow dislocation. In non-displaced fractures the physeal line remains intact. Clinically, there may be swelling and local tenderness directly over the medial epicondyle. In significantly displaced fractures (>5 mm), the fragment remains proximal to the true joint surface. These can be associated with elbow dislocations. With entrapment of the fragment in the joint the elbow may appear to be reduced. The key clinical finding is often a block to elbow motion, specifically extension. Management of most medial epicondyle fractures remain non-surgical, generally consisting of immobilization for 4 weeks in a long arm cast with the elbow flexed to 90°. Documented absolute indications for surgical intervention include open fractures and fracture fragments incarcerated in the joint. Relative surgical indications include ulnar nerve dysfunction and valgus instability of the elbow, as well as high-demand upper extremity function.

Akbarnia BA, Silberstein MJ, Rende RJ, et al. (1986). Arthrography in the diagnosis of fractures of the distal end of the humerus in infants. *J Bone Joint Surg*, 68A, 599–601.

Dias JJ, Johnson GV, Hoskinson J, Sulaiman K (1987). Management of severely displaced medial epicondyle fractures. *J Orthop Trauma*, 1, 59–62.

Hines RF, Herndon WA, Evans JP (1987). Operative treatment of medial epicondyle fractures in children. *Clin Orthop Relat Res*, 223, 170–174.

Kamath AF, Baldwin K, Horneff J, Hosalkar HS (2009). Operative versus nonoperative management of pediatric medial epicondyle fractures: a systematic review. *J Child Orthop*, 3, 345–357.

Papavasiliou VA (1982). Fracture-separation of the medial epicondylar epiphysis of the elbow joint. *Clin Orthop Relat Res*, 171, 172–174.

Pimpalnerkar AL, Balasubramaniam G, Young SK, Read L (1998). Type four fracture of the medial epicondyle: a true indication for surgical intervention. *Injury*, 29, 751–756.

Wilkins KE (1991). Fractures involving the medial epicondylar apophysis. In: CA Rockwood Jr, KE Wilkins, RE King (eds), *Fractures in Children*, 3rd edn, pp 509–828. JB Lippincott, Philadelphia, PA.

Wilson NI, Ingram R, Rymaszewski L, Miller JH (1988). Treatment of fractures of the medial epicondyle of the humerus. *Injury*, 19, 342–344.

4. Answers: 1-C and E; 2-A; 3-B

Fractures of the lateral condyle commonly occur in children between the ages of 5 to 10. Milch described two types of lateral condyle fractures. In Milch type I the fracture extends through the ossification centre of the capitellum and enters the joint lateral to the trochlear groove. In Milch type II the fracture extends medially into the trochlear groove. The most widely used system (not identified by name) identifies three fracture patterns. In a type I fracture, the articular surface is intact and the fracture is non-displaced and stable. In types II and III, the fracture enters the joint. Type II fractures are minimally displaced (2–3 mm); type III fractures are displaced >4 mm and may be rotated. Type I fractures and type II fractures displaced <2 mm may be treated by closed means. Closed reduction and percutaneous pinning should be attempted in type II fractures displaced by 2–3 mm; however, if anatomical reduction is not obtained, open reduction and internal fixation is required. Type II fractures displaced >2–3 mm and all type III fractures are unstable and should be treated with open reduction and internal fixation.

Foster DE, Sullivan JA, Gross RH (1985). Lateral humeral condylar fractures in children. *J Pediatr Orthop*, 5, 16–22.

Milch H (1964). Fractures and fracture dislocations of the humeral condyles. *J Trauma*, 15, 592–607.

Mintzer CM, Waters PM, Brown DJ, Kasser JR (1994). Percutaneous pinning in the treatment of displaced lateral condyle fractures. *J Pediatr Orthop*,14, 462–465.

Sullivan JA (2006). Fractures of the lateral condyle of the humerus. *Am Acad Orthop Surg*, 14, 58–62.

5. Answers: 1-C; 2-B; 3-D

Radial neck fractures in children can be classified using the Judet system. Nerve injuries are common, especially the PIN. AVN can occur if excessive dissection is used during open reduction.

Klitscher D, Richter S, Bodenschatz K, et al. (2009). Evaluation of severely displaced radial neck fractures in children treated with elastic stable intramedullary nailing. *J Pediatr Orthop*, 29, 698–703.

Pring ME (2012). Pediatric radial neck fractures: when and how to fix. *J Pediatr Orthop*, 32(Suppl. 1), S14–S21.

Tibone JE, Stoltz M (1981). Fractures of the radial head and neck in children. *J Bone Joint Surg Am*, 63, 100–106.

6. Answers: 1-C; 2-D; 3-H

The Salter–Harris classification describes physical fractures in children. Type II are the most common, and initial displacement is the biggest predictor of re-displacement.

Hang JR, Hutchinson AF, Hau RC (2011). Risk factors associated with loss of position after closed reduction of distal radial fractures in children. *J Pediatr Orthop*, 31, 501–506.

Salter RB, Harris WR (1965). Injuries involving the epiphyseal plate. *J Bone Joint Surg Am*, 45A, 587–622.

7. Answers: 1-A; 2-B and C; 3-C and F; 4-D, F, and G; 5-E

The management of paediatric femoral fractures varies with age and also the weight of the child. Social circumstances should be taken into account—more recently a shift towards fixation to allow for earlier discharge has been favoured.

Harvey A, Bowyer G, Clarke N (2002). The management of paediatric femoral shaft fractures. *Curr Orthop*, 16, 293–299.

Hunter J (2005). Femoral shaft fractures in children. *Injury*, 36, S-A86–S-A93.

8. Answers: 1-D; 2-E; 3-G

Distal femoral fractures in children should be recognized and treated promptly. Regular follow-up is required as there is a reported incidence of growth disturbance of up to 40% following this injury. Recommended treatment for undisplaced fractures (Salter–Harris types I–IV) is long leg cast immobilization or hip spica. Displaced fractures require reduction. Type II fractures with small metaphyseal fragments should be fixed with smooth transphyseal K-wires minimizing to a single pass through the physis if possible. Type II fractures with larger metaphyseal fragment can be reduced by closed means and metaphyseal screws can be passed from cortex to cortex without passing through the growth plate. Type III and IV fractures should be reduced via an open incision to ensure articular congruency. Leg length discrepancy of (or predicted to be) <2 cm should be accepted and can be successfully treated with a shoe raise only. Predicted discrepancy of 2–5 cm should be addressed by epiphysiodesis of the contralateral leg with appropriate timing using an Eastwood–Cole chart. Discrepancy of >5 cm is usually beyond catch-up growth and an ipsilateral lengthening procedure should be considered. Significant angular deformity can be addressed with hemiepiphysiodesis and osteotomy in isolation or in combination.

Eastwood DM, Cole WG (1995). A graphic method for timing the correction of leg-length discrepancy. *J Bone Joint Surg Br*, 77, 743–747.

Garrett BR, Hoffman EB, Carrara H (2011). The effect of percutaneous pin fixation in treatment of distal femoral physeal fractures. *J Bone Joint Surg Br*, 93, 689–694.

Zionts L (2002). Fractures around the knee in children. *J Am Acad Orthop Surg*, 10, 345–355.

9. Answers: 1-B; 2-C; 3-E

Although injuries of the anterior cruciate ligament were traditionally thought not to be common in children they are becoming increasingly recognized. A loud pop in a non-contact situation is almost pathognomonic for anterior cruciate ligament rupture in all ages. An important clue to the most likely site of extensor mechanism disruption is age. Although not always the case, the lesion generally becomes more proximal as age increases: <16 years, tibial tubercle avulsion; 16–35, patella tendon rupture; 35–60, patella fracture; >60 years, quadriceps tendon rupture.

10. Answers: 1-B; 2-A; 3-B

The Cozen fracture is the proximal tibial metaphyseal fracture that risks a typical valgus deformity of uncertain aetiology.

Jackson DW, Cozen L (1971). Genu valgum as a complication of proximal tibial metaphyseal fractures in children. *J Bone Joint Surg Am*, 53, 1571–1578.

Jordan SE, Alonso JE, Cook FF (1987). The aetiology of valgus angulation after metaphyseal fractures of the tibia in children. *J Pediatr Orthop*, 7, 450–457.

11. Answers: 1-A; 2-I; 3-D

A Tillaux fracture represents an external rotation force pulling on the unevenly fused distal tibial physis. Some authors believe the Tillaux and triplane fractures are caused by similar mechanisms but with higher energy seen in the triplane. A Tillaux fracture is a more subtle injury, which can easily be missed due to limited clinical and radiographic signs. A Salter–Harris type I distal fibula and Salter–Harris type IV distal tibia represents a pull-off from the fibula and push-off on distal tibia similar to a supination–adduction injury in adults.

Cummings RJ, Shea KG (2010). Distal tibial and fibular fractures. In: *Rockwood and Wilkins' Fractures in Children*, 7th edn, pp. 967–1016. Lippincott, Williams and Wilkins, Philadelphia, PA

Dias LS, Tachdjian MO (1978). Physeal injuries of the ankle in children. *Clin Orthop*, 136, 230–233.

El-Karef E, Sadek HI, Nairn DS, et al. (2000). Triplane fracture of the distal tibia. *Injury*, 31, 729–736.

12. Answers: 1-B; 2-H; 3-I

NAI must always been suspected in children, especially those who are not yet walking. Specific pathways for investigation and management should be in place in all institutions caring for children with fractures.

Carty H (1997). Non-accidental injury: a review of the radiology. *Eur Radiol*, 7, 1365–1376.

Jayakumar, MB, Ramachandran M (2010). Orthopaedic aspects of paediatric non-accidental injury. *J Bone Joint Surg Br*, 92-B, 189–195.

Worlock P, Stower M, Barbor P (1986). Patterns of fractures in accidental and non-accidental injury in children: a comparative study. *Br Med J*, 293, 100–102.

Part 3 **Vivas**

chapter 17

ANATOMY AND APPROACHES

A description of a surgical approach, or a question on surgical anatomy, will come up at least twice during your vivas, and often within the trauma viva. It is essential to pick up these easy marks—they are not trick questions, the answer is set and non-negotiable (anatomy is not that variable!): it is how you deliver the facts that will set you apart from others. Often an approach question will be used to get you some marks on the scoreboard before you even start to talk about how to fix the fracture.

When describing a surgical approach, first and foremost it is best to speak as if you yourself have done the operation before: try not to regurgitate a book. Imagine you are telling a story, or describing the approach to someone over the phone. Use phrases such as 'I centre my longitudinal incision over . . . ' or 'I often see a haematoma in this plane . . . ' to personalize your description. It tells the examiner you know what you are talking about and prevents him or her from pushing you on the minutiae.

Your description of every surgical approach should begin with a brief gambit on preparing the patient for surgery. An example of this could include:

> Having prepared and consented the patient for theatre, I will . . .

It sounds better to phrase it like this than go through each pre-operative step verbatim. If the examiner wants to probe you on this he or she will, but otherwise you need to just offer it up. You must not forget to mention these important steps however.

The next thing to say is how you would set the patient up:

> . . . I would position the patient supine with an armboard and a high-arm tourniquet and confirm I am able to achieve adequate images with the intensifier. I would then perform a surgical time-out before commencing with routine skin preparation and draping.

Similar to the pre-operative global phrase, this next step is equally important. Again it shows the examiner that you are talking about how you operate on someone, not just on how you do the approach itself. These two phrases together can be adjusted for any approach (i.e. change of position, tourniquet, etc.), but provide a good 15-second starter. This allows you time to remember the next bit—the nitty-gritty of the approach itself!

It is essential that you know about the World Health Organization (WHO) Safer Surgery Checklist, and similar processes, for the exam, as you are being tested on your readiness to become a consultant. These patient safety aspects of your work as a surgeon are as important as knowledge about the conditions and treatments themselves.

All approaches should then be described in a logical standardized fashion. The remainder of this chapter covers the main points for each approach relevant to orthopaedic trauma. It is worth noting this is an *aide-mémoire* and *not* an anatomy text. You should practise personalizing these descriptions with full details.

Firstly you need to describe the way you position (P) the patient, then surgical landmarks (LM) that guide your incision. Many approaches exploit internervous and intermuscular (IN and IM) planes, in both superficial (sup) and deep levels: these need to be described. Structures at risk (SAR) should be mentioned, as should the ability to extend (Ext) the approach proximally or distally. Some approaches have nuances—like the need to change the position of the limb at various stages (e.g. Henry's volar approach to the radius), and one should not forget these important points. Key approaches that you simply must know are in **bold**. Tips (TIP) have been offered for some of the approaches to add a bit more detail to the descriptions.

Spine

Anterior approach to the cervical spine

P	**Beach chair, head in ring, pad between scapulae, neck extended**
LM	**Transverse skin incision at the desired level (fluoroscopic control). Longitudinal incision along the medial border of the sternocleidomastoid if multilevel surgery**
IN/IM	**Superficial—divide platysma (cranial nerve VII)** **Deep—between sternocleidomastoid (spinal accessory nerve) and strap muscles (C1, C2, C3)** **Deepest—between left and right longus colli muscles (segmental branches of cervical nerves)**
SAR	**Recurrent laryngeal nerve (RLN), sympathetic nerve, carotid sheath contents, thyroid arteries, trachea, oesophagus, spinal cord, roots**
Ext	**If planning multilevel surgery, the incision should be along the medial border of the sternomastoid**
TIP	**Mostly an approach of blunt dissection, but know where sharp dissection is required. Right or left sided? Course of the RLN is more variable on the right, but dissection is easier for the right-handed. Modern data suggest the risk to the RLN is similar on both sides so go with whatever dissection is easier for you**

Posterior approach to the cervical spine

P	Prone
LM	Midline incision
IN/IM	Between two paraspinal muscles (segmental supply from posterior rami)
SAR	Vertebral artery, spinal cord, roots, posterior rami
Ext	Longitudinally along the whole spine
TIP	At occiput (Occ)–C1: remember the safe zone is <1.5 cm from the midline (vertebral artery)

Transthoracic approach to the thoracic spine

P	Lateral decubitus. Break in table to open up spaces. Arm in support forward and internally rotated. Double-lumen endotracheal tube
LM	Half-way along medial border of scapula to tip and curve onwards to the mammary crease. Upper thoracic spine (T2–T9) best from the right side to avoid the heart and aortic arch; thoracolumbar spine (T10–L2) best from the left side to avoid the liver. Options are to resect a rib or work along intercostal space just above the rib
IN/IM	None. Splits fibres of latissimus dorsi and serratus anterior
SAR	Intercostal neurovascular (NV) bundle (NVB), lung, great vessels, heart, liver, oesophagus, spinal arteries
Ext	Limited

Posterior approach to the lumbar spine

P Prone, Montreal mattress
LM Midline incision. Level check using XR
IN/IM Between two paraspinal muscles (segmental supply from posterior rami)
SAR Nerve roots, posterior rami
Ext Longitudinally along the whole spine

Paraspinal approach to the lumbar spine (Wiltsie)

P Prone, Montreal mattress
LM Three centimetres from midline on the appropriate side at the correct level (XR control)
IN/IM Between multifidus and longissimus (both posterior rami)
SAR Dorsal root ganglion, nerve roots
Ext Proximally and distally for the whole lumbar spine, but not the contralateral side

Pelvis

Ilioinguinal to acetabulum

P Supine, urinary catheter, radiolucent table
LM Midline 2–3 cm proximal to the symphysis pubis, proceed laterally to the anterior superior iliac spine (ASIS), then along the anterior two-thirds of the iliac crest
IN/IM No true planes. Divide rectus. Medial window = medial to femoral vessels; middle window = between femoral vessels and iliopsoas; lateral window = lateral to iliopsoas
SAR Spermatic cord, inferior epigastric artery, bladder, corona mortis, lateral cutaneous nerve of thigh, femoral artery, vein, and nerve, obturator artery
Ext To the opposite side
TIP Know the three windows you develop and what their boundaries and uses are

Stoppa to acetabulum

LM Transverse incision 2 cm above symphysis (Pfannenstiel)
IN/IM None. Divide the rectus and work deep to vessels
SAR Spermatic cord, inferior epigastric artery, bladder, corona mortis, femoral vessels, obturator vessels
Ext Can use an ilioinguinal lateral window through a separate incision

Kocher–Langenbach to acetabulum

LM Curved incision over greater trochanter (GT)
IN/IM Divide gluteus maximus (inferior gluteal nerve), detach short external rotators, leave quadratus femoris attached (medial circumflex femoral artery, MCFA)
SAR Sciatic nerve, superior and inferior gluteal NVBs, MCFA in quadratus femoris
Ext Osteotomy of GT will allow access to the anterior joint

Shoulder

Clavicle

P Beach chair, pad between shoulder blades, head tilted away

LM Over clavicle, sternoclavicular joint (SCJ) to acromioclavicular joint (ACJ). Can choose bra strap or longitudinal incision just beneath clavicle

IN/IM Divide platysma. Trapezius (accessory nerve) superiorly, pectoralis major (medial and lateral pectoral nerves) inferiorly

SAR Infraclavicular nerves. Subclavian vein

Ext Laterally to ACJ, medially to SCJ (difficult with strap incision)

Deltopectoral to shoulder and proximal humerus

P Beach chair, check fluoroscopy

LM Coracoid, deltopectoral interval, lateral border biceps brachii

IN/IM Pectoralis major (medial and lateral pectoral nerves) and anterior deltoid (axillary nerve)

SAR Cephalic vein, musculocutaneous nerve, axillary nerve

Ext Distally along lateral border of biceps

TIP Identify the long head of biceps tendon (LHB tendon) in groove to help identify greater tuberosity and lesser tuberosity (LT). Do not describe dividision of the capsule and subscapularis in trauma—that is for elective surgery. In trauma, the LT goes with the subscapularis

Posterior to shoulder

P Lateral with arm over gutter

LM Spine of scapula and acromion

IN/IM Infraspinatus (suprascapular nerve) and teres minor (axillary nerve)

SAR Axillary nerve (wrong plane), suprascapular nerve (retraction)

Ext Limited

TIP This approach represents a good opportunity to examine you on the spaces and intervals (quadrangular, etc.). If you can draw a diagram and relate this to your approach it will look slick

Humerus

Lateral to proximal humerus

P Beach chair

LM Lateral acromion, ACJ

IN/IM IM plane between the anterior and middle deltoid

SAR Axillary nerve—about 4.5–7 cm below the acromion (just distal to the bursa)

Ext Limited by the axillary nerve and deltoid insertion

Anterolateral to humerus (proximal to mid third fracture)

P Beach chair

LM Lateral border of biceps brachii

IN/IM Retract biceps medially to expose brachialis. IN plane via brachialis split (musculocutaneous nerve and radial nerve)

SAR Median nerve and brachial artery, musculocutaneous nerve as lateral cutaneous nerve of the forearm distally, radial nerve posteriorly and distally

Ext Proximal (deltopectoral approach) and distally (Henry)

Posterior to humerus (mid to distal third fractures)

P Lateral with arm over padded bolster so forearm hangs downwards

LM Olecranon, mid-posterior arm. Raphe between long and lateral heads of triceps

IN/IM No IN plane. IM proximally between long and lateral heads. Medial head is split

SAR Radial nerve and branches (14 cm from olecranon in spiral groove; pierces lateral IM septum 7.5 cm proximal to the radiocapitellar joint). Profunda brachii artery

Ext Over olecranon along proximal ulna. Not easily extensile proximally

TIP Develop plane between long and lateral heads. Identify nerve in groove. Split medial head which arises distal to the nerve. Draw nerve position related to metalwork in operating notes

Elbow

Posterior to elbow

P Lateral with arm over padded bolster or supine with arm across body

LM Olecranon, epicondyles

IN/IM Proximally triceps split, retracted, or turned down. Distally may perform olecranon osteotomy, triceps-reflecting anconeus pedicle (TRAP) flap, triceps flaps—no IN plane

SAR Ulnar nerve, radial nerve proximolaterally, median nerve and brachial artery anterior to humerus

Ext Proximally posterior humerus, distally along the ulna [IN plane extensor carpi ulnaris (ECU) and flexor carpi ulnaris (FCU): posterior interosseous nerve (PIN) and ulnar nerve]

Medial to elbow

P Supine and arm board with shoulder externally rotated and elbow flexed, or lateral with arm over bolster. High-arm tourniquet

LM Medial epicondyle and medial condylar ridge of distal humerus

IN/IM Proximal between brachialis (musculoskeletal nerve) and triceps (radial nerve). Distal between brachialis and pronator teres (median nerve). Deep—can perform osteotomy of medial epicondyle to improve exposure

SAR Ulnar nerve, medial antebrachial cutaneous nerve, median nerve (traction)

Ext Proximally subperiosteally expose distal humeral shaft, limited by traction of median nerve and anterior interosseous nerve (AIN)

Anterolateral to elbow/distal humerus

P Supine, arm board, high-arm tourniquet

LM Flexor crease of cubital fossa, medial border of mobile wad, lateral border of biceps

IN/IM Proximally between brachioradialis (radial nerve) and brachialis (musculocutaneous nerve). Distally between brachioradialis and pronator teres (median nerve)

SAR Lateral cutaneous nerve of forearm, radial nerve and its terminal branches, recurrent leash of Henry

Ext proximal (anterolateral humerus) and distal (Henry's forearm)

TIP Identify the lateral cutaneous nerve of the forearm and retract medially, use finger to develop a plane between the brachioradialis and brachialis and expose the radial nerve, then follow distally

Lateral to elbow

P Supine, arm board, elbow flexed and pronated, shoulder internally rotated

LM Lateral epicondyle and lateral condylar ridge of distal humerus

IN/IM Proximally brachioradialis (radial nerve) and triceps (radial nerve). Distally elevate common extensor origin to expose the elbow capsule in Kocher's or Kaplan's interval

SAR PIN distally (pronate to aid protection)

Ext Kocher's distally, limited by PIN. Proximally limited by radial nerve

Radial head—Kocher's

P Supine, arm board, elbow flexed and pronated, shoulder internally rotated

LM Lateral epicondyle, subcutaneous border ulna

IN/IM Anconeus (radial nerve) and ECU (PIN)

SAR PIN 4 cm distal to the radiocapitellar joint. Annular ligament. Lateral ulnar collateral ligament

Ext Proximally—lateral distal humerus, but limited

TIP Kaplan's is sometimes used, but this exploits the plane between the extensor digitorum communis (EDC) and extensor carpi radialis brevis (ECRB) and places the PIN at greater risk

Forearm

Henry's volar approach to the radius

P Supine, arm board, arm tourniquet

LM Lateral edge biceps tendon, radial styloid

IN/IM Radial and median. Pronator teres and mobile wad, flexor carpi radialis (FCR) and brachioradialis

SAR PIN, radial artery, superficial radial nerve, lateral cutaneous nerve of forearm, recurrent leash of Henry

Ext Proximally across elbow to anterolateral humerus

TIP For deep dissection discuss structures on the radius and how to expose bone safely. Distally and proximally supinate. Mid-third pronate. This allows elevation of pronator quadratus distally, pronator teres in mid-third, and safe elevation (PIN) of supinator at its origin on the radius. Be able to describe insertions and origins on the radius from proximal to distal

Thompson's dorsal approach to the radius

P Supine, arm board, arm tourniquet, shoulder internally rotated, elbow flexed and pronated

LM Lateral epicondyle to Lister's tubercle

IN/IM IM between ECRB (PIN) and EDC (PIN) proximally and EDC and extensor pollicis longus (EPL) distally

SAR PIN—must identify supinator and find PIN before exposing the proximal third of the radius
Ext Distally over wrist joint. Need to retract abductor pollicis longus (APL) and extensor pollicis brevis (EPB) as they cross the field in the distal third

Ulna

P Supine, arm table, elbow flexed
LM Subcutaneous border of ulna
IN/IM ECU (PIN) and FCU (ulna)
SAR Dorsal cutaneous branch of the ulnar nerve 5 cm proximal to the ulnar styloid
Ext Proximal into posterior elbow approach

Wrist

FCR bed for volar plating

P Supine arm board, tourniquet
LM FCR tendon, distal wrist crease
IN/IM FCR (median) and brachioradialis (radial) then deep flexor pollicis longus (FPL) (AIN) and brachioradialis (radial)
SAR Median nerve, radial artery, superficial radial nerve
Ext Do not extend into carpal tunnel (threaten palmar cutaneous nerve). Proximal into Henry's

Carpal tunnel

P Supine arm board tourniquet
LM Distal wrist crease, radial border ring finger/ulnar border palmaris longus, Kaplan's cardinal line
IN/IM No IM/IN plane
SAR Recurrent motor branch, deep palmar arcade, median nerve
Ext Proximal curvilinear (take curve ulna-wards) into forearm approaches
TIP Be aware of cross-section anatomy and recurrent branch variables

Volar scaphoid

P Supine arm board tourniquet
LM Medial border FCR, palpable tuberosity of scaphoid, distal wrist crease
IN/IM FCR (median) and brachioradialis (radial) (may divide and repair FCR for access)
SAR Median nerve, palmar cutaneous branch, recurrent branch radial artery
Ext Proximal into FCR bed approach and Henry's. May need FCR tenotomy

Dorsal carpal

P Supine arm board tourniquet, forearm pronated
LM Lister's tubercle
IN/IM Through third compartment, and deeper under fourth extensor compartment
SAR EPL, superficial radial nerve, extensor retinaculum
Ext Proximally into Thompson's, distally over third metacarpal (MC)
TIP Centre incision over Lister's. Release EPL/ECRB/ERCL from their sheaths and retract if necessary. Divide extensor retinaculum over third, then head under fourth compartment deep to tendon sheaths and retract tendons ulna-wards. Berger/Mayo flap for capsulotomy aids repair

Metacarpal

P	Supine arm board tourniquet
LM	MC of interest
IN/IM	No. Expose subcutaneous MC and protect extensor tendons
SAR	Tendons, cutaneous nerves
Ext	Distal to proximal phalanx, proximal to carpus

Phalangeal

P	Supine arm board, tourniquet
LM	Metacarpophalangeal joint (MCPJ), proximal interphalangeal joint (PIPJ), mid-lateral border of glabrous skin, mid-dorsal axis
IN/IM	If dorsal, need to divide or reflect central slip at PIPJ. Mid-lateral lowers risk of tendon adhesions but may hinder fracture management
SAR	Extensor mechanism. Digital NVBs
Ext	Proximally to MC approach

Hip

Posterior hip (Moore–Southern)

P	**Lateral decubitus. Pelvic supports to keep pelvis vertical. Arms supported**
LM	**Tip of GT, posterior superior iliac spine (PSIS), lateral border of proximal femur**
IN/IM	**Superficial—splits tensor fascia latae (TFL) and gluteus maximus. Deep—divides short external rotators from GT and piriformis fossa**
SAR	**Sciatic nerve. Femoral nerve (anterior retraction). Gluteus medius. Inferior gluteal NVB**
Ext	**Distally along lateral femur. Proximally to ilium**
TIP	**Now 60% of total hip replacements are done via a posterior approach. Identify sciatic nerve with a digit before dividing rotators. Plan a trans-osseous capsule and rotator repair**

Direct lateral transgluteal hip (McFarland and Osborne/Hardinge/modified Hardinge)

P	**Lateral decubitus. Pelvic supports to keep pelvis vertical. Arms supported. Leg bag**
LM	**Tip of GT. Lateral border of femur**
IN/IM	**Transgluteal. Elevates one-third of gluteus medius and all of gluteus minimus from GT anterior and lateral facets to expose capsule**
SAR	**Superficial gluteal nerve (>4 cm proximal to tip of GT), femoral nerve (retraction)**
Ext	**Distally along lateral femur (less good than posterior approach)**
TIP	**Know the evolutions of this common approach in terms of how the abductors are detached and in which direction they are divided**

Anterolateral hip (Watson–Jones)

P	Supine by edge of table so buttock hangs off side, hip flexed to 30° and adducted
LM	ASIS, GT, femoral shaft. Incision centred over the posterior third of the GT

IN/IM IM (TFL and gluteus medius both superior gluteal nerve)

Superficial—incise fascia lata in line with fibres and retract (taking TFL). Bluntly develop plane between TFL and gluteus medius (vessels to be ligated). Retract abductors laterally. Externally rotate hip to expose anterior capsule

Deep—either trochanteric osteotomy or partial detachment of abductors improves exposure. Bluntly elevate reflected head of rectus femoris off capsule. Capsulotomy

SAR Femoral nerve and vessels if too anterior. Femoral shaft fracture

Ext Distally along entire length of lateral femur

Anterior hip (Smith–Peterson)

P Supine

LM ASIS. Lateral border patella

IN/IM Superficial—sartorius (femoral nerve) and TFL (superior gluteal nerve, SGN)

Deep—rectus femoris (femoral nerve) and gluteus medius (SGN)

SAR Lateral femoral cutaneous nerve (LFCN), ascending branch of the lateral femoral cutaneous artery (LFCA)

Ext Over ileac crest (for paediatrics, developmental dysplasia of the hip, etc.)

TIP Mention incision planning if child/female—consider Langer's lines. If draining septic joint, once at capsule, aspirate joint before arthrotomy to get a good sample. Decide on whether to excise flap of anterior capsule or just leave open and whether to place a drain

Medial hip (Ludlow)

P Supine, radiolucent table, leg in figure 4 position

LM Pubic tubercle, adductor longus

IN/IM Superficial—IM between adductor longus and gracillis

Deep—IN between adductor brevis (anterior division obturator nerve) and adductor magnus (posterior division)

SAR MCFA. Obturator nerve. Iliopsoas tendon

Ext No

Lateral thigh

P Supine, traction table, fluoroscopic control

LM GT and lateral femoral condyle

IN/IM Normally split posterior 1 cm of vastus lateralis, but can go between vastus lateralis (femoral nerve) and biceps femoris (sciatic nerve)

SAR Perforators entering posterior aspect of vastus lateralis

Ext Proximal into lateral or anterolateral hip approaches. Distal into lateral distal femoral condyle

Lateral to distal femur and knee joint

P Supine. Either traction table or radiolucent table and with a bolster under the thigh

LM Lateral border of patella, lateral femoral condyle, and iliotibial band (ITB)

IN/IM Splits ITB. Lateral arthrotomy

SAR Lateral superior geniculate artery

Ext Proximal to lateral thigh

Knee—anterior

P Supine, radiolucent table, thigh tourniquet, knee flexed with foot bolster and side support
LM Tibial tubercle. Patella
IN/IM No. Medial (or lateral) parapatellar approach
SAR Extensor mechanism. Posterior NVB if drilling/introducing metalwork, common peroneal nerve (CPN) laterally
Ext Limited

Posterior knee (midline lazy-S)

P Prone, radiolucent table, thigh tourniquet (not fully exsanguinated), knee flexed 10° with sandbag under ankle
LM Popliteal crease. Heads of gastrocnemius. Tendon of biceps femoris. S-shaped incision—lateral limb proximally and medial distally
IN/IM No IN plane. Exploits fossa between medial and lateral gastrocnemius heads
SAR Small saphenous vein (SSV), sural nerve, tibial nerve, CPN, popliteal vessels
Ext Midline lazy-S is not extensile
TIP For a more extensile exposure to the back of the knee, a full S (as opposed to a lazy-S) can be used. This involves a descending medial limb along the medial border of the gastrocnemius (as per the posteromedial approach to the tibial plateau), a transverse incision across the popliteal fossa in the skin crease, and an ascending lateral limb along biceps femoris. The deep dissection can include a medial release of the tendon of gastrocnemius, and a release of popliteus from the posteromedial border of the tibia to expose the whole posterior tibia. Any more than the medial descending limb of the incision is rarely needed, but it gives a much better exposure to the posterior tibia than a midline lazy-S approach

Posterolateral corner of knee

P Supine, side support and foot rest, thigh tourniquet, knee flexed 90°
LM Proximally along femur, 3 cm lateral to lateral border of the patella, over Gerdy's tubercle distally
IN/IM ITB (superior gluteal nerve) and biceps femoris (sciatic nerve)
SAR CPN (identify and protect—lies on posterior border of the biceps), lateral superior geniculate artery
Ext Proximally along lateral shaft femur. Distally over anterolateral tibia

Proximal tibia anterolateral (plateau fractures)

P Supine, radiolucent table, thigh tourniquet, bolster under thigh, knee flexed 40°
LM Gerdy's tubercle, fibula head, lateral joint line. Straight, oblique, or hockey-stick incision
IN/IM No—elevate/split tibialis anterior from proximal tibia
SAR CPN if you stray posterior to the fibula head, lateral meniscus
Ext Distally along anterolateral tibia
TIP Use a needle to identify the joint line. To visualize the joint, incise capsule along the inferior border of the lateral meniscus, dividing the coronary ligament posteriorly as far as the fibula head. Place sutures in the anterior horn of the lateral meniscus and elevate it to expose lateral tibial plateau and aid reduction

Proximal tibia posteromedial

P Supine, sandbag beneath contralateral buttock, radiolucent table, figure 4 position
LM Posteromedial border of the proximal tibia
IN/IM Between the medial head of the gastrocnemius (tibial nerve) and the posterior tibia/knee capsule
SAR Popliteal NV structures (protected by the medial head of the gastrocnemius)
Ext Distally along the posteromedial tibia (detaching soleus). Detach head of the medial gastrocnemius

Tibial compartment syndrome release

P Supine, sandbag under ipsilateral buttock
LM Tibial crest medial and lateral edges, Incisions full length 2 cm either side of borders
IM/IN No. Entering all four compartments
SAR Medial—saphenous nerve, saphenous vein, and perforators
Lateral—superficial peroneal nerve
TIP Skin bridge minimum 7 cm between incisions. Preserve perforators. Take the soleus off the back of the tibia to enter the deep posterior compartment. Be able to draw the cross-section anatomy at mid-calf level. Mention and be fully familiar with the full versions of the BOAST/BAPRAS guidelines

Distal tibia anterior

P Supine, radiolucent table, thigh tourniquet
LM Tibia anterior, extensor hallucis longus (EHL), and extensor digitorum longus (EDL) tendons
IN/IM IM between tibia anterior/EHL and EDL (all deep peroneal nerve, DPN)
SAR DPN and anterior tibial artery (retract). Superficial peroneal nerve (SPN) laterally. Long saphenous vein (LSV) and saphenous nerve medial
Ext Limited

Posterolateral ankle

P Prone (or sloppy lateral), radiolucent table, thigh tourniquet, lucent bolster under distal tibia to allow ankle to dorsiflex
LM Posterior lateral malleolus/fibula. Lateral border Achilles tendon
IN/IM Between flexor hallucis longus (FHL) muscle belly (tibial nerve) and peroneal tendons (SPN)
SAR Sural nerve. SSV
Ext Proximally in the same plane into the posterolateral tibial approach

Lateral ankle

P Supine, sandbag under ipsilateral buttock
LM Subcutaneous border of fibula. Lateral malleolus
IN/IM Between anterior compartment (DPN) and lateral compartment (SPN)
SAR SPN
Ext Proximally along fibula

Medial ankle

P	Supine, foot externally rotated
LM	Palpable borders of medial malleolus
IN/IM	Between tibialis posterior (tibial nerve) and tibialis anterior (DPN)
SAR	LSV and saphenous nerve
Ext	Distally into medial utility approach over talonavicular joint

Lateral calcaneus

P	Lateral position, thigh tourniquet, radiolucent table
LM	Lateral border Achilles tendon. Glabrous skin border lateral foot. L-shaped incision starting almost midline proximally and curving at the heel (angle of curve >90°) to run along glabrous skin border of the lateral foot. Curve proximally at distal extent for access to calcaneocuboid joint (CCJ)
IN/IM	Respects angiosome in flap that is elevated
SAR	Sural nerve. Peroneal tendons. Soft tissue flap viability
Ext	Limited. High risk of skin flap necrosis

Subtalar/sinus tarsi (minimally invasive to calcaneus)

P	Supine, sandbag under ipsilateral buttock, radiolucent table, thigh tourniquet
LM	Tip of lateral malleolus, proximal fourth ray, sinus tarsi
IN/IM	Between peroneus tertius (DPN) and peroneii (SPN). Detach fat pad and elevate extensor digitorum brevis (EDB) muscle to expose sinus tarsi, subtalar, and Chopart joints
SAR	SPN, peroneal tendons
Ext	Proximally into distal fibula approach

Dorsal foot (Lisfranc)

P	Supine, foot flat, radiolucent table, calf tourniquet
LM	Second metatarsal (MT) shaft, medial border of medial cuneiform
IN/IM	Retract tendons of EDB to expose MT shaft and Lisfranc joint
SAR	DPN, anterior tibial artery
Ext	Distally to metatarsophalangeal joint (MTPJ)
TIP	NVB of DPN and anterior tibial artery dive between the first and second MT shafts and run just medial to the EDB. Most surgeons expose the Lisfranc joint to confirm anatomical reduction. If comminution, bridge fix MT shafts to navicular/talus

Cross-sections

Some approaches lend themselves to questions on cross-sectional anatomy or the use of anatomical specimens. Here we outline the key ones you need to be familiar with. Practice labelling and drawing cross-sections. If given a cross-section, try to relate the anatomy to your surgical approach, for example:

> This is a cross-section of the neck. Working from the outside inwards, and relating this to the anterior approach, I note the platysma, which I split in line with its fibres. Deep to this is the sternocleidomastoid muscle, along whose anteromedial border I incise the first layer of deep fascia. Gently retracting this laterally and the strap muscles medially I bluntly identify the carotid sheath and midline structures . . .

- Cervical spine—relate to anterior approach
- Mid humerus—relate to anterior/lateral and posterior approaches
- Mid forearm—relate to Henry's, Thompson's, and direct ulnar approaches
- Carpal tunnel and palmar spaces
- Hip—relate to common approaches
- Thigh—approaches and fascial compartments
- Mid calf—mark compartments, contents, and fasciotomy incisions

chapter

18

BASIC SCIENCE OF ORTHOPAEDIC TRAUMA

Viva 1 Questions

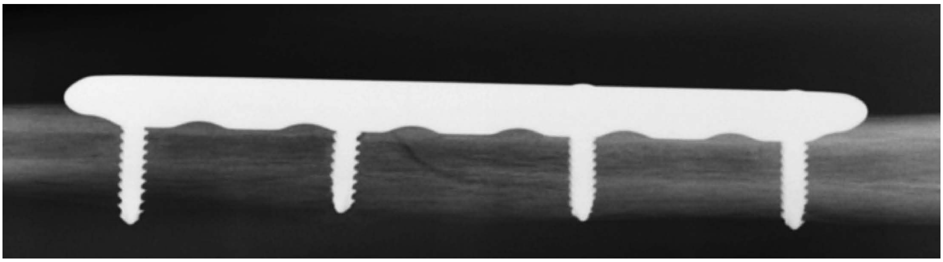

Figure 18.1 Plate fixation of fracture

This image shows a forearm bone fixed with a plate and screws. What type of bone healing would you expect to occur here?

Under what circumstances can the contact healing type of primary/direct bone healing occur?

Describe the Haversian structure of cortical bone.

Can you draw and label a cutting cone?

How can you achieve interfragmentary compression across a fracture in a long bone?

What influences how cortical bone remodels over time?

Viva 1 Answers

This image shows a forearm bone fixed with a plate and screws. What type of bone healing would you expect to occur here?

I would expect primary direct bone healing without callus formation in this situation.

Under what circumstances can the contact healing type of primary/direct bone healing occur?

Primary direct bone healing without callus can only occur with anatomical reduction and rigid internal fixation with compression and absolute stability. Anatomical reduction means a gap of less than 0.01 mm and rigid fixation with interfragmentary compression is characterized by a strain environment of under 2%. These conditions lead to cutting cones forming at the ends of osteons adjacent to the fracture site. They generate longitudinal cavities at a rate of 50–100 μm/day. Subsequently, bone produced by osteoblasts fills these cavities. This results in the simultaneous formation of a bony union and the restoration of Haversian systems formed in an axial direction.

Describe the Haversian structure of cortical bone.

[NB: DRAW A DIAGRAM WHILE YOU TALK.]

Mineralized bone is deposited on concentric lamellae arranged around a central vascular (Haversian) channel containing vessels and nerves. Lacunae containing osteocytes are present between the lamellae and are connected to adjacent lacunae by canaliculi, which facilitate cell-to-cell signalling and nutrient supply. A cement line marks the periphery of an osteon containing the concentric lamellae, lacunae, and Haversian canals. Transverse and oblique Volkmann's canals connect the Haversian canals both to each other and to the endosteal and periosteal vessels. Irregular fragments (interstitial systems) are present between the osteons but are separated from them by cement lines. Inner and outer circumferential lamellae extend around the whole circumference of the cortical bone adjacent to the respective endosteum and periosteum.

Can you draw and label a cutting cone?

[NB: DRAW A DIAGRAM WHILE YOU TALK.]

A cutting cone is characterized by a broad leading front formed of osteoclasts which resorb bone. A narrowing tapered tail—the closing cone, formed of osteoblasts that lay down new bone—follows the cutting cone. The cone is surrounded by lamellar bone, and just behind the lead osteoclasts lies a network of new capillaries.

How can you achieve interfragmentary compression across a fracture in a long bone?

Key to any attempt at gaining compression is the need for bony contact, and in most cases anatomical reduction of the fragments. Assuming this, interfragmentary compression can be achieved by placing a device under tension across the fracture site, which in turn creates compression at the fracture site. There are three main ways in which this can be achieved.

Firstly, it is possible to use a lag screw perpendicular to a fracture plane. In this case, a screw passes through a gliding hole in the near fragment to grip the opposite fragment in a threaded pilot hole, producing interfragmentary compression when it is tightened.

Secondly, one could use a compression plate. The plate should have oval holes through which eccentrically placed screws can be inserted to provide compression across a fracture site. The holes of the plate are shaped like an inclined and transverse cylinder—the screw head slides down the inclined cylinder as it is tightened. This results in the plate (and the previously attached fracture fragment on the opposite side of the fracture) being moved horizontally towards the eccentrically placed screw as it is driven home. For transverse fractures the plate should be slightly pre-bent in order to prevent gapping on the far cortex as tension is applied to the plate. For oblique fractures it is important to apply tension so that the spike of the mobile fragment is pressed into the axilla formed by the plate and the other main fragment.

Finally, you can use an articulated tension–compression device. One side of the fracture is fixed to the plate and on the other side a screw is inserted distal to the end of the plate and through the tension device, which itself is hooked into the last hole of the plate. As the articulated tension–compression device is tightened, it pulls the plate (and the previously attached fracture fragment on the opposite side of the fracture) towards the screw, generating tension in the plate and compression across the fracture site.

What influences how cortical bone remodels over time?

Wolff's law defines the relationship between mechanical stress and bone remodelling. Bone that is subject to compressive loads will be reinforced as osteoblasts are stimulated and additional lamellar bone is deposited. The mechanism for this is piezoelectric charge/polarity; on the compression/concave side of a bone this is electronegative (stimulates osteoblasts) and on the tension/convex side of a bone it is electropositive and stimulates osteoclasts (to resorb bone). There must also be an adequate blood supply and sufficient mechanical stability.

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Viva 2 Questions

Figure 18.2 Tibial nail

What type of fracture healing has occurred in this case?

Describe the stages of secondary fracture healing.

How can you affect this process as a surgeon?

What impact do patient lifestyle factors have on bone healing?

Viva 2 Answers

What type of fracture healing has occurred in this case?

The intramedullary nail provides relative stability. Assuming an adequate blood supply the fracture has healed through callus formation. In orthopaedics we refer to this mode of healing as secondary or indirect healing. The callus that forms will be a mixture of fibrocartilagenous bridging callus (endochondral ossification) and periosteal bony callus (intramembranous ossification).

Describe the stages of secondary fracture healing.

Fracture healing with callus involves a continuum of stages from inflammation and haematoma all the way to bone remodelling. These stages are not mutually exclusive, and in reality the stages happen in parallel rather than rigidly sequentially. Different areas of the fracture may well be subject to different stages of healing as the local strain environment changes within different parts of the fracture site over the course of progression to union.

In essence the phases of fracture healing start with haematoma formation and activation of a local inflammatory cascade. Platelets, polymorphs, macrophages, and osteoclasts aggregate in response to endothelial disruption and the release of pro-inflammatory factors such as IL-1 and IL-6, TGF-β, TNF-α, and PDGF. Dead bone fragments are phagacytosed and fibrin clots are formed. Local strain here will approach 100%. Following this phase, fibroblasts arrive in response to VEGF, forming granulation tissue. This early part of soft callus formation is accompanied by the process of revascularization and neoangiogenesis. Chondrocytes subsequently arrive and form the cartilaginous matrix of the soft callus in response to a strain environment of 2–10%. As the interfragmentary strain reaches levels below 2%, osteogenic cell lines are recruited and osteoblasts are formed, allowing the production of bone (type I collagen matrix). BMPs have an active role at this point. This leads to the formation of hard callus (woven bone) which is ultimately replaced with lamellar bone in response to Wolff's law in the process of remodelling. The continuum lasts for up to 2 years, with the majority of the initial inflammatory and soft callus phases complete by 8–12 weeks.

How can you affect this process as a surgeon?

As a surgeon, I can influence both the biology and the mechanical stability of the fracture environment. Biological interference in the form of soft tissue dissection and stripping can disrupt the healing cascade, as can the introduction of infection. It is essential that a viable blood supply is maintained to the fragments to allow healing to occur, and this has led to the development of minimally invasive operative techniques which often base incisions away from the zone of injury.

The mechanical environment can be manipulated by the surgeon both intentionally and by accident. Failure to achieve reasonable bony contact and alignment may well lead to unacceptably high-strain environments, whilst excessive use of screws and locked implants may induce exceedingly low-strain environments, in effect slowing or even stopping the healing process. There is no way to measure strain clinically at a fracture site, so basic principles such as near–far fixation constructs should be employed to minimize the chance of having a wildly inappropriate level of strain.

What impact do patient lifestyle factors have on bone healing?

Several patient factors beyond medical comorbidities such as diabetes and malnutrition influence bone healing. Smoking has been shown to increase the incidence of delayed and non-union in tibial fractures—indeed even being a previous smoker increases the likelihood of non-union.

Non-steroidal anti-inflammatory drugs (NSAIDs) have also been shown to increase time to union. Interestingly HIV has not been shown to be a risk factor for infection or wound complications in open tibial fractures.

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Viva 3 Questions

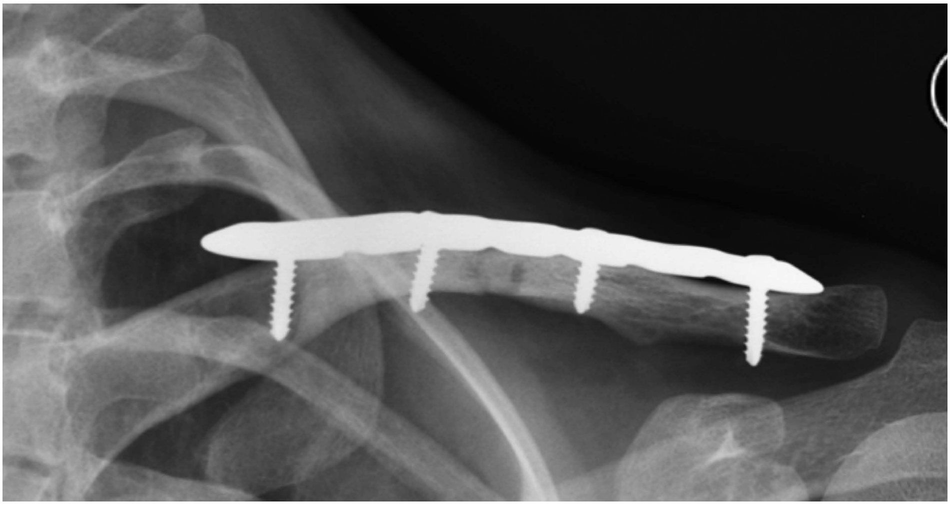

Figure 18.3 Clavicle plate

I am sure you are familiar with images such as this. Given that fractures are frequently treated operatively, what are the biomechanical considerations you need to take into account when undertaking internal fixation?

You decide to use a plate to fix a fracture. How can the design of the plate influence fracture healing?

How does fixation of a transverse mid-diaphyseal fracture with an intramedullary nail compare biomechanically with fixation using a plate?

Viva 3 Answers

I am sure you are familiar with images such as this. Given that fractures are frequently treated operatively, what are the biomechanical considerations you need to take into account when undertaking internal fixation?

The first question I ask myself when fixing a fracture is how do I want the fracture to heal. That is to say, do I intend for secondary healing with callus, or direct primary bone healing without. This guides the biomechanical principles of my fixation construct. In essence I must consider, with any implant I use, the fixation of the implant to the bone, the number of fixation points in each major fragment, the distance between bone ends and also between fixation points, and the geometry and anatomy of the construct itself. Any construct must overcome deforming forces such as bending, torsion, and shear, and this must be taken into account. If I want the fracture to heal by primary direct bone healing, I need a biomechanical construct that can allow me to apply compression to the fracture and maintain that compression. Plates and circular frames are able to do this. A nail, however, is only able to allow for healing by callus, and cannot generate enough tension to translate to adequate compression at the fracture surface for healing by primary means.

It is very important to consider the fracture biology along with the implant biomechanics for fracture healing. Any treatment that involves the use of implants must preserve as much of the blood supply to the bone as possible. The aim of internal fixation is to maintain stable, or relatively stable, fixation for long enough for the fracture to heal without compromising the blood supply to the bone.

You decide to use a plate to fix a fracture. How can the design of the plate influence fracture healing?

Plates can be used in different ways; to neutralize forces after the fracture has been compressed with one or more lag screws, to apply compression, to act as a bridging plate to allow the loads to bypass the fracture, or to act as a buttress. The required level of rigidity is achieved by a combination of implant material, implant design, and surgical application.

Firstly, the material stiffness of the implant is described by the Young's modulus of the material it is made from. A stiff material has resistance to deflection of its internal crystalline structure under a given load. Secondly, the shape of the implant determines its geometric stiffness (its resistance to bending under a given load), which in combination with its material stiffness gives the overall rigidity of the implant. The influence of the shape on the stiffness is calculated using the second moment of area.

For a plate of uniform rectangular cross-sectional contour, making the plate wider will increase its stiffness in direct proportion to the width—doubling the width will double the stiffness. Increasing the thickness will increase the stiffness in proportion to the third power of the thickness—doubling the thickness will make the plate eight times as stiff. For plates of more complex shape calculation of the second moment of area is more complex but the same basic principles apply. Thirdly, the way the plate is applied to the bone, and the bony contact or lack thereof, will influence the rigidity of the construct as a whole.

In the case of conventional plates the fixation strength (as distinct from stiffness) depends upon friction between the plate and the bone—this in turn depends on the compression force applied by the screws. The fracture itself can be compressed on the far side from the plate by contouring the plate. Fixation of an oblique fracture, having been caused by a compressive force in combination with a bending force, will need to resist both these deforming forces, usually by ensuring that the plate is applied to the correct aspect of the bone to form an acute angle into which the other fragment can be compressed.

In the case of locking plates the strength lies in the fixed-angle nature of the whole construct. The stiffness can be reduced by leaving some of the holes unfilled with screws, or by fixing the screws to only one cortex—either the near cortex or the far cortex. The stiffness of a plate/bone construct needs to be matched against the stresses through the plate; if a short working length is used (screws on either side near to the fracture) the strain will be reduced making the construct stiffer but the stresses through the plate will be greater.

How does fixation of a transverse mid-diaphyseal fracture with an intramedullary nail compare biomechanically with fixation using a plate?

A plate is an off-axis fixation, and a nail is an on-axis device—that is to say, assuming the neutral axis of the cylinder of bone is down the centre of the medullary canal, then the nail and the plate will behave differently due to their positions relative to the neutral axis. In on-axis fixations, with intramedullary nails, the forces at the fracture are generally circumferentially even around the device. If I use an off-axis fixation, then I am aware that there are uneven forces acting at the fracture site—there is a low-strain environment under the plate, with increasing strain as you move away from it to the far cortex.

As such, in a plating construct, I try to remain aware of the limitations of fixing a bone with a device that is 'off-axis'. Under a simple bending load in a normal bone of cylindrical shape there will be a tension and a compression surface either side of the neutral axis. The plate would optimally to be applied to the tension side of the bone to resist gapping of the fracture at this surface—it would act as a tension band. If I am forced to plate on the compression side, such as in the volar radial shaft, there is a tendency for the fracture to open up on the tension (dorsal) side. If I need to plate on the compression side, then I like to pre-bend the plate as this can minimize gapping at the far tension cortex by 'pre-stressing' the construct. If I am to use an intramedullary nail, the circumferentially even fracture strain environment is an advantage. The resistance to deformation and bending is pretty much uniform in every direction, unlike the plate.

Other considerations with plates are that, being on the surface, they will take load and relieve stress on the underlying bone. According to Wolff's law bone responds to the loads placed through it, so the bone under the plate may not regain its normal strength, leading to a risk of re-fracture on removal of the plate. There will also be a stress riser at the end of the plate with a risk of fracture at that site if the bone is subject to high force. Using a plate allows me to change the working length of the construct more easily than with a nail, affecting stiffness and resistance to bending. Using a nail is more biologically friendly and also often allows for earlier weight-bearing, especially if there is a lack of bony contact at the fracture site.

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Viva 4 Questions

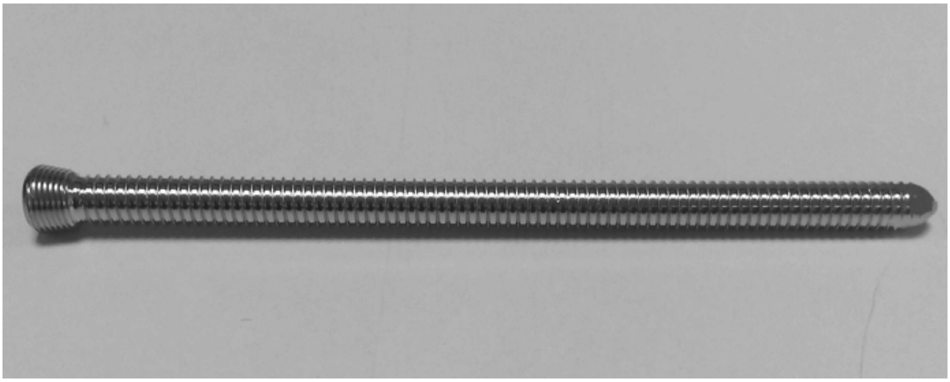

Figure 18.4 Screw. Courtesy of Josh Jacob

What type of device would you expect to be used with this screw?

Can you compare and contrast the mechanisms by which conventional plates and locking plates work?

Based on the different modes of action of the screws in conventional plates compared with the screws in locking plates what would you expect to be the difference in their proportions?

What are the advantages and the disadvantages of a locking plate?

Viva 4 Answers

What type of device would you expect to be used with this screw?

This is a typical screw for use with a locking plate. I can tell this by the characteristic presence of threads on the head of the screw.

Can you compare and contrast the mechanisms by which conventional plates and locking plates work?

In a conventional plate fixation is achieved through friction between the plate and the bone. It is a pre-requisite then that a non-locked plate is actually in direct and indeed firm contact with the periosteum on the surface of the bone. The fixation depends on two main factors: the coefficient of friction between two materials involved, i.e. the plate and the periosteum, and the force applied on the plate–periosteum interface achieved from the compressive force exerted by the screw. It is the high-friction interface in the non-locked plate construct that provides the resistance to failure.

In contrast, in a locking plate construct there is no need for the plate to achieve a high-friction interface with the periosteum. The screws and the plate form a unified fixed-angle device with multiple points of fixed-angle contact with the bone. It therefore requires all the screws on one side of the plate to cut out simultaneously in order for the construct to fail. Conversely, a conventional plate can loosen by progressive 'toggling' of the screws, allowing the screws to come loose sequentially. Once the plate comes slightly loose the friction interface gets weaker and weaker, allowing further loosening of the screws and, ultimately, construct failure.

Based on the different modes of action of the screws in conventional plates compared with the screws in locking plates what would you expect to be the difference in their proportions?

As the screw used in a conventional plate depends upon its pull-out strength a relatively high ratio would be expected between the thread diameter and the core diameter. The pitch would need to be sufficiently small to get adequate purchase on the bone but not so small that there is insufficient bone between the threads.

The screw used in a locking plate, by contrast, requires resistance to bending, both at the junction between the plate and the screw and along the length of the screw, and a relatively small pull-out strength. The locking screw therefore would be expected to have a relatively greater core diameter in relation to the thread diameter—the resistance to bending of a circular cross-section is proportional to the fourth power of the radius.

What are the advantages and the disadvantages of a locking plate?

The mechanism of action of a locking plate makes it suitable for use in osteoporotic bone. As it does not rely on friction it is not necessary for the plate to be compressed against the bone or even necessarily make contact with the bone. This is a more biologically friendly situation as the periosteum under the plate survives. Locked plates also offer the ability to gain good hold in metaphyseal bone where conventional plates would struggle, such as in the proximal humerus and distal femur.

The disadvantages of locking plates include cost—I am aware that the locking screws themselves are several times more expensive than conventional screws. There is also the danger of producing a construct that is too rigid—and as such I need to consider the number of screws I use, whether they are unicortical, bicortical, or far-cortical, and their proximity to the fracture site. Conventional plates offer certain mechanisms of action, such as buttressing. This can be achieved in a plate with locking ability but only if a non-locked screw is used.

Ruedi TP, Buckley RE, Moran CG (2007). *AO Principles of Fracture Management*, 2nd edn, Vol. 1. Thieme Verlag, Stuttgart.

Viva 5 Questions

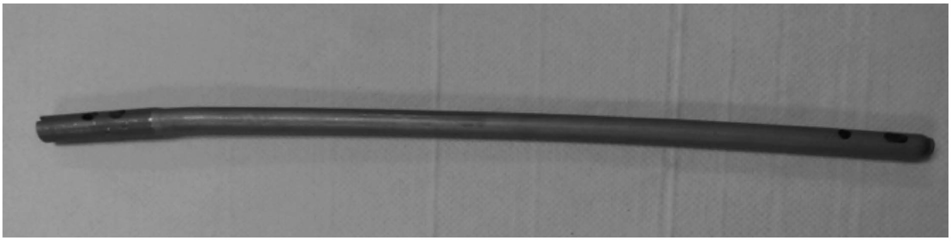

Figure 18.5 Intramedullary nail. Courtesy of Josh Jacob

What does this photograph show?

Which is stiffer—a solid nail or a hollow nail?

How does the working length typically differ between a reamed nail and an unreamed nail for a fracture near the isthmus?

How does the torsional stiffness of a slotted nail compare with that of a nail with a complete circular cross-section?

Viva 5 Answers

What does this photograph show?

This is a photograph of an intramedullary femoral nail. It appears to be made of titanium, has multiple locking options proximally and distally, is cannulated, and has an anterior bow . . .

[NB: DESCRIBE EVERY FEATURE YOU SEE WITH ANY IMPLANT YOU ARE SHOWN A PICTURE OF OR HANDED.]

Which is stiffer—a solid nail or a hollow nail?

The stiffness of construct of cylindrical cross-section is proportional to the fourth power of its radius, as described by the second moment of area. In the case of a hollow cylinder the stiffness is proportional to the fourth power of the outer radius minus the fourth power of the inner radius. It follows, therefore, that for any given material a hollow cylinder is less stiff than a solid cylinder of the same outer diameter. If, on the other hand, a constant volume of material were to be used for construction of an intramedullary nail of fixed length then the use of a hollow nail would allow a greater outer radius to be achieved, resulting in a stiffer nail. This is, however, an artificial hypothesis, as there is a limit to how big the outer diameter can get before the nail becomes unusable!

There are two other factors that contribute to the stiffness of the construct in practice: the material used and the working length of the construct.

Firstly, the stiffness of the material is defined by the slope of the elastic linear portion of the stress–strain plot of the material, i.e. its Young's modulus. This allows us to calculate resistance to bending forces. The shear modulus would have to be used for calculating the torsional stiffness. Steel nails are stiffer than titanium as they have a steeper linear portion to their stress–strain curves.

Secondly, I must consider the working length of the nail, which is defined as the total unsupported length of the nail. This is typically the distance between the proximal locking bolt or point of bony contact and the distal locking bolt or bony contact (such as the isthmus) in any construct. A mid-diaphyseal transverse fracture with a very snug nail with good isthmic contact either side has a short working length. A comminuted midshaft fracture has a long working length between the proximal and distal locking bolts.

How does the working length typically differ between a reamed nail and an unreamed nail for a fracture near the isthmus?

An unreamed nail does not achieve fixation between the bone and the nail by frictional fit at the isthmus and the working length is therefore the distance between the two proximal and distal interlocking screws or bolts nearest to the fracture. In the case of a reamed nail it is possible to increase the contact with surrounding bone at the isthmus by up to 40%, resulting in a much shorter working length for bending forces. For torsional forces, however, it is unusual for sufficient resistance to rotation to be achieved at the isthmus and the working length for torsion therefore is still usually the distance between the nearest proximal and distal interlocking screws to the fracture for both reamed and unreamed nails. The working length can therefore differ for bending and torsional forces.

How does the torsional stiffness of a slotted nail compare with that of a nail with a complete circular cross-section?

The resistance to torsional forces depends upon circumferential shear forces, which are orientated at approximately 45° to the long axis of the nail. When a slot is introduced into the design there is very little resistance to longitudinal displacement of one side of the slot in relation to the other, and torsional stiffness is therefore greatly reduced. Slotted nails only have about 3% of the rigidity of the intact femur in torsion, while an unslotted (closed section) implant produces constructs with about 50% the rigidity. Distal locking bolts increase the torsional rigidity and maximum axial load capacity of the construct, and reduce the potential for shortening. Two distal bolts reduce the toggle of the nail in the femoral shaft.

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Viva 6 Questions

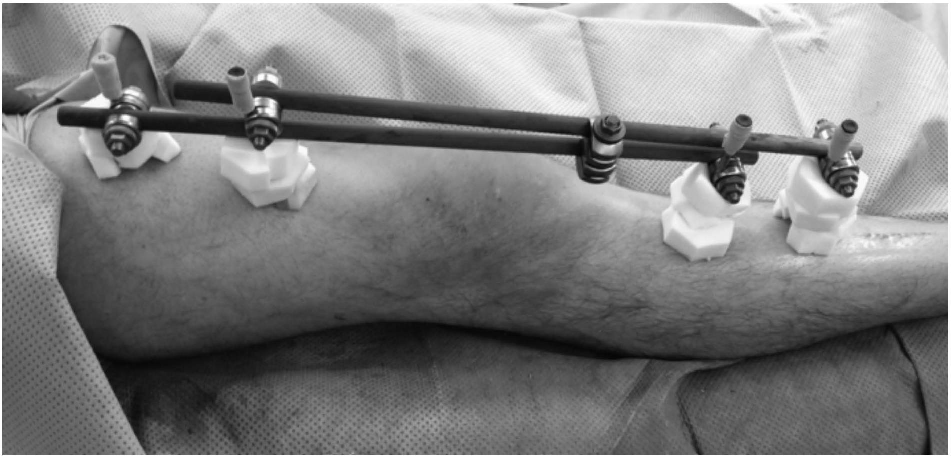


Figure 18.6 External fixator

What does this photograph show?

What are the underlying biomechanical principles that should be followed when applying a basic emergency external fixation device to a mid-diaphyseal fracture?

What methods are available to stiffen a basic external fixation construct?

You mentioned that the effect of adding a second bar in the same plane has a much greater effect on the stiffness in the plane of the fixator than in a plane at right angles to the fixator. What concept explains this?

Viva 6 Answers

What does this photograph show?

This is a photograph of an external fixator bridging a knee joint. It is a four-pin and two-bar construct in a single plane. I suspect it is being used to maintain the reduction of a knee dislocation or a fracture about the knee.

What are the underlying principles that should be followed when applying a basic emergency external fixation device to a mid-diaphyseal fracture?

If possible I like to ensure that the fracture is reduced prior to applying the fixator, although this is not always possible. I avoid placing pins inside the zone of injury. I like to ensure that the fixator pins are applied in a manner that avoids bone necrosis—with the use of a pilot drill first in hard cortical bone such as the anterior tibia, and also using cooling saline solution. I also ensure that 'safe corridors' are followed to avoid neurovascular structures.

Whenever I can, I use the near–near far–far principle—the two pins near to the fracture reduce the strain at the fracture site—they make the construct stiffer. The two 'far' pins reduce the stress on the construct—they can be considered as providing two turning couples (each with its corresponding 'near' pin) to resist the rotation of each length of bone that would occur if angulation forces were applied to the fracture.

The bar is placed far enough away from the skin to allow skin care but not so far away as to allow too much flexibility in the pins. I keep adding pins and bars as needed, including in more than one plane, until the construct is stable enough to resist any movement at the fracture in any direction.

What methods are available to stiffen a basic external fixation construct?

The 'near' pins can be placed closer to the fracture—this reduces the working length of the device. The compromise here is the risk of encroaching into the zone of injury. Thicker pins could be used—this increases the stiffness of the pins as a function of the fourth power of their radius. More pins can be added in the same plane as the existing ones—this increases the stiffness proportionally in the same planes as the initial fixator.

The bar of a uniaxial fixator can be moved closer to the bone—this decreases the working length of the pins. A second bar could be added to the existing pins—this gives a much greater proportional increase in stiffness in the plane of the fixator than in a plane perpendicular to the plane of the fixator.

Pins can be added in a different plane with a second bar added to form a V-configuration—this decreases the difference in stiffness between different planes.

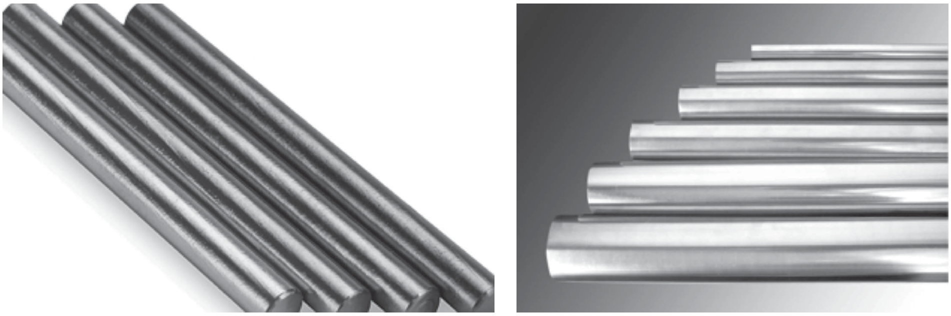
In essence, more pins, thicker pins, and using more bars and thicker bars make stiffen the fixator.

You mentioned that the effect of adding a second bar in the same plane has a much greater effect on the stiffness in the plane of the fixator than in a plane at right angles to the fixator. What concept explains this?

The stiffness of a construct can be calculated using the concept of the second moment of area. For a simple beam the stiffness depends on the modulus of elasticity and the second moment of area. For any given material the stiffness of a rectangular beam will increase in proportion to the width and in proportion to the third power of the thickness. The thickness is defined in relation to the direction of bending. The concept can be applied to more complex cross-sections, although the calculations are more difficult for these. When applying a second bar to a uniaxial external fixation device the effect is to increase the overall 'thickness' of the construct in the plane of the device and this will therefore have a much greater proportional effect on the stiffness to bending in that plane than to bending in a plane at right angles to the plane of the fixation device.

Ruedi TP, Buckley RE, Moran CG (2007). *AO Principles of Fracture Management*, 2nd edn, Vol. 1. Thieme Verlag, Stuttgart.

Viva 7 Questions



(a) (b)

Figure 18.7 Rods

What are the rods in these photographs made of?

Which two graphs or plots would be most useful to you for describing the mechanical properties of a metal? Can you draw an example of both of these graphs and outline their main features.

Is the fact that different graphs are obtained when the material is loaded under tension, compression, and shear mean that the material is anisotropic?

Are the properties described by the stress–strain graph and the *S–N* curve sufficient to describe the mechanical properties of an implant?

Viva 7 Answers

What are the rods in these photographs made of?

The rods in (a) are coloured and thus are most likely to be made of titanium, the colour being a property of the titanium oxide passivation layer. The rods in (b) are most likely of stainless steel.

Which two graphs or plots would be most useful to you for describing the mechanical properties of a metal? Can you draw an example of both of these graphs and outline their main features.

The stress–strain graph and the *S–n* curve would be the two most useful in this instance.

The stress–strain graph describes the mechanical properties of a material under single loading conditions whereas the *S–N* curve describes its fatigue properties under repeated cyclical loading conditions. The stress–strain graph used for metals is that plotted for loading in tension, although there are also similar, but not identical, graphs for compression and shear for any given material.

The tension stress–strain graph is usually more appropriate because the mechanical properties of a device under compression are more greatly influenced by shape and are harder to measure.

[NB: AT THIS POINT OFFER TO DRAW THE GRAPHS. TALK AS YOU DRAW, EXPLAINING THEM IN DETAIL.]

A stress–strain graph for a metal will have an initial linear portion. There is no toe region, as might be found, for example, in ligaments or tendons, where the initial part of the graph is not linear due to 'uncrimping' of the collagen fibres. The slope of the linear portion of the graph is the Young's modulus and describes the stiffness of the material. During this linear portion, the material behaves elastically—any deflection in the crystalline structure will be completely recovered on removal of the applied load. The point at which the plot ceases to be truly linear is called the proportionality limit, which is usually just before the elastic limit—the point at which elastic behaviour no longer occurs. Next comes the yield point, which is the point at which measurable plastic deformation starts to occur (it is almost impossible to measure the first dislocations in the crystalline structure of a material, so a standard measurable definition for yield is taken as 0.2% deformation). The proportionality limit, elastic limit, and yield points are very close together and are often considered as one. After the yield point there is a section where the stiffness increases—due to work hardening where the material can absorb more energy without deforming. This is because as the metal is deformed more dislocations are formed within its crystalline structure. These eventually start to crowd up against the grain boundaries and they are then less easily moved so the material becomes stiffer. The highest point on the plot is the ultimate (tensile) stress, and is indicative of the strength of the material. The graph then slopes downwards as necking of the sample occurs before final failure. The area under the graph indicates the amount of energy absorbed before failure and is a measure of the toughness of the material.

The *S–N* curve describes the behaviour of a material under cyclical loading. The *y*-axis is the stress and the *x*-axis is the number of cyclical loadings, usually on a logarithmic scale. In orthopaedic applications up to 10 million cycles are usually used for the *x*-axis. A *S–N* curve usually follows an exponential downward shape, flattening off towards a horizontal line at the right side of the curve.

The endurance limit is a line drawn tangential to the horizontal part of the curve and marks the stress at which the material could theoretically be loaded an infinite number of times without failing. The point at which the curve starts on the *y*-axis is the same as the ultimate tensile stress of the material, i.e. its failure under a single load.

Does the fact that different graphs are obtained when the material is loaded under tension, compression, and shear mean that the material is anisotropic?

No, anisotropy refers to a structure, such as bone, which has different stress–strain properties according to whether it is loaded along different axes; for example, the mechanical properties for bone are different according to whether the bone is loaded transversely or axially. Changing the type of loading, i.e. from compression to tension, is not the same as changing the direction of loading and is not described by isotropy.

Are the properties described by the stress–strain graph and the *S–N* curve sufficient to describe the mechanical properties of an implant?

No—other factors need to be considered. There are some other properties of materials that can influence their behaviour. Titanium, for example, is notch sensitive and fails much more easily if there are defects on its surface. Stainless steel is subject to crevice crack corrosion, which makes it more susceptible to fatigue failure over time when *in vivo*. The shape of any implant is also very important in defining its mechanical properties (e.g. second moment of area, polar moment area, and so forth)—the stress–strain plot for an implant (a structure) is therefore more properly called a load deformation curve to distinguish it from the plot for a standardized sample of material as used for a stress–strain plot.

Beer FP, Johnston ER, DeWolf JT (2006). *Mechanics of Materials*, 4th edn. McGraw Hill, New York.

Budynas RG, Nisbett, JK (eds) (2008). *Shigley's Mechanical Engineering Design*, 8th edn. McGraw Hill, New York.

Viva 8 Questions

Figure 18.8 Mangled limb

This is a photograph of a mangled extremity. Aside from trauma, what are the other indications for an amputation?

What are the aims of an amputation?

What pre-operative evaluation would you consider?

Describe the surgical technique of a below-knee amputation.

Discuss your aftercare principles for an amputee.

Discuss the complications associated with amputations.

Viva 8 Answers

This is a photograph of a mangled extremity. Aside from trauma, what are the other indications for an amputation?

Other indications would include peripheral vascular disease, infection, tumours, nerve injury (trophic ulceration), and congenital anomalies.

What are the aims of an amputation?

It is essential to retain a maximum level of independent function whilst removing all diseased tissue, and minimizing morbidity and mortality. The amputation should be considered to be the initial stage of a reconstruction procedure aiming to produce a physiological end organ, and as such a multidisciplinary approach is required if I am to be successful in returning the patient to maximal function.

What pre-operative evaluation would you consider?

In the elective setting, after taking a thorough history, I would assess the tissues clinically—feeling pulses and skin temperature. I would use a Doppler ultrasound looking for an ankle–brachial index of more than 0.45, which predicts 90% healing, although this is inaccurate with calcified vessels. A toe systolic blood pressure of 55 mmHg is also predictive of distal healing, as is a minimum transcutaneous PO_2 of 35 mmHg for assured healing. I could use an arteriogram to aid planning. I would like the patient to have a serum albumin of at least 3 g/dl and a white cell count of more than 1500/ml. I would aim for pre-operative control of diabetes, evaluate cardiac, renal, and cerebral circulation, and provide nutritional support for a malnourished patient. As important as clinical evaluation is pre-operative psychological counselling and input from the pain team. In the trauma or acute setting not all of this is always possible, but I would still try to achieve as much of this as I can.

Describe the surgical technique of a below-knee amputation.

I prefer to use a skew flap in order to move the skin incisions away from any areas that bear weight. This relies on skin flaps being half the length of the diameter of the limb, with lateral apices at the level of the bony resection, and 'skewed' to one side of the mid-axis of the limb. A stump of less than 6 cm is not functional so I aim for a minimum of 8 cm, and more if possible. I prefer to use a tourniquet and divide skin, subcutaneous fat, and fascia in the same line as the periosteum of the anteromedial surface of the tibia. I elevate flaps to the level of the amputation and work through each muscle compartment systematically. I identify the superficial peroneal nerve between extensor digitorum longus and peroneus brevis, pull it distally, and divide under tension. Then I divide the anterior tibial vessels and deep peroneal nerve and section anterior muscles 1–2 cm distal of the bony resection. Now the anterior and lateral compartments are prepared, I can section the tibia and bevel the end, and then section the fibula 3 cm proximal to the tibia. In the posterior compartment I must divide the posterior vessels and nerve and fashion a posterior flap which will involve thinning of the muscle bulk and bevelling the muscles. Drill holes in the tibia allow for my gastrocnemius myoplasty. I would then release the tourniquet and obtain haemostasis, and close the wound in layers over a drain.

Discuss your aftercare principles for an amputee.

I prefer a soft dressing for the residuum, and ideally this is taken down within 48 hours. Drains are removed after 24 hours. Any dressings that are used must avoid proximal compression as they risk acting like a venous tourniquet. If the patient has a stiff joint above, or is at risk of a contracture, a splint may be needed. As soon as the wound is healed, pomade can begin, which is the process of massage to reduce swelling. I would then arrange for early prosthetic fitting. All patients should receive input from psychologists and pain specialists.

Discuss the complications associated with amputations.

Common complications include haematoma, infection, and skin necrosis. Contractures and muscle imbalance can occur if the myoplasty is inadequate. Neuromas can occur if nerves are not cut under tension, or not cut proximally enough. Other neurological complications include phantom sensation and phantom pain. Pain can also be a result of a sharp bony prominence—a failure to bevel the bone ends or leave enough muscle to cover them adequately.

Cochrane H, Orsi K, Reilly P (2001). Lower limb amputation. Part 3: Prosthetics—a 10 year literature review. *Prosthetics Orthotics Int*, 25, 21–28.

Geertzen JHB, Martina JD, Rietman HS (2001). Lower limb amputation. Part 2: Rehabilitation—a 10 year literature review. *Prosthetics Orthotics Int*, 25, 14–20.

Persson B (2001). Lower limb amputation. Part 1: Amputation methods—a 10 year literature review. *Prosthetics Orthotics Int*, 25, 7–13.

Viva 9 Questions

Table 18.1 DEXA table for female patient aged 76 years

Region	Area (cm^2)	BMC (g)	BMD (g/cm^3)	*T*-score	Peak reference	*Z*-score
Neck	5.23	2.81	0.538	–2.8	63	–0.7
Trochanter	10.40	4.60	0.443	–2.6	63	–1.0
Intertrochanteric	24.99	16.02	0.641	–3.0	58	–1.3
Total	40.62	23.43	0.577	–3.0	61	–1.1
Ward's	1.05	0.49	0.466	–2.3	64	0.6

BMC, bone mineral content.

What does this table show?

What are the WHO definitions of osteoporosis and osteopenia?

How would you treat this patient?

What are the potential side effects of treatment?

A year after starting treatment this patient presents with a further fracture of her wrist after a fall. Would you alter her treatment?

Viva 9 Answers

What does this table show?

The table shows the result of a dual-energy X-ray absorptiometry (DEXA) scan of the hip of a 76-year-old. DEXA comprises two X-ray beams of different energies passed through the hip and gives values for bone mineral density (BMD) at the femoral neck, trochanter, and intertrochanteric regions. The *T*-score is the number of standard deviations below the mean compared with a race- and sex-matched adult population (25–35-year-olds). The *Z*-score is the number of standard deviations below the mean for an age-, race-, and sex-matched adult population.

What are the WHO definitions of osteoporosis and osteopenia?

The WHO definition of osteoporosis is a *T*-score >2.5 standard deviations below the mean. Osteopenia is defined as a *T*-score of 1–2.5 standard deviations below the mean.

How would you treat this patient?

First-line treatment for osteoporosis according to NICE recommendations is alendronate.

What are the potential side effects of treatment?

Possible side effects of alendronate include upper gastrointestinal disturbance, abnormal taste, muscle and joint pain, dizziness, rash, osteonecrosis of the jaw, and subtrochanteric femoral fractures.

A year after starting treatment this patient presents with a further fracture of her wrist after a fall. Would you alter her treatment?

NICE guidance recommends that alendronate is changed to teriparatide if a woman has another fracture and her bone density has fallen whilst taking alendronate.

National Institute for Health and Care Excellence (NICE). NICE technology appraisal guidance TA160. Alendronate, etidronate, risedronate, raloxifene and strontium ranelate for the primary prevention of osteoporotic fragility fractures in postmenopausal women (amended). http://www.nice.org.uk/guidance/ta160

National Institute for Health and Care Excellence (NICE). NICE technology appraisal guidance TA161. Alendronate, etidronate, risedronate, raloxifene, strontium ranelate and teriparatide for the secondary prevention of osteoporotic fragility fractures in postmenopausal women (amended). http://www.nice.org.uk/guidance/ta161

chapter

19

ADVANCED TRAUMA LIFE SUPPORT (ATLS), POLYTRAUMA, LIMB SALVAGE, AND UK TRAUMA GUIDELINES

Viva 1 Questions

Figure 19.1 Triage

What does this photograph show?

What is triage?

Where does triage occur?

What should be done first?

Viva 1 Answers

What does this photograph show?

This photograph shows major incident triage cards. They have an easily identifiable colour code for placing patients into a triage bracket depending on the severity of their injuries, and also identify the possibility of contamination, for example in a chemical spill. There is also a facility for the documentation of basic vital signs and injuries.

What is triage?

Triage is the process of prioritizing patient treatment during mass-casualty events. The central guiding principle is that you should do the most good for the most patients using the available resources. In mass-casualty (as opposed to multiple-casualty) events the need is greater than the resources available. This will result in delays to evacuation to definitive care and variation in the standard of care achieved—at least initially. Careful command and control with dispersal of casualties to multiple hospitals is intended to avoid overwhelming a single facility.

In general terms triage is based on treating those patients who have an immediate threat to life ahead of other patients. ATLS priorities coincide with triage priorities. Patients with airway problems are triaged ahead of those with breathing problems, circulatory problems, or disability. It is important that those patients with unsurvivable injuries are identified quickly to avoid consuming resources during the time of triage. They are considered less 'urgent' than those with severe but survivable injuries. In the worst-case scenario, resources that could have saved several other casualties are depleted during attempts to save a single critically injured casualty whose chances of survival were always exceedingly remote.

Where does triage occur?

Triage happens at each stage of the medical response to an event. Triage officers are deployed to the scene of an incident, and are again located just outside the emergency department of a receiving hospital and also within the pre-operative area of a theatre complex. The role of the triage officer at the scene is to decide where patients should be evacuated to, by what means, and in what order. At the receiving hospital the major incident plan will have details of where casualties are treated on arrival. For example, a day surgery or fracture clinic could be used for walking and less seriously wounded patients and the emergency department itself for patients with significant airway, breathing, or circulation problems. Further triage happens within the theatre complex as each surgical case finishes and the next most urgent casualty is selected. The on-call consultant orthopaedic surgeon frequently has a role at one of these levels of triage so must be familiar with the role and responsibilities.

What should be done first?

The first priority is my own safety. If, for example, there is unstable infrastructure, fire, or the threat of secondary explosive devices I may have to decide whether it is appropriate for me to do anything. How much risk one is prepared to expose oneself to in order to help the injured is a personal decision.

Next I must ensure that an appropriate emergency response is being launched. In the UK the police usually have primacy of command except where fire or other danger results in the fire service having control within the inner cordon. Each emergency service will have an operational-level commander at the scene. If it is safe and appropriate to approach the casualties I have to consider what I can do with the equipment available.

Basic airway manoeuvres can be accomplished without any equipment, and haemorrhage control using direct pressure through use of a tourniquet. Other casualties can be reassured and/or assessed. This will allows me to prioritize treatment and evacuation and direct other medical professionals as they arrive with additional equipment and skills.

American College of Surgeons (2012). *Advanced Trauma Life Support (ATLS) Student Course Manual*, 9th edn. American College of Surgeons

Viva 2 Questions

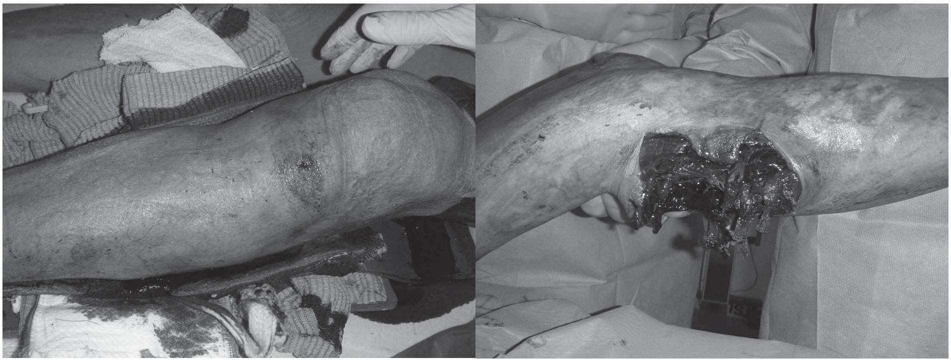

(a) (b)

Figure 19.2 Gunshot wound: (a) entry wound and (b) exit wound. Courtesy of Hugo Guthrie

You see a patient who has been shot. Describe what these clinical photographs show.

This is an isolated injury. How would you assess and manage this patient in the emergency department?

There is a significant exit wound. Why has this occurred?

During exploration of the wound you find that the popliteal artery has been transected just above the trifurcation and that the tibial and common peroneal nerves are in continuity. Is this extremity salvageable? What is your decision-making process? Do the existing scoring systems help?

If you decide to salvage, what is the sequence in which you will manage the injury at the first visit to theatre?

Viva 2 Answers

You see a patient who has been shot. Describe what these clinical photographs show.

These are clinical photographs of a left leg with a penetrating injury. Photograph (a), taken in an emergency department or battlefield hospital, shows the entry wound on the anterolateral proximal shin. There are blood-soaked dressings under the limb and there may be an emergency tourniquet applied proximally, although it is hard to tell. In photograph (b) the same limb is seen in the operating theatre. Here the extensive posterior exit wound can be seen with significant soft tissue damage and a very large zone of injury. The limb has been prepped in betadine prior to debridement.

This is an isolated injury. How would you assess and manage this patient in the emergency department?

History, examination, observations, and investigations form the mainstay to any assessment I perform.

The history in this situation would include gathering basic information on the patient's medical co-morbidities, allergies, regular medications, and basic details of the events, as well as when they last ate and drank. This is known as the AMPLE history. As this is an isolated injury, and assuming the patient has been managed and resuscitated according to ATLS protocols, I would go on to assess and manage the injury specifically. I would continue to resuscitate and warm the patient. I would assess for distal pulses and would have a high index of suspicion for neurological and vascular injury in this setting. Basic splintage, antibiotic and tetanus prophylaxis, and clean saline-soaked dressings would also be mandatory here. Imaging, both plain radiographs and a CT angiogram, would be preferable, but there may not be time if there is a major vascular injury.

There is a significant exit wound. Why has this occurred?

High-velocity rifle rounds carry massive kinetic energy as opposed to lower-energy handgun rounds. When the projectile hits bone there is a massive immediate transfer of energy, resulting in shattering due to the brittle property of cortical bone. As it passes through the body the projectile expands, tumbles, and yaws resulting in an increase in the frontal cross-sectional area of the projectile. The permanent cavity left in its wake is therefore larger. Temporary cavitation also occurs within soft tissues as a shock wave displaces tissue away from the advancing projectile. This creates a negative pressure within the cavity, which sucks debris and contamination into the cavity before it collapses.

During exploration of the wound you find that the popliteal artery has been transected just above the trifurcation and that the tibial and common peroneal nerves are in continuity. Is this extremity salvageable? What is your decision-making process? Do the existing scoring systems help?

The absolute indications for amputation remain the avulsed extremity, unreconstructable bony damage, severe multilevel injuries, and a warm ischaemia time of more than 6 hours. There remain few relative indications to amputation. These include significant extremity injury in a multiply injured patient, unreconstructable damage to the ipsilateral foot as functional outcome is frequently poor, and uncontrollable haemorrhage where amputation is life saving. In civilian practice the LEAP study has largely discredited scoring systems including the Mangled Extremity Severity Score (MESS), the Limb Salvage Index (LSI), the nerve injury, ischaemia, soft-tissue injury, skeletal injury, shock, and age of patient score (NISSA), and the Hanover Fracture Scale-98. MESS is specific in that low scores rule out the need for amputation but not sensitive in that high scores do not accurately predict the requirement for amputation. Recently a validated scoring system from the Ganga Hospital in India has been shown to be more predictive but is still cumbersome in the 'grey area'.

The UK Military Limb Trauma Working Group has made recommendations when considering amputation or limb salvage. Firstly, the examination findings together with indications to amputate a limb should be documented. Secondly, existing limb salvage scores should not be used to determine the need for amputation. Thirdly, whenever possible, decisions to amputate should be confirmed by a second surgeon. It is also recommended that all wounds should be photographed; radiographs should be obtained prior to amputation, unless the delay may compromise the care of the casualty; and neurological dysfunction should not be part of the criteria for deciding upon amputation, as it is documented that up to 50% of cases can recover.

If you decide to salvage, what is the sequence in which you will manage the injury at the first visit to theatre?

If there is a vascular injury a shunt should be performed first and foremost, followed by a spanning external fixator and debridement, with wound extension along fasciotomy incisions. Formalized vascular repair can then be carried out before the wounds are dressed with conventional or topical negative-pressure dressings.

Brown KV, Guthrie HC, Ramasamy A, Kendrew JM, Clasper JC (2012). Modern military surgery: lessons from Iraq and Afghanistan. *J Bone Joint Surg Br*, 94-B, 536–543.

Ly TV, Travison TG, Castillo RC, et al. (2008). LEAP Study Group. Ability of lower-extremity injury severity scores to predict functional outcome after limb salvage. *J Bone Joint Surg Am*, 90, 1738–1743.

Standards for the Management of Open Fractures of the Lower Limb, 1st edn (2009). BAPRAS and BOA, London.

Viva 3 Questions

Figure 19.3 A polytrauma patient

What does this photograph show?

Do you know any ways of scoring patients with multiple injuries?

Can you explain how these systems work?

Why do we bother to score these patients?

Which of these systems would you choose to use, and why?

Viva 3 Answers

What does this photograph show?

This photograph shows a patient being prepared for an emergency laparotomy. The patient has a pressure dressing or tourniquet on her right thigh and also has her legs bound in internal rotation in order to stabilize the pelvic ring.

Do you know any ways of scoring patients with multiple injuries?

There are a number of scoring systems in use, including the Injury Severity Score (ISS), the New Injury Severity Score (NISS), and the Maximum Abbreviated Injury Score (AISmax). These are all based on the Abbreviated Injury Scale (AIS). There are also further systems in use for paediatric patients, such as the Modified Injury Severity Score (MISS).

Can you explain how these systems work?

For the adult scoring systems each injury is given an AIS score from 1 (minor) to 6 (unsurvivable). The various systems then use these AIS scores in different ways to give an overall score. The AISmax is simply the score for the single worst injury. To calculate the ISS the body is divided into six anatomical regions: head, face, chest, abdomen, extremities and pelvis, external. The single highest AIS score in each body region is used. The three most severely injured body regions have their scores squared and added together to produce the ISS score. Scores range from 0 to 75 ($5^2+5^2+5^2$), but if any body region has an AIS of 6 (unsurvivable) then the ISS is automatically given as 75. Major trauma is usually defined as an ISS of more than 15. The NISS differs from the ISS by including the squares of the three highest scores, regardless of whether or not they are within the same body region. For example, in a patient with bilateral open femoral fractures the ISS would only permit the inclusion of one of these injuries, but the NISS would permit inclusion of both (assuming that they were both two of the three most severe injuries). For paediatric patients the MISS is very similar to the ISS, but with injuries scored from 1 to 5, and just five anatomical regions.

Why do we bother to score these patients?

There are many potential applications for providing a quantitative summary of injury severity. All of the systems in common use provide some prognostic information, including sepsis rates, multiple organ failure (MOF), length of stay (LOS), and mortality. However, it is important to remember that whilst these scores may be useful in large populations, applying them to individual patients provides limited information. Despite this, the scoring of patients can allow evaluation of services both within and between units. Another useful role is in trauma care research. Scores can be applied in both prospective and retrospective research. Prospectively patients can be stratified into similar groups for clinical trials, and retrospectively scores can be used to identify and control for differences in baseline injury severity. By facilitating high-quality research these scores play an integral role in continuous quality improvement.

Which of these systems would you choose to use, and why?

All three adult scoring systems are significant outcome predictors for sepsis, MOF, LOS, length of intensive care unit (ICU) admission, and mortality. However, several studies, including the paper by Giannoudis and colleagues in the *Journal of Trauma* in 2006, have shown the NISS to be a better predictor than the others, and that would therefore be my preferred choice.

Baker SP, O'Neill B, Haddon W Jr, Long WB (1974). The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*, 14, 187–196.

Balogh ZJ, Varga E, Tomka J, Suveges G, Toth L, Simonka JA (2003). The New Injury Severity Score is a better predictor of extended hospitalization and intensive care unit admission than the Injury Severity Score in patients with multiple orthopaedic injuries. *J Orthop Trauma*, 17, 508–512.

Harwood PJ, Giannoudis PV, Probst C, Van Griensven M, Krettek C, Pape HC; Polytrauma Study Group of the German Trauma Society (2006). Which AIS based scoring system is the best predictor of outcome in orthopaedic blunt trauma patients? *J Trauma*, 60, 334–340.

Mayer T, Matlak ME, Johnson DG, Walker ML (1980). The Modified Injury Severity Scale in pediatric multiple trauma patients. *J Pediatr Surg*, 15, 719–726.

Osler T, Baker SP, Long W (1997). A modification of the Injury Severity Score that both improves accuracy and simplifies scoring. *J Trauma*, 43, 922–925 [discussion 925–926].

Viva 4 Questions

Figure 19.4 Cervical collar

What does is this photograph show?

What is the justification/need for guidelines on spinal clearance?

What are your principles for spinal clearance in a patient with prolonged (>48 hours) unconsciousness?

What are the respective uses/benefits of plain radiographs, CT, and MRI?

Viva 4 Answers

What does is this photograph show?

This is an adjustable rigid cervical orthosis. It is sized and adjusted appropriately for each patient and is used for immobilization of the cervical spine during the primary survey of a trauma patient.

What is the justification/need for guidelines on spinal clearance?

All patients with significant blunt trauma should be assumed to have unstable spinal injury or injuries.

The incidence is reported to be as high as 34% in unconscious patients: 50% of these injuries are in the thoracic or lumbar spine and 50% in the cervical spine. The incidence of cervical spine injuries is increased in the presence of head injury. Up to 20% of people with a spinal injury have another injury at another level.

Whilst it is important that all appropriate patients have proper spinal immobilization, there is the need for protocols in how this is managed. Prolonged spinal immobilization causes difficulties in ITU and a risk of pressure sores and pulmonary complications. A protocol for protection of the entire spine should be in place in all hospitals. This will give guidance on how protection must be maintained until examination and investigations are completed, and the spine cleared of injury.

What are your principles for spinal clearance in a patient with prolonged (>48 hours) unconsciousness?

I follow the guidance set out by the British Orthopaedic Association in their Standards for Trauma on the management of spinal injuries. Firstly, radiological spinal clearance imaging should be undertaken in all patients. In the cervical spine this involves a thin slice (2–3 mm) helical CT scan from skull to T1 with sagittal and coronal reconstructions. In the lumbar spine anteroposterior and lateral plain radiographs may be adequate, but generally sagittal and coronal reformatting of helical CT scans of chest/abdomen/pelvis as part of modern CT trauma series (<5 mm slices) is done. With all spinal injuries, a senior radiologist must report images prior to removing spinal protection.

What are the respective uses/benefits of plain radiographs, CT, and MRI?

Plain radiographs are good for lower thoracic and lumbar bony injuries, but insensitive for the neck and upper thoracic spine. They are cheap, carry a low radiation dose, and are accessible and quick to perform, but may not always be easy to interpret or sensitive enough to identify all injuries.

Thin slice (2–3 mm) helical CT, with reformatting, can show fine abnormalities with high sensitivity and specificity for unstable injuries of the cervical spine. It should be considered the investigation of choice in trauma with suspicion of bony injury, and it should be done as routine with the first CT brain scan in all head-injured patients with a reduced GCS score. It is quick to perform, but does give a significant radiation dose and is moderately expensive.

MRI is the urgent investigation of choice for spinal cord injury. It has the best sensitivity and specificity for identifying injury to the soft tissues of the spine, including ligaments and discs as well as the spinal cord. It is expensive, however, and time-consuming, and requires the patient to remain still, so is not appropriate in the agitated or intoxicated patient. It may also be inappropriate for an unstable patient to spend time in the MRI scanner until they are fully resuscitated.

The British Orthopaedic Association has issued guidance on spinal clearance in the trauma patient (BOAST 2).

British Orthopaedic Association (2008). BOAST 2: Spinal clearance in the trauma patient. https://www.boa.ac.uk/wp-content/uploads/2014/05/BOAST-2-Spinal-clearance-in-the-Trauma-Patient.pdf

Viva 5 Questions

Figure 19.5 Pelvis radiograph

What does this radiograph show?

What would be your initial management of this patient?

Do you know of any guidelines for the management of such injuries?

Having reduced the dislocation, what are the guidelines for subsequent management?

Do you know the evidence upon which the BOAST guidelines are based?

Viva 5 Answers

What does this radiograph show?

This is an anteroposterior image of the pelvis of a skeletally mature patient showing a left hip dislocation with an associated acetabular wall fracture. Ideally I would like to see another view, but this is most likely to be a posterior dislocation and posterior wall fracture.

What would be your initial management of this patient?

This is a high-energy injury with a high probability of associated injuries, and the patient should therefore be assessed and resuscitated following ATLS guidelines. Once life- and limb-threatening injuries have been identified and treated, and the patient is stable, I can move on to the management of this particular injury. Hip dislocations must be reduced urgently, with the neurovascular status before and after reduction assessed and documented. Ideally I would perform the reduction under general anaesthetic, in order to allow an assessment of hip stability following reduction. Having the patient anaesthetized in theatre would also allow me to apply skeletal traction. I would then seek urgent advice from a specialist in acetabular reconstruction and would consider urgent transfer of the patient to my regional pelvic and acetabular centre.

Do you know of any guidelines for the management of such injuries?

Yes, in 2008 the British Orthopaedic Association Trauma Group published a Standard for Trauma (BOAST) for the management pelvic and acetabular fractures.

Having reduced the dislocation, what are the guidelines for subsequent management?

A CT scan must be performed within 24 hours of the injury in order to assess associated fractures and joint congruence, and to exclude entrapment of any bony fragments. However, CT scanning should not be relied upon to predict stability, and those patients whose dislocations have been reduced in A&E should have a formal examination under anaesthesia. The images should be reviewed promptly by an expert in acetabular reconstruction in order to plan definitive treatment, and arrange for urgent transfer if surgery is required. Patients for whom reduction and fixation of the fracture is required should undergo surgery as soon as possible. Ideally this should be within 5 days of the injury, and certainly no later than 10 days post-injury. Chemical thromboprophylaxis should be commenced within 48 hours of the injury, unless there are specific contraindications.

Do you know the evidence upon which the BOAST guidelines are based?

The guidelines are based on a combination of retrospective case series and prospective cohort studies, and are consistent with evolved international consensus.

The British Orthopaedic Association has issued guidance on the management of patients with pelvic and acetabular fractures (BOAST 3).

British Orthopaedic Association (2008). BOAST 3: pelvic and acetabular fracture management. https://www.boa.ac.uk/wp-content/uploads/2014/12/BOAST-3.pdf

Grimshaw CS, Moed BR (2010). Outcomes of posterior wall fractures of the acetabulum treated nonoperatively after diagnostic screening with dynamic stress examination under anesthesia. *J Bone Joint Surg Am*, 92, 2792–2800.

Viva 6 Questions

Figure 19.6 Leg wound

What does this photograph show?

How would you define a severe open lower limb injury?

What are the principles of management of open fractures?

What is compartment syndrome?

What are the facial compartments of the lower leg?

Describe how you would perform a fasciotomy of the lower leg.

Viva 6 Answers

What does this photograph show?

This is a clinical photograph showing a significant soft tissue injury to the distal medial left tibia of a female patient. Judging by the nature of the wound and the attitude of the limb, I have a high index of suspicion that this is a severe open distal tibial fracture.

How would you define a severe open lower limb injury?

I would consider both the soft tissue and the bony injury in this situation. From a bony point of view, the fracture pattern in a severe injury would often be either a multifragmentary or segmental tibial fracture. If the fibula is fractured at the same level, this often implies higher energy transfer and greater instability. And of course fractures with bone loss, either from extrusion or after debridement, would fall into the spectrum of severe bony injuries.

Considering the soft tissue injury, any situation where there is swelling or skin loss such that direct, tension-free wound closure is not possible, or a degloving injury, should be treated a severe injury requiring specialist input. If there is a muscle injury that requires excision of devitalized muscle or an injury to one or more major arteries of the leg this would fall into the definition of severe injury, as would any contamination of the wound with marine, agricultural, or sewage material.

What are the principles of management of open fractures?

All open fractures should receive appropriate antibiotics and tetanus prophylaxis as a matter of urgency in the emergency department. Initial limb splintage, clinical photography, and simple saline-soaked barrier dressings are also essential. Once the patient is stabilized, they should be managed in the operating theatre with joint senior orthopaedic and plastic surgery input, with initial soft tissue with/without bone debridement to healthy tissue plus temporizing fixation being performed urgently, but not emergently unless heavily contaminated or associated with significant vascular injury. Definitive soft tissue cover and skeletal fixation should be achieved within 5–7 days.

What is compartment syndrome?

Acute compartment syndrome is defined by a rise in the pressure within an osseofascial compartment above the perfusion pressure of the muscle and nerve within that compartment. Untreated it leads to irreversible muscle ischaemia and death. It is characterized by extreme pain that worsens as pressure within the muscles builds. Neurological dysfunction, pallor, and loss of pulse may be late signs. A high index of suspicion should be had in any high-energy injury or crush injury to the limb.

Chronic compartment syndrome, also known as exertional compartment syndrome, is a different condition, where pressures reached within the compartment are much higher but they only occur transiently on exercise. It is commonly associated with activities such as distance running and is also seen in military recruits.

What are the facial compartments of the lower leg?

There are four compartments to the lower leg.
[NB: AT THIS POINT YOU SHOULD DRAW THE CROSS-SECTION OF THE LOWER LEG AND LABEL IT FULLY AS YOU GO, INCLUDING NEUROVASCULAR STRUCTURES AND INDIVIDUAL MUSCLES.]

The anterior compartment contains tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius. The lateral (peroneal or fibular) compartment contains peroneus longus and peroneus brevis. The posterior compartment is divided into superficial and deep: the deep portion contains tibialis posterior, flexor digitorum longus, and flexor hallucis longus, while the superficial portion contains gastrocnemius, soleus, and plantaris.

Describe how you would perform a fasciotomy of the lower leg.

The superficial and deep posterior compartments are decompressed through a medial longitudinal incision placed 1–2 cm posterior to the medial border of the tibia. A second longitudinal incision 2 cm lateral to the anterior tibial border decompresses the anterior and peroneal compartments. Accurate placement of the incisions is essential. The medial incision must be anterior to the posterior tibial artery to avoid injury to the perforating vessels that supply the skin used for local fasciocutaneous flaps. However, placement too anteriorly leads to exposure of the tibia and any underlying fracture. Palpation of the subcutaneous borders of the tibia can be difficult in a swollen leg and we recommend marking anatomical landmarks before making the incisions. Care must be taken when decompressing the deep posterior compartment because the posterior tibial NVB lies just deep to the investing fascia. Proximally, part of the origin of the soleus muscle may need to be released from the tibia. A lateral incision inadvertently placed over the fibula will expose periosteum, and extending the incision too far distally may expose the peroneal tendons. Exposure of bone or tendons increases the risks of delayed healing, infection, and, ultimately, amputation. Following decompression, the viability of the muscle should be carefully assessed and all non-viable tissue must be excised.

The British Orthopaedic Association has issued guidance on the management of severe open lower limb fractures (BOAST 4).

British Orthopaedic Association (2009). BOAST 4: the management of severe open lower limb fractures. https://www.boa.ac.uk/wp-content/uploads/2014/12/BOAST-4.pdf

Viva 7 Questions

Figure 19.7 VTE prophylaxis. Courtesy of Josh Jacob

What does this photograph show?

Would you consider chemoprophylaxis for a patient being treated non-operatively for an ankle fracture? Does it matter if the patient is being treated with full weight-bearing or not, a plastic walking boot, or a standard plaster cast?

What patient factors are considered to increase the risk of VTE?

What potentially fatal risks are associated with the use of low-molecular-weight heparin (LMWH) and how would you minimize such risks?

Viva 7 Answers

What does this photograph show?

This is a clinical photograph showing a pair of Flowtron boots and a pair of thromboembolic deterrent (TED) stockings—these are mechanical thromboprophylactic agents.

Would you consider chemoprophylaxis for a patient being treated non-operatively for an ankle fracture? Does it matter if the patient is being treated with full weight bearing or not, plastic walking boot, or a standard plaster cast?

This is a controversial area. Some would argue that any patient who is weight-bearing and ambulatory does not need pharmacological prophylaxis, but others suggest that any limb immobilization mandates the use of chemical prophylactic agents. I prefer to follow the guidance offered by NICE, which says I should consider offering pharmacological VTE prophylaxis to patients with lower-limb plaster casts. If they are therefore in a full cast, which cannot be removed, even if they are allowed to bear weight, I would offer a LMWH until the plaster cast is removed. Of course, I would first check that there are no contraindications, and ensure the patient is happy to receive such treatment. I would not offer pharmacological therapy to patients with removable boots.

What patient factors are considered to increase the risk of VTE?

There are numerous patient factors to consider. Any patient aged over 60 or with active cancer is at increased risk, as are those admitted to critical care. A previous history of clotting disorder or a family history is also significant. Medical comorbidities such as heart disease, metabolic disorders, or acute infectious or inflammatory conditions should be considered as risk factors. Obesity and malnutrition and dehydration also increase risk. Smokers and women using hormonal therapies also demonstrate a higher risk of VTE.

What potentially fatal risks are associated with the use of low-molecular-weight heparin (LMWH) and how would you minimize such risks?

Heparin-induced thrombocytopenia (HIT) is the main risk factor associated with the use of LMWH. It is actually independent of heparin type, dose, or route of administration. It is immune-mediated and typically appears five or more days after the start of heparin therapy, but has been documented to develop more rapidly in patients who have previously been exposed to heparin. The estimated incidence of HIT is between 1% (with LMWH) and 5% (with unfractionated heparin, UFH). There is a 5–10% incidence of asymptomatic thrombocytopenia, defined as a platelet count of less than 50% of the pre-operative value, in patients receiving LMWH following lower limb arthroplasty surgery, highlighting the incidence of patients at risk of HIT.

In response to this the British Society for Haematology (BSH) has produced evidence-based guidelines for the identification and management of HIT which suggest that all patients who receive heparin (of any sort) should have a platelet count on the day they start treatment. Then for all medical and surgical patients receiving LMWH or UFH, platelet counts should be performed every 2–4 days from days 4–14.

If the platelet count falls by over 50%, or below normal lab limits, a haematologist should be involved early to plan further management. A fall in platelet count alone does not equate to HIT and a full evaluation of the clinical scenario should be done to predict the probability of HIT. There are four principal features that point to a diagnosis of HIT: the degree to which platelet count falls, the timing of onset, the presence of thrombus, and whether an alternative cause of thrombocytopenia is likely (e.g. sepsis or disseminated intravascular coagulation, DIC).

With a diagnosis of HIT the clinician then needs to stop heparin and consider the risks and benefits of treatment with an alternative anticoagulant such as lepirudin or danaparoid. Warfarin is not recommended until the platelet count has normalized because in the acute phase as it can lead to significant skin necrosis.

The National Institute for Health and Care Excellence (NICE) has issued clinical guidance and quality standards on VTE. These detail the preventative measures against VTE for all adults on hospital admission.

Baglin T, Barrowcliffe TW, Cohen A, Greaves M (2006). Guidelines on the use and monitoring of heparin. *Br J Haematol*, 133, 19–34.

Chong BH (1995). Heparin-induced thrombocytopenia. *Br J Haematol*, 89, 431–439.

Farner B, Eichler P, Kroll H, Greinacher A (2001). A comparison of danaparoid and lepirudin in heparin-induced thrombocytopenia. *Thromb Haemost*, 85, 950–957.

King DJ, Kelton JG (1984). Heparin-associated thrombocytopenia. *Ann Intern Med*, 100, 535–540.

Leyvraz PF, Bachmann F, Hoek J, et al. (1991). Prevention of deep vein thrombosis after hip replacement: randomised comparison between unfractionated heparin and low molecular weight heparin. *Br Med J*, 303, 543–548.

National Institute for Health and Care Excellence (NICE) (2010). Venous thromboembolism: reducing the risk of venous thromboembolism (deep vein thrombosis and pulmonary embolism) in patients admitted to hospital. *NICE Guideline CG92*. https://www.nice.org.uk/guidance/cg92

National Institute for Health and Care Excellence (NICE) (2010). Venous thromboembolism prevention quality standard. *NICE Quality Standard QS3*. https://www.nice.org.uk/guidance/qs3

Shaieb MD, Watson BN, Atkinson RE (1999). Bleeding complications with enoxaparin for deep venous thrombosis prophylaxis. *J Arthroplasty*, 14, 432–438.

Stern SH, Wixson RL, O'Connor D (2000). Evaluation of the safety and efficacy of enoxaparin and warfarin for prevention of deep vein thrombosis after total knee arthroplasty. *J Arthroplasty*, 15, 153–158.

Warkentin TE (1999). Heparin-induced thrombocytopenia: a clinicopathologic syndrome. *Thromb Haemost*, 82, 439–447.

Warkentin TE, Heddle NM (2003). Laboratory diagnosis of immune heparin-induced thrombocytopenia. *Curr Hematol Rep*, 2, 148–157.

chapter

20

SPINAL TRAUMA

Viva 1 Questions

Figure 20.1 Lumbar spine CT

What does this image show?

What further imaging would you like?

MRI shows no injury to the posterior elements. How would you classify this fracture?

How would you manage this patient?

Viva 1 Answers

What does this image show?

This is a sagittal CT slice of a skeletally mature spine. There is an anterior compression fracture of the vertebral body of L1. I would like further imaging in order to fully assess the fracture morphology.

What further imaging would you like?

I would like full CT imaging, including axial and coronal reconstructions, to establish whether there is any further injury within the vertebral body and posterior elements, any scoliosis, lateral displacement, or any other indication that there may be injury to other structures causing instability and in particular the posterior ligamentous complex. In 1990 White and Panjabi defined the concept of instability as 'the loss of the ability of the spine under physiologic loads to maintain its pattern of displacement so that there is no initial or additional neurological deficit, no major deformity, and no incapacitating pain'. Before that, in 1970, Holdsworth had proposed the two-column theory while Denis proposed the three-column theory in 1984. Recent evidence has suggested that the middle column in Denis' theory may be less important than the integrity of the posterior elements as originally described by Holdsworth. The posterior elements, and in particular the posterior ligamentous complex, are vital in preventing post-traumatic kyphosis leading to poor outcomes and neurological deficits. Further imaging including MRI may be needed to exclude injury to the posterior ligamentous complex. MRI has a 100% negative predictive value, and excluding an injury helps to ascertain that the fracture may have stability.

MRI shows no injury to the posterior elements. How would you classify this fracture?

I would classify this fracture according to Denis as a compression fracture. There is less than 20° kyphosis and less than 50% loss of vertebral body height. It is therefore likely to be stable.

How would you manage this patient?

I would brace this patient immediately with an extension orthosis and then perform standing anteroposterior and lateral radiographs to ensure that further kyphosis does not occur under physiological load. If there was no increase in kyphosis I would see the patient weekly for 2 weeks with standing anteroposterior and lateral radiographs, and then at 6 weeks and 3 months when the fracture should have healed. At this point the brace can be removed.

Weninger P, Schultz A, Hertz H (2009). Conservative management of thoracolumbar and lumbar spine compression and burst fractures: functional and radiographic outcomes in 136 cases treated by closed reduction and casting. *Arch Orthop Trauma Surg*, 129, 207–219.

Viva 2 Questions

(a)

(b)

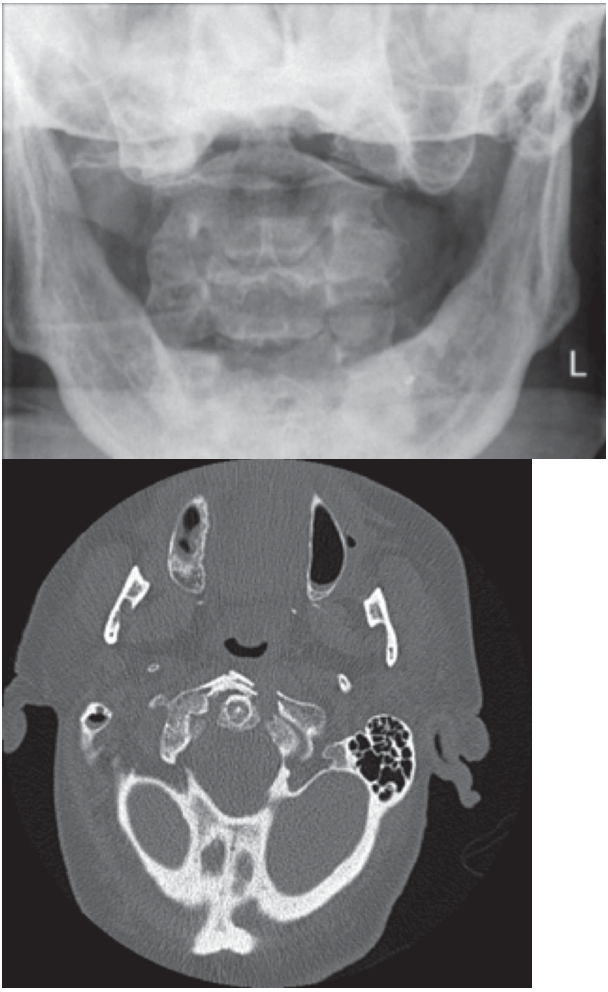


Figure 20.2 Open mouth radiograph (a) and CT (b)

What does the radiograph show?

What does the CT show?

How would you classify this fracture?

How would you treat this injury?

Do you know of any evidence from the literature to support this management?

Viva 2 Answers

What does the radiograph show?

This radiograph shows lateral displacement of the left C1 lateral mass. I would be concerned that there is an unstable C1 fracture. I would like a CT to further assess this injury and to measure the displacement more accurately. Lateral displacement of the C1 lateral mass of more than 6.9 mm is indicative of a rupture of the transverse ligament which is critical in stabilizing the atlantoaxial joint (Spence's rule). Other indicators of transverse ligament rupture/competence are bony avulsion fragments of the ligament attachments and an atlantodens interval (ADI) of more than 3 mm in adults and 5 mm in children.

What does the CT show?

This is an axial slice through the C1–C2 articulation, confirming a Jefferson burst fracture with significant lateral displacement and comminution of the left lateral mass.

How would you classify this fracture?

Given the displacement, which is likely to be more than 7 mm, and the comminution I would classify this as a Jefferson type III fracture or Levine type IV. It is unstable.

Jefferson initially classified C1 fractures into three groups:

I. Bilateral single arch fractures

II. Classic four-part bilateral double arch fractures

III. Lateral mass fractures

In 1991 Levine further classified them into five distinct groups:

I. Extra-articular transverse process fracture

II. Isolated posterior arch fracture

III. Isolated anterior arch fracture

IV. Comminuted lateral mass fracture

V. Burst fracture (more than two fragments)

Data from:

Jefferson G (1919). Fracture of the atlas vertebra. Report of four cases, and a review of those previously recorded. *British Journal of Surgery*, 7, 407–422.

Levine AM and Edwards CC (1991). Fractures of the atlas. *The Journal of Bone and Joint Surgery*, 73(5), 680–691.

How would you treat this injury?

I would treat this injury with a halo vest for 3 months, with radiographs at 2, 6, and 12 weeks to ensure that no residual or recurrent displacement occurs. A small proportion of patients (4%) treated in this way will go on to develop non-union or persistent atlantoaxial instability; in these patients posterior C1/2 fusion is the preferred solution.

Do you know of any evidence from the literature to support this management?

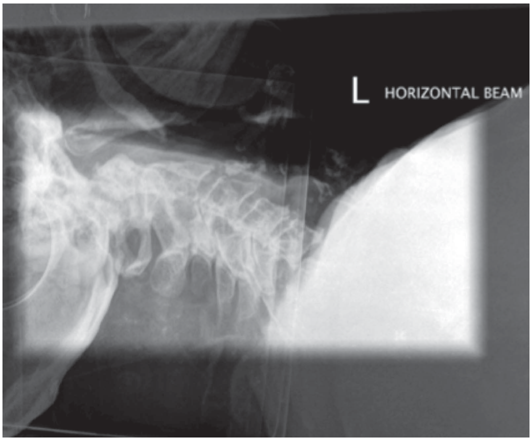
Kontautas showed in a prospective study of 29 patients that stable C1 fractures could be successfully treated in a cervical orthosis and displaced fractures could be treated with a halo vest with a union rate of 96%. Dvorak showed in a study of 34 patients that displacement of more than 7 mm or associated injuries lead to a poor outcome.

Dvorak MF, Johnson MG, Boyd M, Johnson G, Kwon BK, Fisher CG (2005). Long-term health related quality of life outcomes following Jefferson type burst fractures of the atlas. *J Neurosurg Spine*, 2, 411–417.

Kontautas E, Ambrozaitis KV, Kalesinkas RJ, Spakauskas B (2005). Management of acute traumatic atlas fractures. *J Spinal Disord Tech*, 18, 402–405.

Viva 3 Questions

(a)



(b)

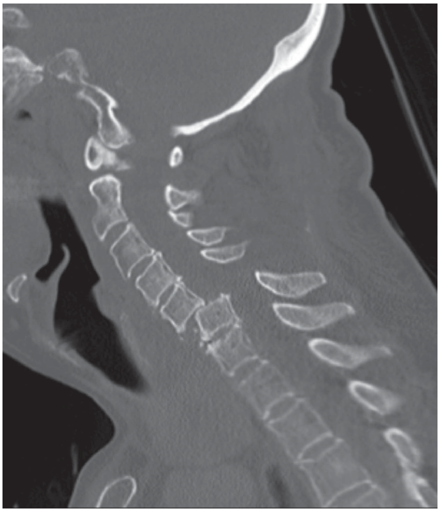


Figure 20.3 Cervical spine: radiograph (a) and MRI (b)

What does the radiograph show?

What does the CT demonstrate?

What features of this injury concern you?

What would you do next?

This patient is grossly neurologically intact at present, without any other injuries. What would be the most appropriate management plan?

If the patient was neurologically compromised, would your treatment differ?

Viva 3 Answers

What does the radiograph show?

This is an inadequate lateral plain view of the cervical spine. I cannot see the whole spine. There is a suggestion of a dislocation at the C5–C6 articulation. Further imaging is required and CT would be my choice in the trauma patient.

What does the CT demonstrate?

This sagittal CT slice confirms a C5–C6 subluxation, with disruption of the posterior elements and anterior translation of C5 on C6 of over 50%, on the background of a generalized degenerative cervical spine.

What features of this injury concern you?

This is a highly unstable injury due to the dislocation. In addition to the potential instability anteriorly, there is an intervertebral disc injury and injury to the posterior elements. Should the dislocation be present in association with a disc prolapse, then any attempt at reduction either awake or asleep may paralyse a previously neurologically intact patient.

What would you do?

I would assess this patient using ATLS principles, ensuring adequate fluid resuscitation and supplementary oxygen to maintain cord perfusion. Associated injuries would need to be excluded because other injuries are present in 5% of patients. Once the primary survey has been completed, a full neurological examination would be conducted to assess the completeness of the injury and give an ASIA grading, followed by adequate imaging including CT and MRI when safe. High cord injuries above T6 may lead to the loss of sympathetic vasomotor control with spinal shock including bradycardia and hypotension unresponsive to fluid resuscitation. Such patients must be nursed flat to prevent ascending injuries to the cord due to the area of critical ischaemia at the level of injury. Care must also be taken to logroll and prevent pressure areas and VTE by means appropriate to the region. Early referral should be made to the local spinal injuries centre within 4 hours unless local protocols determine otherwise.

This patient is grossly neurologically intact at present, without any other injuries. What would be the most appropriate management plan?

Assuming the patient is now being managed in an appropriate spinal injuries unit, then surgical intervention would be appropriate. This is a potentially catastrophic situation as any attempt to reduce and stabilize the unstable fracture may result in irreversible spinal cord injury if there is a disc prolapse compressing the cord anteriorly. Accepted best practice would be to perform an anterior cervical discectomy and fusion (ACDF) with a plate, followed if necessary by posterior instrumented stabilization. This decompresses the cord anteriorly and confers some stability before turning the patient prone to give more secure stability in the knowledge that the cord should not be in danger.

If the patient was neurologically compromised, would your treatment differ?

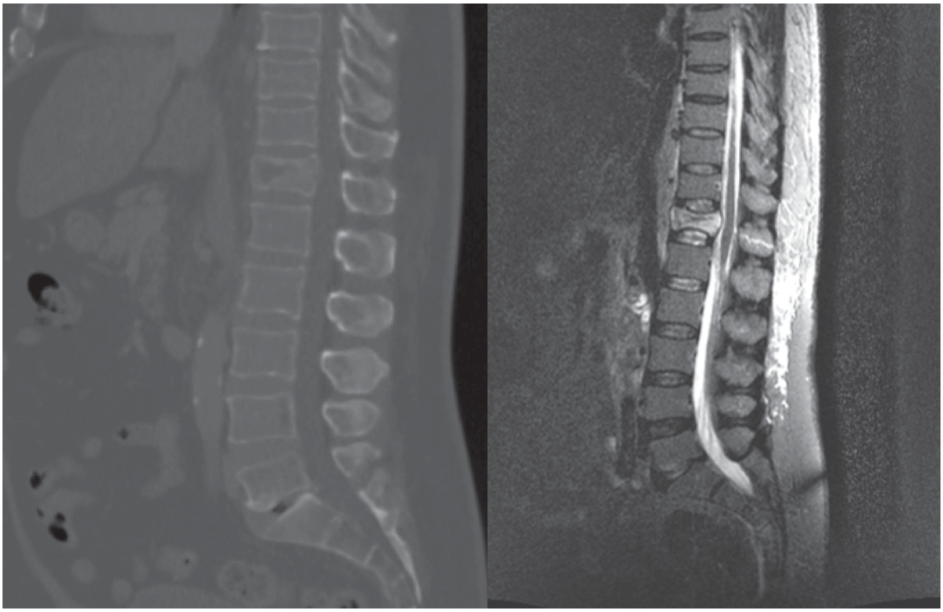
Until recently, conflicting evidence has existed as to whether early surgical stabilization with or without decompression is beneficial or detrimental to prognosis and recovery. A recent randomized controlled trial (the STASCIS Study) has shown that early surgical stabilization and decompression may improve outcome compared with delayed surgery, including certain subgroups that improved by two Frankel grades. Importantly, there was no detrimental effect of early intervention as had previously been postulated—the so-called second-hit theory.

British Orthopaedic Association (2006). *The initial care and transfer of patients with spinal cord injuries*. http://www.spitjudms.ro/_files/protocoale_terapeutice/neurochirurgie/boa_spinal_injuries.pdf

Fehlings MG, Vaccaro A, Wilson JR, Singh A, Cadotte DW, et al. (2012). Early versus delayed decompression for traumatic cervical spinal cord injury: results of the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS). *PLoS One*, 7, e32037.

Vaccaro AR, Falatyn SP, Flanders AE, Balderston RA, Northrup BE, Cotler JM (1999). Magnetic resonance evaluation of the intervertebral disc, spinal ligaments, and spinal cord before and after closed traction reduction of cervical spine dislocations. *Spine*, 24, 1210–1217.

Viva 4 Questions



(a) (b)

Figure 20.4 Lumbar spine CT (a) and MRI (b)

What does the imaging show?

Can you classify this injury?

What would you do next?

What does the MRI show?

What other injuries are common and often missed in such patients?

How would you manage this injury?

Are you aware of any other techniques or approaches?

Viva 4 Answers

What does the radiograph show?

This radiograph shows a T12 flexion–distraction type injury. There is compression anteriorly, but a horizontal distraction fracture through the spinous process posteriorly. There is minimal retropulsion of the posterior vertebral body wall into the spinal canal.

Can you classify this injury?

This is a T12 flexion–distraction injury with compression of the anterior column and distraction of the posterior elements. It is an unstable injury with a risk of developing post-traumatic kyphosis, neurological deficit, and a poor outcome.

What would you do next?

A detailed neurological assessment of the patient is mandatory as spinal cord injury is not uncommon in these patients and may present with mixed upper and lower motor neurone signs if the conus medullaris is injured. I would request a MRI scan to assess the degree of cord compromise and confirm the posterior complex injury.

What does the MRI show?

This sagittal T_2/STIR (short-tau inversion recovery) sequence shows both the anterior flexion fracture and the distraction injury posteriorly causing the horizontal fracture through the spinous process and blood in the posterior structures.

What other injuries are common and often missed in such patients?

Intra-abdominal injuries are present in about 40% of thoracolumbar flexion–distraction fractures. Careful examination and appropriate imaging should be completed in all these patients with frequent re-examination, and a high index of suspicion should be maintained. Multidisciplinary team working with other specialities is of utmost importance.

How would you manage this injury?

Although some clinicians would treat this injury non-operatively there is a risk of post-traumatic kyphosis and neurological compromise. I would treat this injury operatively to enable early mobilization and reduction in the risk of kyphotic collapse. Traditionally, this has been done using a pedicle screw construct two above and two below the level of injury (T10–L2 in this example); however, modern fixed-angle screw constructs have demonstrated successful outcomes whilst preserving motion segments. I would use this method via a posterior midline approach to stabilize T11–L1 maintaining sagittal alignment.

Are you aware of any other techniques or approaches?

Combined anterior and posterior approaches have been described for flexion–distraction injuries.

Minimally invasive techniques have recently been described and used by some surgeons. The perceived advantage of such techniques is to minimize posterior muscle stripping in an area that has already had the posterior elements damaged. Currently there is no evidence that minimally invasive techniques are superior in terms of final outcome measures, but there is evidence that intra-operative blood loss, length of stay in hospital, and opioid use are significantly reduced. These techniques are not for the inexperienced surgeon and should be used after appropriate training and with rigorous audit processes in place to report outcomes and complications.

Finkelstein JA, Wai EK, Jackson SS, Ahn H, Brighton-Knight M (2003). Single-level fixation of flexion–distraction injuries. *J Spinal Disord Tech*, 16, 236–242.

Viva 5 Questions

(a)
(b)

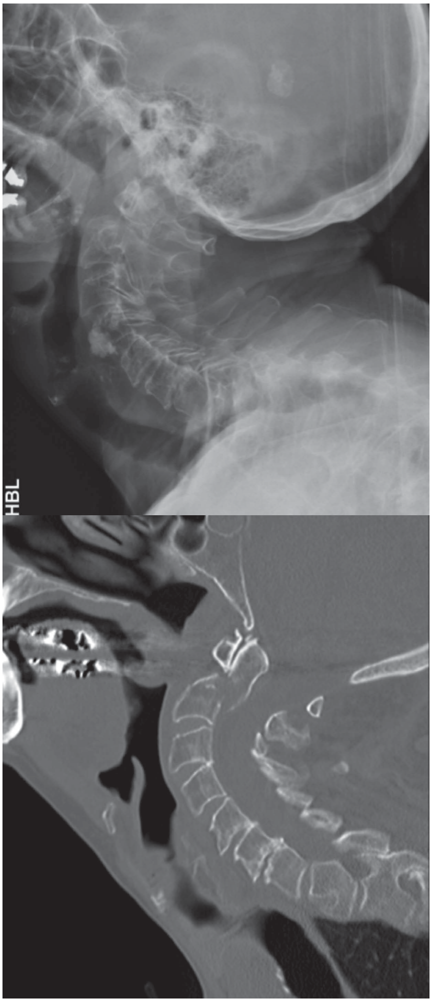


Figure 20.5 Cervical spine: radiograph (a) and CT (b)

What does the radiograph show?

What does the CT show?

This patient has no neurological deficit on examination. Why is that, given the displacement?

How would you manage this type of injury in a young man?

Are you aware of any other options?

How would you manage this type of injury in an elderly patient?

Viva 5 Answers

What does the radiograph show?

This lateral C-spine view shows a posteriorly displaced C2 odontoid peg fracture in an overall degenerative cervical spine. I would like to see more images, ideally including a CT scan.

What does the CT show?

The CT confirms the radiographic findings. I would classify this as a type II odontoid peg (C2) fracture. It is displaced and has a risk of non-union and potential progressive or catastrophic displacement leading to cord injury, myelopathy, or sudden death.

This patient has no neurological deficit on examination. Why is that, given the displacement?

The spinal canal is at its most capacious at the C1/2 level. As such, fairly significant displacement can occur before compression of the spinal cord occurs. Death is caused by cord transection above the phrenic nerve roots (C3–C5) and injury to the respiratory centre in the brainstem. Soft tissue restraints around C1/2 stop catastrophic cord injury in many patients at the time of injury. If the patient survives the initial incident the neurological compromise tends to happen progressively over some time unless another fall occurs before union or fibrous non-union occurs. Myelopathic changes may occur in patients who develop a non-union.

How would you manage this type of injury in a young man?

I would probably manage this with internal fixation via an anterior approach, with either a single screw or two screws across the fracture into the odontoid process. The plane of the fracture lends itself to being fixed from an anterior approach.

Are you aware of any other options?

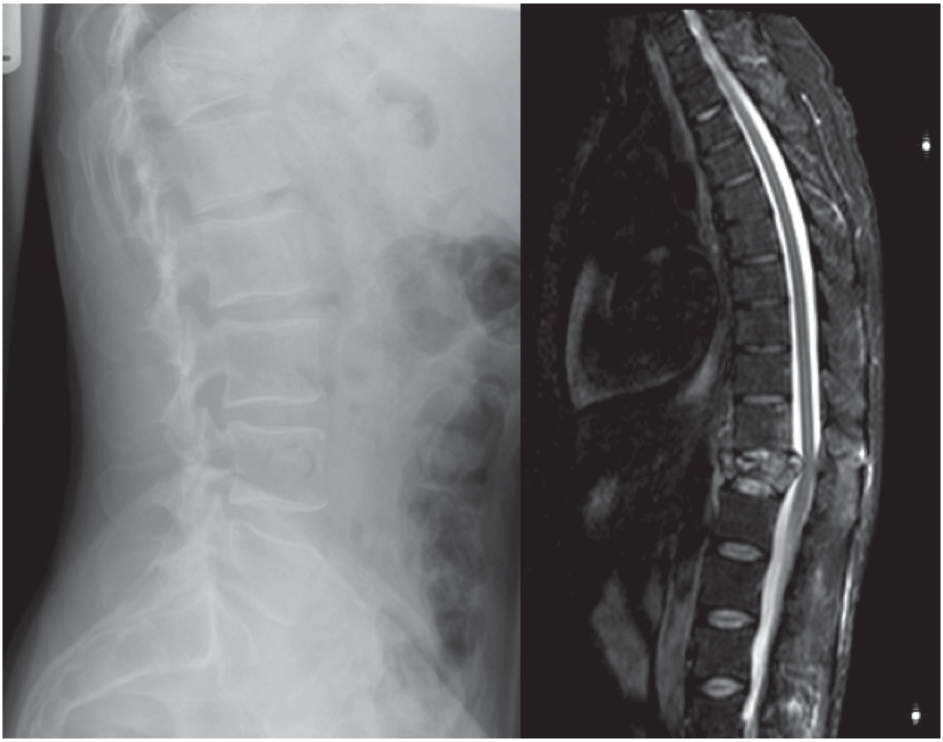
In a young person there is the option of a halo vest or posterior C1/2 fusion for type II fractures. The operative option depends on the fracture morphology.

How would you manage this type of injury in an elderly patient?

Significant morbidity and mortality has been shown in studies with elderly patients treated in halo vests. Posterior C1/2 fusion has been shown to have superior results to anterior screw fixation in this age group if they are fit with no significant comorbidities. However, many patients suffering this type of injury *do* have significant comorbidities and the goal should be to immobilize in a soft or semi-rigid collar for 3 months, accepting the risk of non-union, catastrophic displacement with a subsequent fall, or late myelopathic problems. Some centres will manage this injury with a soft collar and counsel the patient and family appropriately. The risk of a catastrophic complication is less than the morbidity and mortality associated with operative treatment in elderly patients with significant comorbidities.

Chapman J, Bransford R (2007). Geriatric spine fractures: an emerging healthcare crisis. *J Trauma*, 62(6, Suppl.), S61–S62.

Viva 6 Questions



(a) (b)

Figure 20.6 Lumbar spine: radiograph (a) and MRI (b)

What does the radiograph show?

How would you manage this patient?

How would you manage this injury (he has no other injuries)?

He has CT and MRI scans. What does the MRI show?

How should this injury be treated definitively?

Viva 6 Answers

What does the radiograph show?

This lateral plain radiograph shows a T12 fracture with greater than 50% loss of anterior vertebral height. I would be concerned that this is an unstable burst type thoracolumbar injury, which is unstable. It is difficult to interpret, but I would suspect middle and posterior column involvement given the degree of anterior collapse.

How would you manage this patient?

I would use ATLS protocols to assess and manage this patient. Full spinal precautions would be in place, including cervical spine immobilization and strict logrolling until the full extent of all injuries was known.

How would you manage this injury (he has no other injuries)?

CT imaging would be useful as the first modality for assessing fracture morphology and potential instability. However, MRI is also indicated to assess the stability of the posterior ligamentous complex and integrity of the intervertebral disc. This would help determine the most appropriate management.

He has CT and MRI scans. What does the MRI show?

This shows Denis three-column or Holdsworth two-column disruption. There is injury to the anterior and posterior columns with ligamentous incompetence. This injury is unstable and highly likely to collapse into kyphosis with potential neurological sequelae even if the patient is initially neurologically intact. There is significant encroachment into the spinal canal and I suspect the posterior longitudinal ligament is disrupted.

How should this injury be treated definitively?

I would perform posterior instrumented stabilization and decompression. In a fit, healthy patient there may be the option to perform single-level above and below the fracture stabilization. In a patient with osteoporosis/osteopenia two-level above and below stabilization would be the preferred option.

Holdsworth F (1970). Fractures, dislocations, and fracture-dislocations of the spine. *J Bone Joint Surg Am*, 52, 1534–1551.

McAfee PC, Yuan HA, Lasda NA (1982). The unstable burst fracture. *Spine*, 7, 365–373.

Oner FC, van Gils AP, Dhert WJ, Verbout AJ (1999). MRI findings of thoracolumbar spine fractures: a categorisation based on MRI examinations of 100 fractures. *Skeletal Radiol*, 28, 433–443.

Radcliff K, Su BW, Kepler CK, et al. (2012). Correlation of posterior ligamentous complex injury and neurological injury to loss of vertebral height, kyphosis and canal compromise. *Spine*, 37, 1142–1150.

chapter

21

UPPER LIMB—SHOULDER, HUMERUS, AND ELBOW

Viva 1 Questions

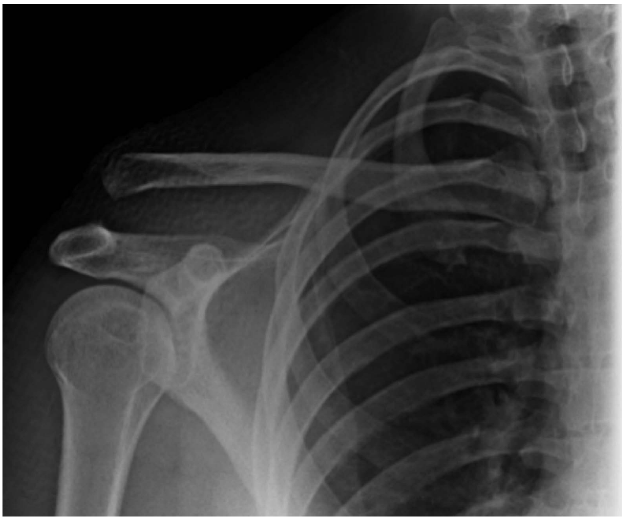


Figure 21.1 Shoulder radiograph

This is a radiograph of a 31-year-old man who fell whilst skiing in France. He has injured his right shoulder. Describe what you see.

It is now 5 days since this injury, and the patient has been treated with an acromioclavicular injection, manual reduction of the dislocation, and taping. How are you going to manage him now?

How would you fix this injury?

Viva 1 Answers

This is a radiograph of a 31-year-old man who fell whilst skiing in France. He has injured his right shoulder. Describe what you see.

This is a weight-loaded radiograph of the right acromioclavicular joint (ACJ) demonstrating a type V right acromioclavicular dislocation.

It is now 5 days since this injury, and the patient has been treated with an acromioclavicular injection, manual reduction of the dislocation, and taping. How are you going to manage him now?

This is type V ACJ dislocation and is best managed with surgical intervention. A type V dislocation involves a complete rupture of both coracoclavicular (CC) ligaments and the acromioclavicular ligament. I would refer him to a colleague with a special interest in shoulder and upper limb surgery. The principles of acute surgical management are to reduce the dislocation and reconstruct the CC ligaments. Various techniques have been described. I am familiar with the following techniques:

- Hook plate. Advantages of the Hook plate are that it is technically simple and does not disrupt the deltoid. Its disadvantages are: the plate has to be removed; osteolysis of the acromion; regeneration/healing of ruptured CC ligaments is required to regain stability; the range of movement must be restricted until the plate is removed at 3–4 months post-operation.
- Reconstruction of CC ligaments with suture/new ligament. The advantages of this technique are that no routine operation is needed to remove metalwork and a full range of movement can be allowed after 6 weeks. Its disadvantages are that it is technically more demanding; there is the possibility of iatrogenic injury to the brachial plexus or coracoid fracture; and the anterior deltoid can be disturbed with an open approach.

How would you fix this injury?

I would fix this through an open approach. In the beach chair position under general anaesthetic I would make a bra strap incision based distally over the coracoid process and proximally 1–2 cm from the ACJ. Raising skin flaps and protecting cutaneous nerves I would open the ACJ and lift a flap of anterior deltoid off the anterior clavicle. I would then expose the coracoid process. [DESCRIBE THE TIGHTROPE TECHNIQUE.] I would protect the patient in a sling for 6 weeks post-operatively.

Andreani L, Bonicoli E, Parchi P, Piolanti N, Michele L (2014). Acromio-clavicular repair using two different techniques. *Eur J Orthop Surg Traumatol*, 24, 237–242.

Grassbaugh JA, Cole C, Wohlrab K, Eichinger J (2013). Surgical technique affects outcomes in acromioclavicular reconstruction. *J Surg Orthop Adv*, 22, 71–76.

Simovitch R, Sanders B, Ozbaydar M, Lavery K, Warner JJ (2009). Acromioclavicular joint injuries: diagnosis and management. *J Am Acad Orthop Surg*, 17, 207–219.

Viva 2 Questions

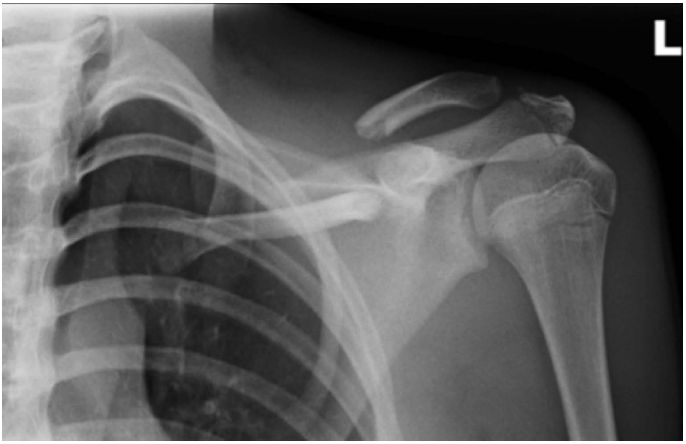


Figure 21.2 Left Shoulder radiograph

What does this radiograph show?

The patient is 15 years old and came off a 3-m jump when mountain biking. He was wearing a helmet and has a GCS score of 15/15. How are you going to manage him?

His neck has been cleared and he is haemodynamically stable. His left hand is warm and well perfused with good pulses. He has some tingling in his hand but the power and sensation are otherwise normal in his hand and elbow. What is your next step?

What are your indications for acute fixation of midshaft clavicle fractures?

What risks would you mention to this patient when obtaining informed consent?

Viva 2 Answers

What does this radiograph show?

This is an anteroposterior radiograph of the left clavicle and proximal humerus of an immature skeleton, demonstrating a fracture of the midshaft of the left clavicle with over 2 cm of displacement. There is no fragmentation at the fracture site. The proximal clavicle appears to be displaced under the coracoid process. I would be concerned about a neurological injury to the brachial plexus in this case.

The patient is 15 years old and came off a 3-m jump when mountain biking. He was wearing a helmet and has a GCS score of 15/15. How are you going to manage him?

I would manage him according to ATLS principles. The mechanism of injury would arouse my suspicions for other pathology such as cervical spine and head injuries. Assuming this is a closed, isolated injury, I would offer analgesia and simple splintage such as a sling, and perform a thorough documented neurological and vascular examination.

His neck has been cleared and he is haemodynamically stable. His left hand is warm and well perfused with good pulses. He has some tingling in his hand but the power and sensation are otherwise normal in his hand and elbow. What is your next step?

Given the position of the fracture this needs to be treated with surgical fixation. The fracture is displaced by over 2 cm and is a result of a high-energy mechanism. It is also displaced under the coracoid. I would like to take him to theatre to reduce the fracture and fix it with internal fixation. This could be done on the next routine trauma list, with no need for emergent out of hours management.

What are your indications for acute fixation of midshaft clavicle fractures?

My indications for fixation of midshaft fractures are open fractures, skin risk over the fracture site, superior displacement/shortening of 2 cm or more, neurovascular compromise, or high-energy injuries with gross fragmentation. I would also consider fixation in multitrauma patients if it allowed early mobilization of other joints/limbs. In 2007 the Canadian Orthopaedic Trauma Society published the results of a randomized controlled study of non-operative treatment compared with plate fixation of midshaft clavicle fractures. It was concluded that those treated with plate fixation had better functional scores and less chance of non-union and malunion at 1-year follow-up compared with those in the non-operative group. There were weaknesses to the study, particularly the large number lost to follow-up in the non-operative group.

What risks would you mention to this patient when obtaining informed consent?

I always consent patients as to the general risks of surgery relating to the anaesthetic, infection, and thromboembolic events. Specific to fixation of clavicle fractures, I would mention the risk of neurovascular damage, numbness below the scar site, prominent hard wear, re-operation to remove metal work, non-union, and hypertrophic scar formation.

Canadian Orthopaedic Trauma Society (2007). Nonoperative treatment compared with plate fixation of displaced midshaft clavicular fractures. A multi-center, randomized clinical trial. *J Bone Joint Surg Am*, 89, 1–10.

Potter JM, Jones C, Wild LM, Schemitsch EH, McKee MD (2007). Does delay matter? The restoration of objectively measured shoulder strength and patient-oriented outcome after immediate fixation versus delayed reconstruction of displaced midshaft fractures of the clavicle. *J Shoulder Elbow Surg*, 16, 514–518.

Vander Have KL, Perdue AM, Caird MS, Farley FA (2010). Operative versus nonoperative treatment of midshaft clavicle fractures in adolescents. *J Pediatr Orthop*, 30, 307–312.

Viva 3 Questions

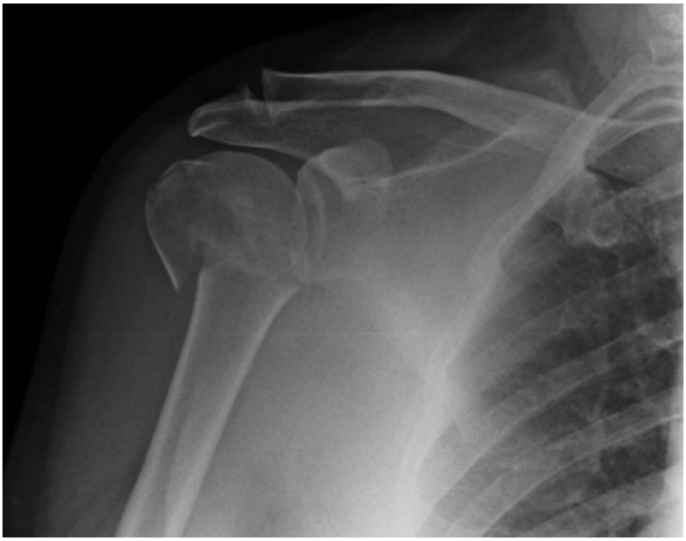


Figure 21.3 Right shoulder radiograph

A64-year-old right-hand dominant man who is normally fit and well falls onto his outstretched right arm. He complains of right shoulder pain, and A&E arrange the radiograph shown here. Describe what you see.

How would you classify this injury?

What are the management options for this patient?

How are you going to proceed?

Describe the deltopectoral approach.

What are the complications of internal fixation of proximal humerus fractures?

Viva 3 Answers

A 64-year-old right-hand dominant man who is normally fit and well falls onto his outstretched right arm. He complains of right shoulder pain and A&E arrange the radiograph shown here. Describe what you see.

This is an anteroposterior view of the right shoulder demonstrating a three- to four-part fracture of the proximal humerus. There is fragmentation medially at the neck of the humerus and the humeral head is in valgus. The humeral head is in joint.

How would you classify this injury?

I would classify this injury according to Neer's scheme. This scheme defines the fracture according to the number of osseous parts (Codman's parts) that are displaced. Neer classified displacement as separation >1 cm or 45° angulation between the fragments. This is at least a three-part fracture with displacement of the greater tuberosity and humeral head from the shaft of the humerus. I cannot comment on the position of the lesser tuberosity on this radiograph.

What are the management options for this patient?

The position of the fracture on these views is unacceptable and I would treat this patient with ORIF using a pre-contoured periarticular locking plate. However, the Level 1 evidence for operative treatment and type of operative treatment is sparse. A Cochrane review published in 2012 states that there is insufficient evidence to suggest that surgery is better for three- or four-part fractures of the proximal humerus, although surgery is associated with a requirement for further surgery. It also stated that there is not enough evidence to suggest a best method of treating fractures of this type. However, there are Level 3 studies demonstrating that locking plates have good function with this type of injury, and from my experience I would treat this with a locking plate.

How are you going to proceed?

Assuming that the patient is adequately prepared for theatre, including being starved, marked, consented, and having had the appropriate anaesthetic investigations, I would place the patient in the beach chair position. I would perform the procedure through the deltopectoral approach under image intensification.

Describe the deltopectoral approach.

The deltopectoral approach is an extensile approach based proximally on the coracoid process and distally along the deltopectoral groove. I would mark out the anterior acromion, distal clavicle, and coracoid process. The incision is 10–15 cm based proximally on the coracoid following the deltopectoral groove. The internervous plane . . . [see Chapter 17].

What are the complications of internal fixation of proximal humerus fractures?

The complications of proximal humeral fractures are varus malunion, AVN, screw perforation, re-operation, and infection. A 2011 review article by Sproul et al. published in *Injury* suggested that the complication rate approaches 49% if all of these are included as complications.

Neer CS 2nd (1970). Displaced proximal humeral fractures. I. Classification and evaluation. *J Bone Joint Surg Am*, 52, 1077–1089.

Handoll HH, Ollivere BJ, Rollins KE (2012). Interventions for treating proximal humeral fractures in adults. *Cochrane Database Syst Rev*, 12:CD000434.

Jost B, Spross C, Grehn H, Gerber C (2013). Locking plate fixation of fractures of the proximal humerus: analysis of complications, revision strategies and outcome. *J Shoulder Elbow Surg*, 22, 542–549.

Owsley KC, Gorczyca JT (2008). Fracture displacement and screw cut-out after open reduction and locked plate fixation of proximal humeral fractures [corrected]. *J Bone Joint Surg Am*, 90, 233–240.

Südkamp N, Bayer J, Hepp P, et al. (2009). Open reduction and internal fixation of proximal humeral fractures with use of the locking proximal humerus plate. Results of a prospective, multicenter, observational study. *J Bone Joint Surg Am*, 91, 1320–1328.

Sproul RC, Iyengar JJ, Devcic Z, Feeley BT (2011). A systematic review of locking plate fixation of proximal humerus fractures. *Injury*, 42, 408–413.

Viva 4 Questions

Figure 21.4 Radiograph of elbow

What does this radiograph show?

Can you classify this fracture?

What are the principles of management for this type of injury?

What are the short- and long-term consequences of distal humeral fractures?

Viva 4 Answers

What does this radiograph show?

This is an anteroposterior view of the distal humerus of a skeletally mature patient, showing a displaced intra-articular distal humeral fracture. There is some comminution, especially of the medial column and possibly of the articular surface itself, although the joint appears to be in two principal fragments.

Can you classify this fracture?

Both column distal humeral fractures have been classified by Jupiter. Although displaced, this is most likely a type C fracture as it has the characteristic Y-shaped pattern. Other classification systems include the AO-OTA classification which in this case would be a 13-C fracture. Further imaging in the form of lateral radiograph and CT views would be mandatory in this case for planning any surgical procedure.

What are the principles of surgical management for this type of injury?

Although some distal humeral fractures may be treated non-operatively, this would only be the case for undisplaced fractures and injuries in those patients who don't warrant surgery. In my department these injuries may get referred on to the specialist trauma centre, but the principles of management are to achieve anatomical articular reduction and preserve the blood supply while providing rigid stable internal fixation that is strong enough to withstand early functional motion.

Several surgical approaches have been described: triceps sparing is useful for extra-articular or simple articular fractures; triceps splitting is useful for exploiting skin lesions; and triceps reflecting preserves triceps function in the event of need for total elbow replacement. Olecranon osteotomy is still considered to be the approach best suited for articular visualization, but it risks non-union and involves prominent hardware, and should also be avoided if elbow arthroplasty is likely in the future.

Locking plates appear to provide optimal biomechanical fixation, and recent cadaveric studies have shown that parallel and perpendicular plates both provide adequate biomechanical strength. Post-operative immobilization is associated with stiffness and should generally only be used to allow the soft tissues a chance to heal for 7–10 days. Early active and active-assisted exercises should be undertaken. It is very important to be sure that the fixation provided will be sufficient to allow early mobilization.

Total elbow replacement should be considered in patients with osteoporosis if there is any doubt as to whether fixation will be possible. In patients over 65 the results of total elbow replacement are more predictable and better at 2 years, and there is less need for re-operation.

What are the short- and long-term consequences of distal humeral fractures?

Unfortunately there is generally a residual degree deficiency of flexion, extension, and pronosupination, with figures quoted for the flexion contracture of up to 25°. Other complications of distal humeral fractures include failure of fixation, non-union, infection, and heterotopic ossification.

Doornberg JN (2007). Surgical treatment of intra-articular fractures of the distal part of the humerus: functional outcome after 12–30 years. *J Bone Joint Surg Am*, 89, 1524–1532.

McKee MD, Wilson TL, Winston L, Schemitsch EH, Richards RR (2000). Functional outcome following surgical treatment of intra-articular distal humeral fractures through a posterior approach. *J Bone Joint Surg Am*, 82, 1701–1707.

McKee MD, Veillette CJ, Hall JA, et al. (2009). A multicenter, prospective, randomized, controlled trial of open reduction internal fixation versus total elbow arthroplasty for displaced intra-articular distal humeral fractures in elderly patients. *J Shoulder Elbow Surg*, 18, 3–12.

Viva 5 Questions

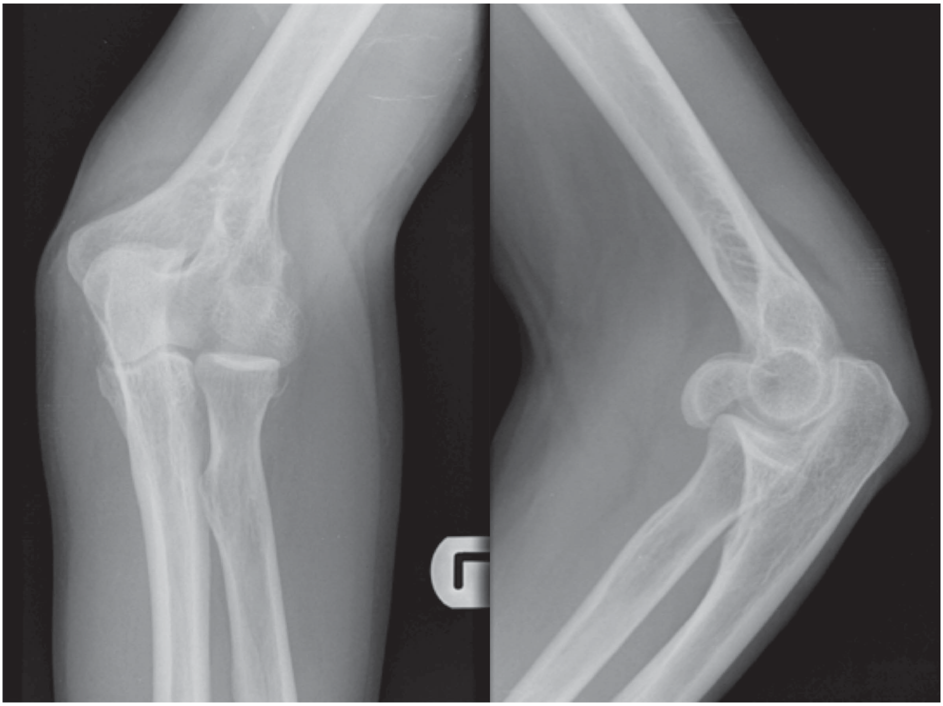


Figure 21.5 AP and lateral elbow radiograph

What do these radiographs show?

Can you classify this fracture?

What is the significance of this injury?

What are the principles of management for this injury?

What are the short- and long-term consequences of capitellar fractures?

Viva 5 Answers

What do these radiographs show?

These are lateral and anteroposterior views of the distal humerus of a skeletally mature patient showing a displaced capitellar fracture.

Can you classify this fracture?

Capitellar fractures were originally subdivided into three groups by Bowner: type I, a complete fracture; type II, a superficial osteochondral fragment also known as the lesion of Kocher Lorenz; and type III, a comminuted capitellar fracture. Types I and II usually have coronal shear patterns. McKee modified the classification to include a type IV, which is where the trochlear is fractured along with the capitellum, also in a coronal shearing pattern.

This is a type I fracture as the capitellum is one whole fragment as per Jupiter's original description.

What is the significance of this injury?

This shows the double shadow or 'double bubble' sign which represents a coronal shear fracture of the distal humerus and involves most of the anterior joint surface. As such it is quite possible in this case that some of trochlear may be involved, making it a type IV fracture. However, it seems the trochlear on the anteroposterior projection is intact. I would like further imaging in the form of a CT as this would be helpful in this case to aid diagnosis and for planning treatment.

What are the principles of management for this injury?

Non-operative treatment can be used for minimally displaced type I fractures and type II fractures where displacement is less than 2 mm. Operative treatment in the form of ORIF is required for displaced fractures, and fixation is with headless screws. Reduction must be anatomical and fixation must be rigid and stable as these are articular fractures.

What are the short- and long-term consequences of capitellar fractures?

Complications of this injury include non-union after ORIF (1–10%), heterotopic ossification, AVN, ulnar nerve neuropathy, and post-traumatic arthrosis.

Dubberley J, Faber K, MacDermid J, Patterson S, King G (2006). Outcome after open reduction and internal fixation of capitellar and trochlear fractures. *J Bone Joint Surg Am*, 88, 46–54.

Viva 6 Questions

Figure 21.6 Lateral elbow radiograph

What does this radiograph show?

Which structures normally contribute to stability of the elbow?

How do most elbow dislocations arise?

How would you manage this isolated closed injury in the emergency department?

CT confirms the radial head fracture and a coronoid tip fracture. What are the principles of management for this type of injury?

What surgical approach would you use, and how would deal with the radial head?

What would your rehabilitation regime be?

Viva 6 Answers

What does this radiograph show?

This lateral elbow radiograph demonstrates a posterior elbow fracture dislocation. I'd like to see another view, but it looks as though there is a radial head fracture and possibly a fracture of the coronoid tip.

Which structures normally contribute to stability of the elbow?

While we often think of static and dynamic restraints, O'Driscoll of the Mayo Clinic has described a fortress of stability, which considers both static and dynamic restraints as primary or secondary stabilizers. Primary restraints include the ulnar–humeral articulation and the collateral ligament complexes. Secondary restraints include the radiocapitellar articulation and the common flexor and extensor origins. The capsule is also important.

How do most elbow dislocations arise?

Most elbow dislocations occur as a result of axial load, valgus force, and forearm supination. Hori described a circle of injury progressing from lateral to medial. The first structure to fail is the lateral collateral ligament complex. The radial head then dislocates or fractures and the continuing force then tears the capsule (front and back) from lateral to medial as the elbow hinges out of joint. The final structure to fail is the medial collateral ligament.

How would you manage this isolated closed injury in the emergency department?

Having taken a brief history from the patient, I would document whether the distal neurovascular supply is intact. This injury requires urgent reduction and I would do this under sedation in the emergency department. I would then re-examine the patient for neurovascular status, place the elbow in a plaster backslab at 90°Flexion, and obtain further radiographs to confirm reduction. The patient would be admitted. I would like post-reduction films and a CT scan to help me plan my approach and whether or not I expect to fix or replace the radial head. I strongly suspect the coronoid is also fractured here.

CT confirms the radial head fracture and a coronoid tip fracture. What are the principles of management for this type of injury?

This represents a terrible triad injury—an elbow dislocation with a fracture to the coronoid and the radial head. These are unstable and, unlike simple dislocations, they are best treated with early surgery. I am careful to emphasize the gravity of this injury to the patient when gaining consent for surgery as long-term stiffness and reduced function are common.

My goals in surgery are to restore the bony anatomy of the elbow and address the capsule-ligamentous injuries such that early mobilization of the elbow is possible. I would adopt a stepwise approach to restoration of anatomy as described by McKee and colleagues in 2004 from their series of 36 cases. First, the bony anatomy, then the lateral ulnar collateral ligament, then, rarely, the MCL and/or hinged external fixation.

Ideally I would try and fix this fracture, but I would have a radial head replacement available. The coronoid tip is likely to be a small fragment that doesn't compromise the integrity of the ulnar–humeral articulation. While anatomical reduction of this fragment is not required, it may still need to be re-attached if it carries a portion of the anterior capsule and confers stability on fixation. The lateral ligaments, and sometimes the medial ones, need repairing.

What surgical approach would you use, and how would deal with the radial head?

Having prepared the patient for surgery I would place him lateral with the injured arm over a bolster and fit a high-arm tourniquet. I would confirm I could achieve fluoroscopic imaging before scrubbing. I'd use an extended Kocher's posterolateral approach between the anconeus and the ECU . . . [see Chapter 17].

What would your rehabilitation regime be?

Having optimized stability intraoperatively I'd allow the wound and soft tissues to rest in a cast for 1 week. I would then encourage active elbow flexion in a hinged brace. This will initially be locked at 60° of flexion. After two more weeks I would allow extension to 30°Flexion and at 6 weeks full extension would be allowed. There should be no resistance training for 3 months to allow healing of the ligaments and capsule.

O'Driscoll SW, Jupiter JB, King GJ, Hotchkiss RN, Morrey BF (2001). The unstable elbow. Instr Course Lect, 50, 89–102.

Viva 7 Questions

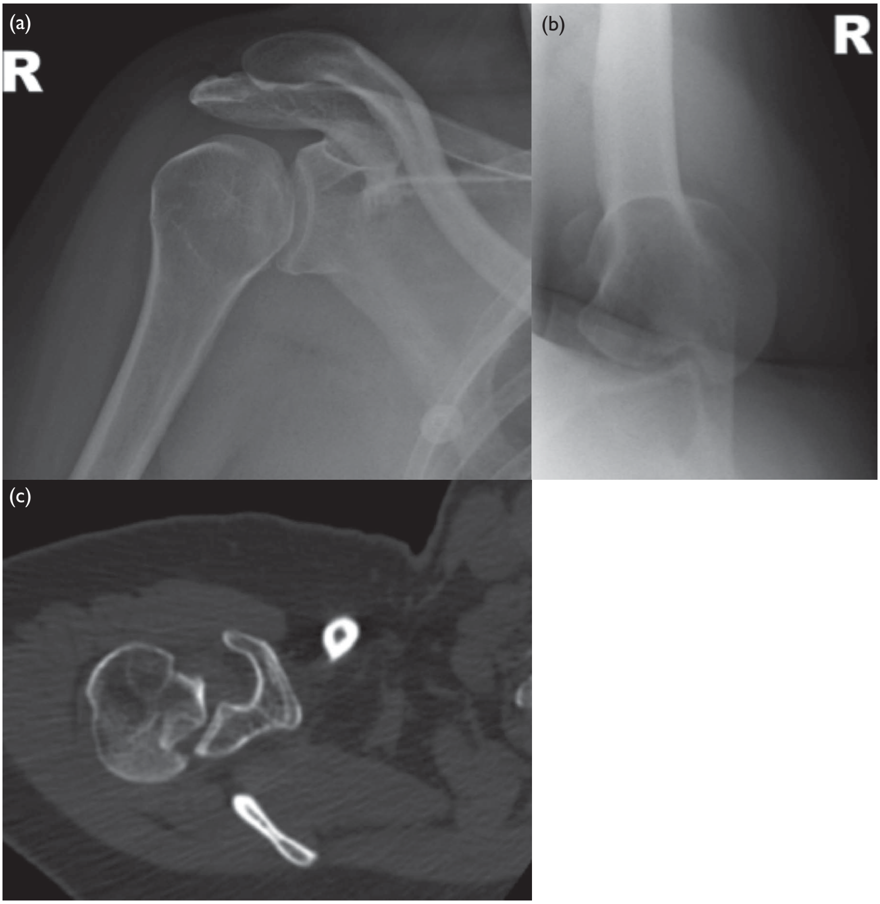


Figure 21.7 Right shoulder (a), (b) plain radiographs; (c) axial CT

Describe these images.

What would you expect to find upon physical examination?

What aspects of the clinical history would raise one's suspicion of such an injury?

How would you definitely treat such an injury?

Viva 7 Answers

Describe these images.

These are plain radiographs of a skeletally mature right shoulder and an axial CT through the same shoulder. The anteroposterior (AP) view in the plane of the scapula demonstrates the 'light bulb' appearance of the humeral head consistent with a posterior dislocation of the glenohumeral joint. The axillary lateral view demonstrates a 'locked' posterior glenohumeral dislocation with the humeral head impacted on the glenoid rim creating a depression in the anteromedial aspect of the humeral head, termed a 'reverse Hill–Sachs lesion'. The axial CT image demonstrates a defect of approximately 40% of the articular surface of the head.

What would you expect to find upon physical examination?

On examination the patient would typically hold his or her arm in internal rotation in the adducted position. The arm is locked in internal rotation and neither active nor passive external rotation is possible from this position. Rowe and Zairns described a test in which there is inability to supinate the forearm when the arm is flexed forwards because of the internal rotation deformity of the shoulder. There is increased prominence of the coracoid process anteriorly and of the humeral head posteriorly.

What aspects of the clinical history would raise one's suspicion of such an injury?

This type of injury is usually caused during an epileptic seizure, an electric shock, or by trauma such as a fall on an outstretched arm. In the case of involuntary muscle contraction, the strong internal rotators (latissimus dorsi, pectoralis major, subscapularis, and teres minor) simply overpower the weak external rotators (infraspinatus and teres minor). Clinical suspicion of such an injury is imperative, because although they account for less than 2% of all dislocations of the shoulder most are missed on initial examination. Djurdjevic reported that in a series of 24 patients with posterior dislocation, 21 had not been recognized initially.

How would you definitely treat such an injury?

Appropriate management of a posterior glenohumeral dislocation depends upon the size of the defect, the duration of the dislocation, and the age and activity of the patient. Non-operative treatment must be considered for patients with uncontrolled seizures or any patient unable to comply with a post-operative rehabilitation programme. Gerber recommends 'supervised neglect' for elderly patients with limited demands on the affected shoulder, an acceptable functional range of motion, and a normal contralateral shoulder.

Reduction of acute traumatic posterior dislocation should be carried out under general anaesthetic as soon as possible. Under general anaesthetic and muscle relaxation gentle reduction is attempted by flexion and adduction with axial traction on the arm. If the humeral head is 'locked' upon the glenoid rim, gentle internal rotation may be applied prior to lateral traction to unlock the humeral head from the glenoid rim. Once unlocked the humerus is gently externally rotated. If closed reduction is unsuccessful open reduction is performed under the same general anaesthetic. Such an injury would be deemed chronic when the duration is longer than 3 weeks and closed reduction is usually impossible.

A small impression defect of up to 25% of the articular surface of the head can be treated by closed or open reduction. If the shoulder is unstable, a transfer of the upper one-third of the subscapularis can be performed via a deltopectoral approach. A medium defect, between 25% and 50% of the articular surface, can be treated by transfer of the lesser tuberosity. McLaughlin described the transfer of subscapularis for a defect between 20% and 40%. Rotational osteotomy of the surgical neck of the humerus may be considered to ensure the defect remains anterior to the glenoid throughout the entire range of motion. The defect may be filled with an allograft from the femoral head which is contoured to fit the segmental defect and restore sphericity of the head. A large defect of more than 50% of the articular surface can be treated by shoulder arthroplasty. Retroversion of the humeral component should be decreased from approximately 35° to 20°.

Cicak N (2004). Posterior dislocation of the shoulder. *J Bone Joint Surg Br*, 86-B, 324–332.

Djurdjevic D (2003). Unrecognised posterior dislocation of the shoulder. Masters Thesis, Zagreb.

Gerber C. Chronic, locked anterior and posterior dislocation. In: Warner JJP, Ianotti JP, Gerber C (eds) (1997). *Complex and Revision Problems in Shoulder Surgery*, pp.99–113. Lippincott-Raven, Philadelphia, PA.

McLaughlin HL (1952). Posterior dislocation of the shoulder. *J Bone Joint Surg Am*, 34-A, 584–590.

Robinson MC, Aderinto J (2005). Posterior shoulder dislocations and fracture-dislocations. *J Bone Joint Surg Am*, 87-A, 639–650.

Rowe C, Zairns B (1982). Chronic unreduced dislocation of the shoulder. *J Bone Joint Surg Am*, 64-A, 494–505.

Petersen SA (2000). Posterior shoulder instability. *Orthop Clin North Am*, 31, 263–274.

Viva 8 Questions

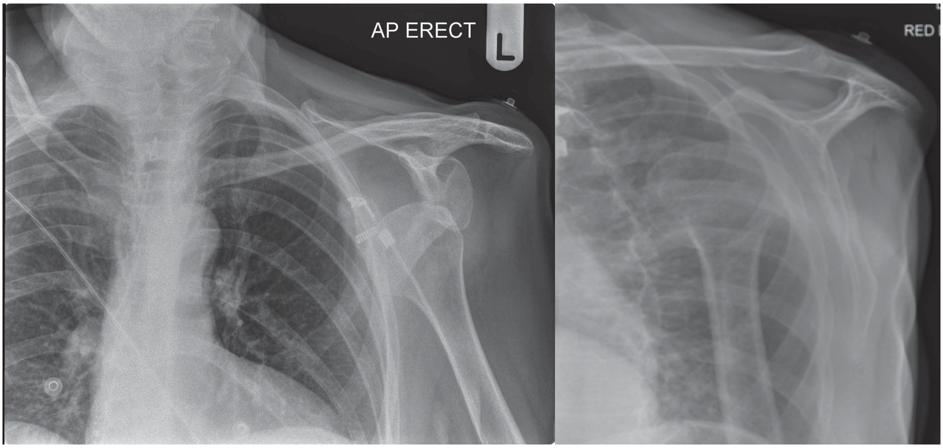


Figure 21.8 Left shoulder radiographs

A 42-year-old man falls off a 1.2-m fence, injuring his left shoulder. He is brought to A&E and complains of pain in his left shoulder. Describe the radiograph.

You are called to assess him in A&E. Outline your management of his shoulder.

Do you know how to reduce a dislocated shoulder?

What are the risks of manipulation?

What structures may be preventing a stable reduction?

Assuming you have achieved a satisfactory reduction, how do you plan to manage this patient?

Viva 8 Answers

A 42-year-old man falls off a 1.2-m fence, injuring his left shoulder. He is brought to A&E and complains of pain in his left shoulder. Describe the radiograph.

This is an anteroposterior view of the left shoulder. There is an anterior dislocation of the left glenohumeral joint. An axial image is useful to confirm the direction of dislocation and my diagnosis, although from this radiograph that is not necessary.

You are called to assess him in A&E. Outline your management of his shoulder.

I would assess this patient using an ATLS approach. As his has fallen off a fence he may have other injuries, some of which could be life threatening. Assuming this is an isolated injury, my primary goal would be to reduce the left glenohumeral joint. I would perform a neurovascular examination of the patient before any reduction was attempted and document the findings in the notes. Specifically, I would check for axillary nerve sensation over the regimental badge area and musculocutaneous nerve sensation over the lateral edge of the forearm. I would also test distal pulses and medial, ulnar, and radial nerve sensation and document all my findings.

Do you know how to reduce a dislocated shoulder?

There are several methods for reducing an anterior dislocation of the glenohumeral joint. The principles involve applying gentle traction or leverage with adequate pain relief and muscle relaxation. The simplest method is Stimson's technique. This method needs the patient to be awake but with plenty of analgesia. The patient is asked to lie face down on the bed with the injured shoulder hanging off the bed towards the floor while holding a 4.5-kg (10-lb) weight in his or her hand. This allows for gentle traction, and often the shoulder will fall back into joint. If this fails I prefer to use a modification of the Hippocratic method or Matsen's method. Gentle traction in placed in the longitudinal direction of the arm with counter traction from one's own heel or a sheet in the axillae. The arm is then adducted and slowly externally rotated until the glenohumeral joint reduces. After manipulation, I would obtain anteroposterior and axial radiographs and repeat a neurovascular examination of the affected limb.

What are the risks of manipulation?

The risks include proximal humeral fracture (including greater tuberosity fracture), rotator cuff injury, nerve injury (particularly the axillary nerve), vascular injury, and inability to reduce the dislocation. Robinson and colleagues performed a prospective study of over 3000 patients presenting with an anterior glenohumeral dislocation. Over 30% had either a rotator cuff injury, a greater tuberosity fracture, or neurological injury.

What structures may be preventing a stable reduction?

The shoulder is maintained in joint by both static and dynamic factors. Static factors include the humeral head and glenoid version, conformity of the joint, the labrum, the glenohumeral ligaments and joint capsule, and negative intra-articular pressure. If there is a significant glenoid fracture or significant capsular labral injury, the humeral head may not remain reduced. Dynamic factors include the rotator cuff muscles, long head of biceps, and the deltoid muscle. A massive rotator cuff tear or large greater tuberosity fracture or axillary nerve injury may prevent the shoulder from remaining stable. The long head of biceps can get caught posterior to the humeral head and prevent reduction. An iatrogenic fracture of the humeral head during reduction may also prevent reduction of the glenohumeral joint.

Assuming you have achieved a satisfactory reduction, how do you plan to manage this patient?

I would manage this patient in a broad arm sling for comfort and allow a gentle range of movement as pain allows. I would encourage elbow and wrist movements immediately. Historically, patients were advised to remain in a broad arm sling in internal rotation for 3 weeks. However, in 2008, Hovelius and colleagues showed that shoulder immobilization had no effect on the recurrence of dislocation. Use of an external rotation brace for 3 weeks was popularized by a 2007 study by Itoi and colleagues. In that randomized controlled trial patients were placed in a sling in internal or external rotation for 3 weeks following an acute first-time anterior glenohumeral joint dislocation. Patients placed in an external rotation brace had a significantly lower re-dislocation rate in the first 2 years. However, these encouraging results (along with MRI studies suggesting that the damaged anterior labrocapsular structures are reduced better with the arm in external rotation) have not been replicated by other work, and compliance in an external rotation brace is a problem. I would also recommend follow-up at the fracture clinic with an upper limb specialist within the next 1–2 weeks. There is some evidence that it may be better to manage patients with a first-time dislocation of the glenohumeral joint with acute surgical stabilization; therefore patients warrant a discussion regarding this with a shoulder specialist.

Hovelius L, Olofsson A, Sandström B, et al. (2008). Nonoperative treatment of primary anterior shoulder dislocation in patients forty years of age and younger. A prospective twenty-five-year follow-up. *J Bone Joint Surg Am*, 90, 945–952.

Itoi E1, Hatakeyama Y, Sato T, et al. (2007). Immobilization in external rotation after shoulder dislocation reduces the risk of recurrence. A randomized controlled trial. *J Bone Joint Surg Am*, 89, 2124–2131.

Robinson CM, Jenkins PJ, White TO, Ker A, Will E (2008). Primary arthroscopic stabilization for a first-time anterior dislocation of the shoulder. A randomized, double-blind trial. *J Bone Joint Surg Am*, 90, 708–721.

Robinson CM, Shur N, Sharpe T, Ray A, Murray IR (2012). Injuries associated with traumatic anterior glenohumeral joint dislocations. *J Bone Joint Surg Am*, 94, 18–26.

chapter 22

UPPER LIMB—FOREARM, WRIST, AND HAND

Viva 1 Questions

Figure 22.1 Right forearm radiographs

A 32-year-old man has fallen off his motorcycle, sustaining this closed neurovascularly intact injury. Describe what the radiograph shows.

Why is surgical treatment preferred for this type of injury?

What method of fixation would you use for each bone?

Which bone would you fix first, and why?

How could you achieve compression of the ulna fracture?

How would you manage a non-union of the radius?

Viva 1 Answers

A 32-year-old man has fallen off his motorcycle, sustaining this closed neurovascularly intact injury. Describe what the radiograph shows.

These radiographs show middle third diaphyseal fractures of a skeletally mature right radius and ulna. The ulna fracture is a short oblique pattern and the radius fracture is comminuted with a radial-sided butterfly fragment. The fractures are at the same level.

Why is surgical treatment preferred for this type of injury?

The preferred treatment for all adult forearm fractures is surgical, with the aim being to restore length, rotation, and the correct bow of both bones. This maintains forearm rotation and prevents pain, instability, and arthrosis occurring at the distal and proximal radioulnar joints. It is important to remember that the bones of the forearm act together as a unit facilitating rotation and this must be anatomically restored for the return of full function.

What method of fixation would you use for each bone?

I would use open anatomical reduction and rigid internal fixation with small-fragment locking compression plate or dynamic compression plate systems. I would aim for absolute stability techniques where possible—in this case a compression plate for the ulna and, if possible, interfragmentary screws and a neutralization or protection plate for the radius. If there is significant comminution of the radius, it may be that relative stability is the only achievable technique for some or all of the fracture fragments.

Which bone would you fix first, and why?

There is no fixed rule for this. Problems reducing one bone may occur after the first bone has been rigidly fixed. It is hence prudent to stabilize the more difficult fracture first, which tends to be the radius. It may be wise to partially stabilize one bone by leaving some screw holes free before addressing the other bone in case the fixation of the first bone needs to be released to achieve reduction of the second bone. In this case, therefore, it would be wise to address the radius first and the ulna second.

How could you achieve compression of the ulna fracture?

Whilst an interfragmentary screw could be placed either through the plate or separate from the plate, my preferred technique would be a compression plate technique. In this case, after reducing the fracture anatomically, the configuration of screws should allow the fracture to be compressed into the 'axilla' formed by the plate and the bone to prevent sliding with compression.

How would you manage a non-union of the radius?

Non-unions should be initially worked up to rule out infection. Adverse patient factors should be controlled or reversed as much as possible. Surgical principles include removal of non-viable bone, drilling of the canals to encourage bleeding, and management of residual segmental defects with cancellous autograft, which has good results for defects of less than 6 cm. If there is a fracture gap and/or excessive interfragmentary strain, then re-fixation, compression, and reduction of interfragmentary strain is likely to work without grafting. More complex techniques such as bone transport or vascularized grafting may be needed for very large defects.

Bucholz R, Court-Brown C, Heckman J, Tornetta P (eds) (2009). *Rockwood and Green's Fractures in Adults*, 7th edn. Lippincott Williams and Wilkins, Philadelphia, PA.

Kloen P, Buijze G, Ring D (2012). Management of forearm nonunions: current concepts. *Strategies Traum Limb Reconstr*, 7, 1–11.

Viva 2 Questions

Figure 22.2 AP and lateral wrist radiographs

A 22-year-old man has fallen 2 m from a ladder onto his hand, sustaining this isolated injury. Can you tell me what you see?

What structures might be injured?

How would you manage this patient?

What approach would you use for surgery? Describe it.

How would you assess DRUJ stability?

What options do you have if the DRUJ is unstable after fixation of the radius?

What are the consequences of malreduction or continued instability?

What are your salvage options?

Viva 2 Answers

A 22-year-old man has fallen 2 m from a ladder onto his hand sustaining this isolated injury. Can you tell me what you see?

This radiograph shows a skeletally mature distal forearm and wrist with a short oblique fracture of the distal radius which is shortened and dorsally translated 100%. There is an associated dislocation of the distal ulna dorsally from both its ulnocarpal and radioulnar articulations, which is likely to be open or at least putting the skin in peril. This is a Galeazzi fracture–dislocation of the forearm.

What structures might be injured

Apart from the bony injury to the radius, the structures that stabilize the DRUJ are potentially injured, especially the triangular fibrocartilaginous complex, the most important component of which is now thought to be the ligamentum subcurentum. There may also be an injury to the ulnar nerve, its dorsal cutaneous branch, and the extensor and flexor tendons of the fingers and wrist.

How would you manage this patient?

If this is an open injury, then antibiotics, tetanus prophylaxis, saline gauze, and clinical photography would be mandated. A documented neurological and vascular examination prior to any reduction is also essential. I would attempt to perform a closed reduction and cast immobilization initially to reduce soft tissue and neurological compression. Definitively this patient requires anatomical reduction and stable fixation of the radius followed by assessment of the DRUJ, which is usually, but not always, rendered stable after appropriate fixation of the radius.

What approach would you use for surgery? Describe it.

Either a volar Henry's approach or a dorsal Thompson's approach may be used . . . [see Chapter 17].

How would you assess DRUJ stability?

The DRUJ of the unaffected wrist should be assessed pre-operatively and an X ray should be saved for reference. Once the radius of the affected wrist has been stabilized a radiographic assessment of the congruity of the DRUJ should be performed. The DRUJ is then stressed for anteroposterior stability with the elbow flexed and rested on the table while the forearm is pronated, put in neutral, and supinated. Anteroposterior translation should not be greater than that of the opposite wrist in any position. Finally continuous fluoroscopy should be used to assess if there is dynamic subluxation of the DRUJ during pronosupination.

What options do you have if the DRUJ is unstable after fixation of the radius?

In the acute setting the reduction and length of the radius should first be scrutinized. The fluoroscopy images should then be assessed to see if there is a gap at the DRUJ, which may indicate soft tissue interposition. If this is the case the DRUJ should be explored via a dorsal approach and open reduction performed. If there is no interposition, there are three broad options: explore and repair the soft tissue restraints of the DRUJ; immobilize the forearm in a position where the DRUJ is stable (usually supination); or place two quadracortical K-wires between the radius and ulna to maintain reduction of the DRUJ and immobilize the forearm in a plaster. Which option is used depends on the experience of the surgeon and the pattern of instability encountered. My preferred choice is to . . .

What are the consequences of malreduction or continued instability?

The patient will have decreased grip strength, limited pronation and supination, and on-going pain. He is likely to go on to develop DRUJ arthritis and chronic instability which is likely to affect his function.

What are your salvage options?

Salvage options include reconstruction of the triangular fibrocartilage complex, distal ulna resection, Suave–Kapandji-type procedures, and DRUJ fusion. Arthroplasty is unlikely to work due to soft tissue instability in the acute setting.

Atesok K, Jupiter J, Weiss A (2011). Galeazzi fracture. *J Am Acad Orthop Surg*, 19, 623–633.

Murray PM, Adams JE, Lam J, Osterman AL, Wolfe S (2010). Disorders of the distal radioulnar joint. *Instr Course Lect*, 59, 295–311.

Tsai PC, Paksima N (2009). The distal radioulnar joint. *Bull NYU Hosp Jt Dis*, 67, 90–96.

Viva 3 Questions

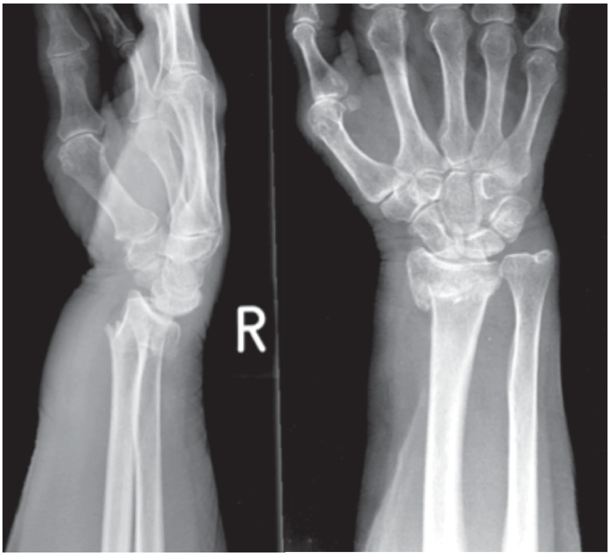


Figure 22.3 AP and lateral wrist radiographs

This independent, right-hand dominant 70-year-old woman presented with an isolated injury to her right wrist after a fall in her kitchen. She is neurovascularly intact. Can you describe the radiographs?

What might help predict instability after a distal radius fracture?

What factors affect functional outcome?

What are the management options for this patient? What would you do?

What are the specific complications of that treatment modality? How would you avoid these?

Viva 3 Answers

This independent, right-hand dominant 70-year-old woman presented with an isolated injury to her right wrist after a fall in her kitchen. She is neurovascularly intact. Can you describe the radiographs?

These radiographs show an extra-articular right distal radial fracture with dorsal angulation and translation. There is shortening, loss of normal radial inclination, and radiocarpal malalignment. There is some dorsal comminution and the bone appears osteopenic.

What might help predict instability after a distal radius fracture?

Patient factors include anything that may cause osteoporotic, weaker bone, such as age, medications, or alcohol and smoking. Higher-energy injuries with greater soft tissue damage may indicate that the fracture is more likely to be unstable. Initial severe displacement is an indicator of instability, as are intra-articular fracture, dorsal comminution, and loss of carpal alignment.

What factors affect functional outcome?

The three primary factors proven to affect functional outcome are radiocarpal malalignment on the lateral view; intra-articular step or gap > 2 mm, and radial shortening > 2 mm. Dorsal tilt > 12° from the normal position has also been shown to affect function, although not as conclusively as the other parameters.

What are the management options for this patient? What would you do?

Evidence for treatment of distal radial fractures in the elderly is controversial. Some studies show satisfactory function in the elderly population despite significant radiographic malunion. Treatment should therefore be tailored to the individual depending on pre-morbid functional level, handedness, and expectations. The aim should be to recognize which fractures may be unstable and therefore fail plaster treatment and those with features of poor functional outcome. In this case the patient had a high pre-morbid functional state and has features of instability and poor functional outcome. Operative treatment is therefore reasonable. Most commonly this would be in the form of a volar periarticular locking plate, because of her osteoporotic bone and greater danger of late collapse with use of K-wires alone. External fixation is not ideal for elderly patients due to pin site infection, pin loosening, metacarpal fracture, its cumbersome nature, and wrist stiffness. Nevertheless, the various surgical treatment modalities appear to have similar long-term functional outcomes.

What are the specific complications of that treatment modality? How would you avoid these?

Despite its exponentially increasing use, volar locking plate fixation is associated with a significant rate of complications, ranging between 4% and 30% in published studies. Specific complications include median nerve injury, CRPS, rupture of the EPL and FPL, intra-articular screw placement, and late collapse and loss of fixation. EPL rupture can be minimized by avoiding breach of the dorsal cortex when drilling, using smooth pegs rather than threaded screws distally, and avoiding overly long screw placement. Taking an axial view radiograph helps to appreciate screw length. FPL rupture is usually caused by incorrect positioning of the plate beyond the watershed line or too radially. This causes prominence of the plate and has been associated with FPL rupture. Correct plate positioning and fracture reduction also prevent intra-articular screw placement. CRPS may be minimized by early range of motion and use of post-operative vitamin C. Careful retractor placement and adequate exposure will minimize median nerve injury.

Laino D, Tejwani N (2012). Indications for operative fixation of distal radius fractures. A review of the evidence. *Bull NYU Hosp Jt Dis*, 70, 35–40.

Lichtman DM, Bindra RS, Boyer MI, et al. (2010). Treatment of distal radius fractures. *J Am Acad Orthop Surg*, 18, 180–189.

Ng CY, McQueen MM (2011). What are the radiological predictors of functional outcome following fractures of the distal radius? *J Bone Joint Surg Br*, 93-B, 145–150.

Viva 4 Questions

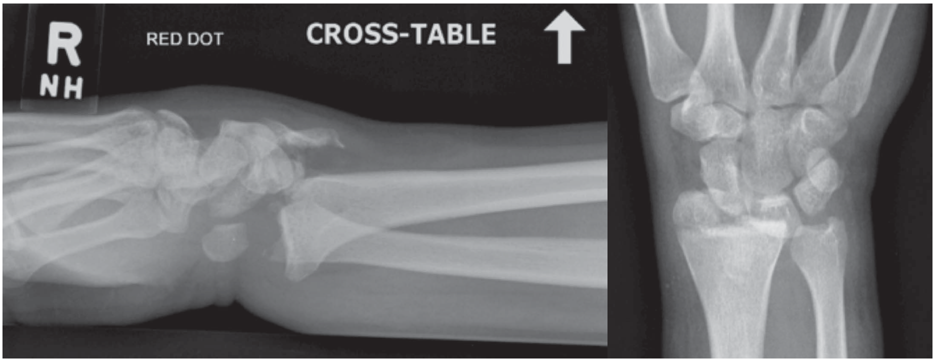


Figure 22.4 AP and lateral wrist radiographs

Describe these radiographs of a 23-year-old who was involved in a high-speed RTA, sustaining an isolated, neurovascularly intact, closed wrist injury. Tell me how you would manage this patient.

The wrist remains unstable despite closed reduction—what are your options?

How would you apply an external fixator and what are the risks?

What measures could you use to increase the rigidity of the external fixator?

Do you know of any evidence to support or refute the use of external fixation for distal radius fractures?

Viva 4 Answers

Describe these radiographs of a 23-year-old who was involved in a high-speed RTA, sustaining an isolated, neurovascularly intact, closed wrist injury. Tell me how you would manage this patient.

These radiographs shows a highly comminuted fracture of the dorsal rim of the right distal radius with dislocation of the radiocarpal joint in a skeletally mature patient. This is a high-energy injury and mandates urgent management as I would expect structures such as the median nerve to be compromised.

The wrist remains unstable despite closed reduction—what are your options?

The priority is to achieve a concentric, stable reduction. If this is not possible by closed means then the options are ORIF, external fixation, or a combination of both. I would use external fixation in the acute setting as this is a complex fracture requiring planning and appropriate expertise if internal fixation is desired.

How would you apply an external fixator and what are the risks?

I would perform a closed reduction and use the principle of ligamentotaxis applied through the external fixator to maintain the reduction. I would place two pins in the radial aspect of the radius proximal to the zone of injury. I would do this with a mini-open approach to avoid damage to the superficial radial nerve. I would bridge the radiocarpal joint and place two pins in the radial aspect of the index metacarpal at approximately 45° radially inclined to avoid the extensor tendon, in particular the extensor hood. The metacarpal is also at risk of fracture if the pins are inappropriately large or placed incorrectly. I would therefore feel the bone with the tip of the pin prior to insertion to ensure I was not aiming eccentrically, which would increase the likelihood of iatrogenic fracture. I would connect the pins to bars, taking care not to overdistract the radiocarpal joint.

What measures could you use to increase the rigidity of the external fixator?

Increasing the number and diameter of the pins and/or the bars and placing the pins in a near–far configuration can help, as does using pins in different planes relative to each other. Stiffness increases as the distance between the bars and the skin is reduced. Placing the pins in a slightly divergent manner increases pre-load in the system and thus stiffness, but risks earlier loosening of the pins. Above all else, however, I must ensure that the fracture is reduced with maximal bony contact as this has the greatest effect on stability.

Do you know of any evidence to support or refute the use of external fixation for distal radius fractures?

Multiple prospective randomized and non-randomized trials have shown improved functional and radiographic outcomes, or only improved radiographic outcomes, with external fixation versus closed reduction and casting. Two prospective randomized control trials have shown improved early functional outcomes (3 months) but equivalent medium-term outcomes (1 year) between volar plate fixation and bridging external fixation. Bridging external fixation is thought to be superior to non-bridging external fixation which was once in vogue but not appropriate in this case.

Egol K, Walsh M, Tejwani N, McLaurin T, Wynn C, Paksima N (2008). Bridging external fixation and supplementary Kirschner-wire fixation versus volar locked plating for unstable fractures of the distal radius: a randomised, prospective trial. *J Bone Joint Surg Br*, 90, 1214–1221.

Laino DK, Tejwani N (2012). Indications for operative fixation of distal radius fractures: a review of the evidence. *Bull NYU Hosp Jt Dis*, 70, 35–40.

McQueen MM, Hajducka C, Court-Brown CM (1996). Redisplaced unstable fractures of the distal radius. A prospective randomized comparison of four methods of treatment. *J Bone Joint Surg Br*, 78, 404–409.

Wei D, Raizman NM, Bottino CJ, Jobin CM, Strauch RJ, Rosenwasser MP (2009). Unstable distal radial fractures treated with external fixation, a radial column plate, or a volar plate. A prospective randomized trial. *J Bone Joint Surg Am*, 91, 1568–1577.

Viva 5 Questions

Figure 22.5 AP and lateral wrist and forearm radiographs

A 46-year-old man involved in a RTA presents at 11 p.m. with an isolated right wrist injury. Describe the radiographs.

On examination, he has tingling in the index finger and thumb since the injury—how will you manage him further?

Despite reduction and elevation, he now has complete numbness in his index finger and thumb—how will you manage him further?

What are your indications for urgent surgical intervention?

What surgery would you perform and how would you do it? What approach would you use?

Would you use a single or separate incision for the carpal tunnel release?

Viva 5 Answers

A 46-year-old man involved in a RTA presents at 11 p.m. with an isolated right wrist injury. Describe the radiographs.

These are anteroposterior and lateral views of a skeletally mature individual with a comminuted radius fracture and associated ulna styloid tip fracture. There is volar subluxation of the carpus, and I suspect there is a partial articular component to this fracture in the sagittal plane.

On examination, he has tingling in the index finger and thumb since the injury—how will you manage him further?

Given that he has a high-energy injury I would assess him as per the ATLS protocol to rule out systemic or life-threatening injuries. I'd assess his limb for the extent of neurological compromise, specifically in the median nerve distribution, as well as looking for vascular compromise and for signs of compartment syndrome. I would document my findings. I would splint his wrist and elevate his arm and reassess his neurological state—again documenting the result.

Despite reduction and elevation, he now has complete numbness in his index finger and thumb—how will you manage him further?

This patient has clinically evolving median nerve compression. As such I would like to take him urgently to theatre with the intention of stabilizing his fracture and decompressing his carpal tunnel.

What are your indications for urgent surgical intervention?

The main indication for urgent surgery is evolving, progressive median nerve compression despite simple measures such as fracture reduction, splinting, and elevation. Mild neurological symptoms that are unchanged or improve after simple measures do not warrant emergent surgery as they are indicative of a neurapraxia rather than a progressive compression neuropathy that may result in significant neural damage and poor prognosis if surgery is delayed. There are three general scenarios relating to nerve dysfunction after distal radius fracture. (1) There is neurological compromise from the outset, which does not get worse—this indicates a neurapraxia or rarely a laceration sustained at the time of injury. Emergent intervention will not change the natural course of nerve recovery. (2) There are evolving and deteriorating neurological signs/symptoms that are not alleviated by simple measures. This indicates an acute carpal tunnel syndrome at best and impending compartment syndrome at worst. Emergent decompression should be performed. (3) Neurological symptoms develop in the subsequent days or weeks. This is probably due to perineural oedema or inflammation. If symptoms are significant then decompression is warranted but not on an emergent basis.

What surgery would you perform and how would you do it? What approach would you use?

This is an unstable fracture as indicated by the injury mechanism, the comminution, and the soft tissue component, resulting in nerve compression. Surgery should include reduction and stable plate fixation of the fracture as well as median nerve decompression. A distal radial volar periarticular plate with sufficient length to bridge the comminution should be used and reduction should concentrate on restoring radial length, alignment, and any intra-articular step. Most commonly the Henry approach or a modification through the bed of the FCR would be used.

Would you use a single or separate incision for the carpal tunnel release?

It is recommended that concurrent carpal tunnel decompression should be performed via a separate incision. This avoids ulnar zig-zagging of the Henry incision to meet the carpal tunnel incision which places the palmar cutaneous branch of the median nerve at risk. This is because this branch arises from the radial aspect of the median nerve around 5 cm proximal to the wrist crease and lies on the ulna aspect of the FCR before supplying the skin over the thenar eminence.

Hoppenfeld S, DeBoer P, Buckley R (2009). *Surgical Exposures in Orthopaedics: the Anatomic Approach*, 4th edn. Lippincott Williams and Wilkins, Philadelphia, PA.

Niver G, Ilyas M (2012). Carpal tunnel syndrome after distal radius fracture. *Orthop Clin N Am*, 43, 521–527.

Schmidt AH, Anglen J, Nana AD, Varecka TF (2010). Adult trauma: getting through the night. *J Bone Joint Surg Am*, 92, 490–505.

Viva 6 Questions

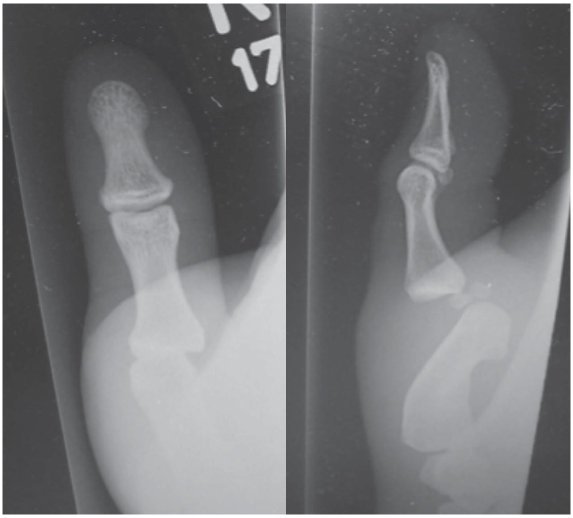


Figure 22.6 Thumb AP and lateral radiograph

Describe these radiographs.

What is unique about this injury?

Explain the ‘noose effect’.

What are the complications associated with this injury?

What would your approach be—volar or dorsal? Are you aware of any relevant literature?

Viva 6 Answers

Describe these radiographs.

These are radiographs of the thumb of a skeletally mature patient showing a dorsal dislocation of the thumb metacarpophalangeal joint. I cannot see any associated fractures but the thumb sesamoids are entrapped between the metacarpal and proximal phalanx.

What is unique about this injury?

Most dislocations of the thumb metacarpophalangeal joints are dorsal, although palmar dislocations have also been reported. The mechanism of injury involves hyperextension with associated complete rupture of the volar plate. Rupture of the volar plate mostly occurs proximal to the sesamoids. These injuries are usually reducible but sometimes they can be irreducible if it is a complex dislocation. These radiographs show the intra-articular position of the sesamoid; this is pathognomonic for a complex dislocation with the so-called 'noose effect'.

Explain the 'noose effect'.

In a complex dislocation the FPL tendon remains within the flexor tendon sheath and displaces to the ulnar side of the metacarpal head, creating a 'noose' around the metacarpal neck together with the radially displaced thenar intrinsic musculature. Any traction applied to reduce the dislocation tightens this noose, making reduction difficult.

What are the complications associated with this injury?

In the short term there is a risk of injury to the digital nerve if the volar approach is used, along with the risk of infection. In the long term there is a risk of stiffness, secondary arthritis, osteonecrosis of the metacarpal head, and even premature closure of the physis in the paediatric population.

What would your approach be—volar or dorsal? Are you aware of any relevant literature?

In his original description of the surgical approach for an irreducible dorsal dislocation Farabeuf used a dorsal incision. This involves a lower risk of NVB injury and easier access to the entrapped volar plate than the volar approach. Also, it may be easier to address any associated metacarpal head fractures using a dorsal approach. Kaplan described a volar approach for the treatment of irreducible dorsal dislocations. A volar approach allows access to the volar plate and also to the surrounding ligaments and tendons that can trap the metacarpal head and cannot be addressed through a dorsal incision. Eaton and Dray described a technique of releasing the A1 pulley, which then releases tension on the flexor tendons allowing the proximal phalanx and attached volar plate to reduce into their anatomical positions.

Dinh P, Franklin A, Hutchinson B, Schnall SB, Fassola I (2009). Metacarpophalangeal joint dislocation. *J Am Acad Orthop Surg*, 17, 318–324.

Eaton RG, Dray GJ (1982). Dislocations and ligament injuries in the digits. In: DP Green (ed.) *Green's Operative Hand Surgery*, Vol. 1, pp.647–668. Churchill Livingstone, New York.

Farabeuf LHF (1876). De la luxation du ponce en arrière. *Bull Soc Chir*, 11, 21–62.

Kaplan EB (1957). Dorsal dislocation of the metacarpophalangeal joint of the index finger. *J Bone Joint Surg Am*, 39, 1081–1086.

Viva 7 Questions

Figure 22.7 Thumb radiograph

Describe the injury shown in this radiograph.

Can you describe the mechanism of injury?

What would you do before you stress this injury?

Describe a Stener lesion.

How would you manage a chronic ulnar collateral ligament injury?

Viva 7 Answers

Describe the injury shown in this radiograph.

This is a plain radiograph of a thumb showing an avulsion fracture of the proximal phalanx suggestive of avulsion of the ulnar collateral ligament. I would like to see another view.

Can you describe the mechanism of injury?

Valgus stress to the thumb can result in ligamentous or bony disruption of the ulnar collateral ligament. The most common mechanism is a fall on the abducted thumb. This can also result in rupture of the dorsal capsule, adductor mechanism, and extensor pollicis brevis tendon which will increase the degree of instability found on examination. When the proper collateral ligament is ruptured, instability will be present when the thumb is tested in flexion. When the accessory collateral ligament is also torn the tear is considered complete, and there is instability in extension as well as flexion.

What would you do before you stress this injury?

When dealing with any patient with a possible injury of the ulnar collateral ligament I would ensure a radiograph of the involved thumb is performed as there is a risk of displacing the avulsed fragment, creating a Stener lesion, which could jeopardize the option of treating this injury non-operatively.

Describe a Stener lesion.

In a Stener lesion there is displacement of the distal end of the completely ruptured ligament and it comes to lie superficial and proximal to the adductor aponeurosis. Due to the interposition of the adductor aponeurosis, these injuries do not heal with non-operative treatment and need operative intervention to restore function.

How would you manage a chronic ulnar collateral ligament injury?

Chronic ulnar collateral ligament injury usually results from the failure of a patient to seek advice following an acute injury. Management is dependent on the underlying condition of the metacarpophalangeal joint. If there are no arthritic changes then a reconstruction can be performed with a graft harvested from the palmaris longus or partial flexor carpi radialis. The graft is woven through the metacarpal neck and the proximal phalanx and secured with suture anchors. In long-standing cases patients can develop arthritic changes and would benefit from fusion of the metacarpophalangeal joint.

Heyman P (1997). Injuries to the ulnar collateral ligament of the thumb metacarpophalangeal joint. *Am Acad Orthop Surg*, 5, 224–229.

Tang P (2011). Collateral ligament injuries of the thumb metacarpophalangeal joint. *J Am Acad Orthop Surg*, 19, 287–296.

Viva 8 Questions

Figure 22.8 Finger tip injury

What type of injury is shown in this photograph?

How would you assess this injury?

What are your principles of management in such injuries?

What are the various complications associated with such injuries?

Viva 8 Answers

What type of injury is shown in this photograph?

This is a clinical photograph showing a nail bed injury affecting a significant part of the proximal nail fold. I would like to get a radiograph of this finger to assess the underlying injury to the distal phalanx in order to plan further management.

How would you assess this injury?

I would like to obtain a full history of the mechanism of injury and check for any associated medical conditions that will impact on the overall management of this patient, such as diabetes mellitus or heavy smoking. Clinically it is essential to evaluate the sensation and vascularity in the tip of the finger. I would like to assess the integrity of the flexor and extensor tendons by checking the mobility of the finger tip. Furthermore plain radiographs are needed to ensure any underlying fracture is identified.

What are your principles of management in such injuries?

After a full clinical examination I would assess for any underlying bone loss of the distal phalanx. If there is over 50% loss of the distal phalanx, irreparable injury to the nail matrix, or a significant systemic illness I would offer a terminalization of the digit. I would be careful in ablating the nail, shortening the bone, and preserving the flexor and extensor insertions.

Nail bed injuries can be classified broadly into those involving exposure of the bone and those without bone exposure. Surgical management is influenced by the type of soft tissue loss, which can be classified as volar oblique, dorsal oblique, or transverse. If the bone is not exposed and the wound is less than 1 cm then its best to let it heal by second intention, but this can take as long as 5–7 weeks. If the wound is over 1 cm then the patient will need a full-thickness skin graft. If the bone is exposed then the patient will need a flap, which depends upon the type of soft tissue loss. Local V–Y flaps can be used for transverse and volar oblique injuries. Large wounds with exposed bone and dorsal oblique injuries can be managed with cross-finger flaps.

What are the various complications associated with such injuries?

In the short term there can be infections or flap or graft necrosis. In the long term the patient can present with stiffness in the finger, especially if the finger needs immobilization as in treatment with a cross-finger flap. Various complications can be seen with the growth of nail, such as a nail ridge, a nail split if there is injury to the germinal matrix, and non-adherence of the nail if there is injury to the sterile matrix. Failure to remove all the germinal matrix can result in nail spikes or nail cysts. Scarring of the eponychium and nail fold to the nail bed is known as pterygium; this leads to functional and aesthetic deformities such as an absence of nail growth and splitting of the nail. Hooking of the nail occurs with tight closure of a fingertip amputation or loss of bony support under the nail bed, which leads to curving of the matrix in a volar direction. Many patients with finger tip injuries complain of temperature sensitivity, mainly in cold weather, and this should be explained to the patient in advance.

Sammut D (2002). Finger tip injuries: a review of indications and methods of management. *Curr Orthop*, 16, 271–285.

Sommer N, Brown R (2011). The perionychium. In: SW Wolfe, RN Hotchkiss, WC Pederson, SH Kozin (eds) *Green's Operative Hand Surgery*, 6th edn, Vol. 1, pp.339–350. Churchill Livingstone, New York.

Viva 9 Questions

Figure 22.9 Wrist AP radiograph

What does this radiograph show?

What causes non-union of the scaphoid?

What are the principles of management of this type of injury?

If a patient presents late with a non-union and already has osteoarthritic change in the wrist joint, what salvage procedures might you consider?

Viva 9 Answers

What does this radiograph show?

This is an anteroposterior view of the wrist showing an established non-union of the scaphoid. There does not appear to be any osteoarthritis or scaphoid non-union advanced collapse (SNAC). I would like to see further views to look for any humpback deformity of the scaphoid, and also a CT of the wrist to aid surgical planning.

What causes non-union of the scaphoid?

The blood supply to the scaphoid has been considered to be the most important cause of non-union. The blood supply comes from branches of the radial artery that enter the bone through dorsal foramina. As these are mainly located distally, the proximal pole has a poor blood supply, increasing the risk of non-union. The degree of displacement of the fracture or instability of the fracture may be relevant. Proximal pole fractures have high non-union rates and all of these factors may play a role. The length of time from fracture to diagnosis and institution of the correct treatment may influence the union rate.

What are the principles of management of this type of injury?

The objective of treatment is to achieve union, relieve symptoms, and reduce the long-term risk of osteoarthritis in the joint. If the non-union is established then internal fixation with bone grafting is appropriate. A headless compression screw, of which there are several on the market, is considered the gold standard for fixation as it allows the screw to be buried so impingement is not an issue. The graft may be cancellous or corticocancellous depending on the type of bone defect that is found at surgery. Some surgeons use vascularized grafts. Grafts may be taken from the distal radius or the iliac crest.

If a patient presents late with a non-union and already has osteoarthritic change in the wrist joint, what salvage procedures might you consider?

Simple procedures include radial styloidectomy, excision of part of the scaphoid—usually the proximal pole—and denervation of the wrist joint. More formal reconstructive procedures include scaphoid excision and four-corner fusion, arthroplasty, proximal row carpectomy, and total wrist fusion.

Barton NJ (1992). Twenty questions about scaphoid fractures. *J Hand Surg Br*, 17, 289–310.

chapter 23

LOWER LIMB—PELVIS, HIP, FEMUR, KNEE, AND TIBIA

Viva 1 Questions

Figure 23.1 Pelvis radiograph

An 80-year-old woman is admitted under your care. How would you manage the fracture shown in the radiograph?

Why have you suggested a nail rather than a dynamic hip screw?

What DVT prophylaxis would you use?

What causes the deformity typical in these fractures, and how will you reduce the fracture?

You mentioned the suspicion of skeletal metastases and pathological fracture. What primary cancers are most likely? How will this affect your management?

Viva 1 Answers

An 80-year-old woman is admitted under your care. How would you manage the fracture shown in the radiograph?

The radiograph shows a subtrochanteric fracture of the left femur, with reverse obliquity. I would provide prompt analgesia then take a history, paying particular attention to the mechanism of injury, comorbidities, and pre-injury functional level. Specifically I would ask about previous history of cancer, as there is a high incidence of these fractures occurring secondary to pathological lesions of the bone. I would assess the patient for cognitive impairment and examine her. This examination would be focused on the identification of dehydration, neurovascular status and the soft tissue condition of the limb, cardiac and respiratory pathologies, and, in this patient, a screen for common cancers that metastasize to bone because subtrochanteric fractures are often pathological.

I would then arrange simple investigations. These would include full-length femur radiographs, a chest radiograph, ECG, urine dipstick, and blood tests. Blood tests would include full blood count, urea and electrolytes, liver function tests, erythrocyte sedimentation rate, bone profile, and a cross-match for two units of blood. If the imaging showed a lytic lesion I would be concerned about renal deposit and major bleeding and, if supported by further investigation, would consider pre-operative embolization and further cross-matching. I would begin rehydration with intravenous crystalloids and ask the orthogeriatrician to assess the patient pre-operatively. If the patient is frail I'd also ask for an anaesthetic review.

Having done this, I would recommend surgical stabilization of the fracture with the use of a long cephalomedullary nail and consent the patient. I would organize the surgery to be performed on the next routine trauma list (ideally within 24 hours). At my hospital we adopt enhanced recovery principles with our neck of femur patients and I would therefore prescribe the appropriate carbohydrate drinks. The patient would be allowed to eat until 6 hours before surgery and drink water until 2 hours before.

Why have you suggested a nail rather than a dynamic hip screw?

This is a subtrochanteric fracture. With a dynamic hip screw (DHS) dynamization will not compress the fracture. Instead, the reduction may fail as the shaft medializes due to loss of lateral buttressing—if this happens there is a significant risk of screw cut-out and failure. An intramedullary device is on-axis and therefore has a mechanical advantage in resisting varus cantilever forces compared with a DHS in an unstable proximal femoral injury. Further, it resists shaft medialization as the nail is within the diaphyseal bone.

There are now clinical data to support this biomechanical theory. An example is the paper by Matre and colleagues from 2013, based on the Norwegian Hip Fracture Database. The DHS group had 50% higher re-operation rate, worse pain scores, and worse mobility at 1 year.

What DVT prophylaxis would you use?

Patients with hip and femur fractures are at high risk of VTE. I would therefore use both mechanical and chemical prophylaxis. Unless contraindicated, I would prescribe **thromboembolic deterrent** (TED) stockings and use an intermittent calf-compression boot during surgery. After surgery, I would encourage early mobilization and aim to keep the patient well hydrated throughout her stay. In line with NICE guidelines for VTE prophylaxis after hip fracture, I would prescribe LMWH (dalteparin 5000 units) and begin this on admission. It would need omission for 18 hours before spinal anaesthetic, but would then recommence 6–12 hours post-operatively. I would continue this and the stockings for 35 days.

What causes the deformity typical in these fractures, and how will you reduce the fracture?

The proximal fragment is abducted by the insertions of the gluteus minimis and medius tendons on the anterior and middle facets of the greater trochanter. If the lesser trochanter remains attached to the proximal fragment, it provides a flexion force. The distal fragment is adducted by the insertion of adductors on the diaphysis of the femur. I often find it difficult to achieve adequate reduction via closed means on the traction table. When I have achieved as much as possible by closed means on the traction table I therefore routinely open subtrochanteric fractures (via a small mid-lateral incision) to reduce the fracture. I hold the fracture reduced with a large plate-holding forceps and, if required, pass a circlage cable. Having achieved reduction I then insert my nail, ensuring that my entry point is not too lateral so I don't re-displace the fracture. The small open incision is almost always at the correct site for placing the recon screws, so does not add significantly to the operative insult. I always take time to ensure there is no residual varus deformity as this increases the risk of failure of my construct.

You mentioned the suspicion of skeletal metastases and pathological fracture. What primary cancers are most likely? How will this affect your management?

Lytic bony lesions in men are commonly from lung or renal primaries. In contrast, prostate cancer tends to cause sclerotic deposits. Chest radiograph and urine cytology would therefore help. A contrast CT of chest, abdomen, and pelvis would pick up 85% of unknown primaries.
Renal metastases can bleed heavily at surgery. I would therefore consider angiography and embolization of the lesion before surgery and would ensure I have several units of blood cross-matched and tranexamic acid available. I would warn the anaesthetic team of the potential for haemorrhage and counsel the patient accordingly. In patients with skeletal metastases it is preferable to stabilize the whole bone, so a short nail would not be acceptable.

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Viva 2 Questions

Figure 23.2 Pelvis radiograph

Describe this radiograph.

What are the radiological features on an anteroposterior pelvis radiograph that are evaluated for acetabular fractures?

What are Judet views?

How are these fractures classified?

Are you aware of any guidelines regarding acetabular fractures?

What are the complications of both these fractures and their treatment? Do you know of any factors which predict outcome?

Viva 2 Answers

Describe this radiograph.

This is an anteroposterior view of the pelvis of an adult male showing a displaced right acetabular fracture with medial displacement of the femoral head.

What are the radiological features on an anteroposterior pelvis radiograph that are evaluated for acetabular fractures?

The anterior column is represented by the ilioinguinal line, and the posterior column by the ilioischial line. The anterior and posterior walls are examined; they can be identified by tracing the inferior border of the superior and inferior pubic rami, respectively, to the edge of the acetabulum. The teardrop is the radiographic representation of the medial wall. The sourcil represents the weight-bearing dome. Further evaluation of the fracture pattern would be helped with Judet views and a CT scan with coronal and sagittal reformats.

What are Judet views?

These are 45° oblique views taken using a wedge, and centred on the affected hip joint. Two views are gained. For the right hip, angling the left hip up by 45° provides an iliac oblique view which visualizes the posterior column and the anterior wall. Angling with the right hip upwards gives an obturator oblique view to visualize the anterior column and the posterior wall.

How are these fractures classified?

These fractures are classified using the Judet and LeTournel classification. This describes five simple fracture patterns: posterior column, posterior wall, anterior column, anterior wall, and transverse. There are also five combined fracture patterns: posterior column with posterior wall, anterior column with posterior hemitransverse, T-fractures, and an associated fracture of both columns. The defining feature of this final fracture pattern is the loss of contact of any of the articular surface with the axial skeleton.

Are you aware of any guidelines regarding acetabular fractures?

The BOAST guidelines lay out standards for the management of these fractures. Fractures requiring reduction and internal fixation should undergo surgery by a specialist trained in acetabular reconstruction, ideally within 5 days of injury, and no later than 10. Hip dislocations must be reduced urgently, with a pre- and post-reduction neurovascular examination, and skeletal traction applied. Following reduction, a CT scan should be performed within 24 hours and referral should be made to a specialist centre. Thromboprophylaxis should start within 48 hours of injury provided there are no contraindications.

What are the complications of both these fractures and their treatment? Do you know of any factors which predict outcome?

Posterior fractures and dislocations have a high risk of nerve damage and carry a high risk of DVT. Operative fixation, especially though posterior approaches, carries a high risk of heterotopic ossification. With intra-articular fractures, the main risk is joint arthrosis as a late complication. There may also be a risk of AVN to the femoral head, especially in the setting of a hip dislocation.

The outcome of these fractures, especially with a view to joint degeneration, is related to many factors. Some are uncontrollable, such as the type of fracture, associated dislocation, femoral head damage, associated injuries, age, and the effect of comorbidities. Others factors can be influenced by the surgeon, including the timing of the operation, the surgical approach, and, most importantly, the quality of fracture reduction. Correctly selected and performed ORIF of displaced fractures can lead to an 80% survivorship of the native hip out to 20 years.

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Viva 3 Questions

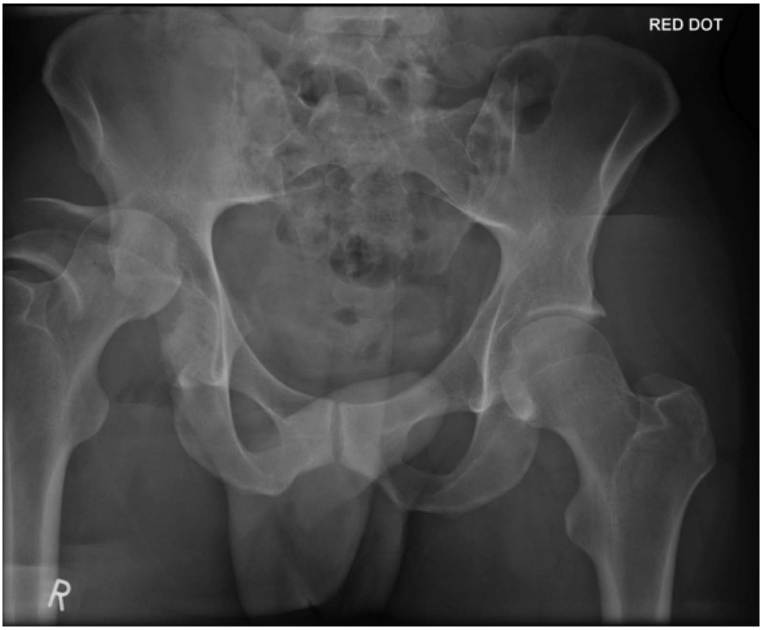

Figure 23.3 Pelvis radiograph

A 27-year-old motorcyclist comes in to A&E after being thrown from his motorbike in a collision. This radiograph was taken in the resuscitation bay. Describe it and tell me how you are going to manage this patient.

What if you cannot reduce the hip?

How would you proceed in the setting of a successful closed reduction?

The post-operative CT scan shows a large, displaced posterior wall fragment, and the hip was very unstable on examination under anaesthetic. If you were the acetabular surgeon how would you proceed?

What other surgical approaches for the treatment of acetabular fractures are you aware of?

Viva 3 Answers

A 27-year-old motorcyclist comes in to A&E after being thrown from his motorbike in a collision. This radiograph was taken in the resuscitation bay. Describe it and tell me how you are going to manage this patient.

This is an anteroposterior view showing a right hip dislocation with an associated acetabular fracture. This is a high-energy injury, and the patient should initially be assessed according to the ATLS protocol so that life-threatening injuries are not missed. If this is an isolated injury, then the neurovascular status of the limb must be examined and documented before any intervention. Then the hip needs to be reduced. This can be attempted in A&E if there is sufficient skill available for analgesia and sedation, but if not it can be done in theatre. At the time of reduction, the stability of the hip should be documented: given the size of the posterior wall it is likely that it will be significantly unstable in this case. Post-reduction, skeletal traction should be applied and the neurovascular status of the limb monitored.

What if you cannot reduce the hip?

In this situation, a discussion with the regional acetabular reconstruction service would be appropriate. Immediate transfer to them might be preferable, as in this case an open reduction would be required and it would be logical to fix the fracture at the same time. If transfer was going to be delayed, or should I be so instructed, then I would proceed with an open reduction through a posterior approach.

How would you proceed in the setting of a successful closed reduction?

A CT scan should be done to further evaluate the fracture pattern and the presence of any intra-articular fragments. These images should then be discussed with a specialist in acetabular reconstruction.

The post-operative CT scan shows a large, displaced posterior wall fragment, and the hip was very unstable on examination under anaesthetic. If you were the acetabular surgeon how would you proceed?

Treatment should consist of an ORIF. On a radiolucent table, I would place the patient in the lateral position and use the Kocher–Langenbach approach, removing the short external rotators to access the posterior aspect of the acetabulum. The fracture could then be exposed, reduced, and secured with lag screws and a posterior plate. If the wall fracture extends superiorly, then it is possible to increase the surgical exposure using a trochanteric osteotomy.

What other surgical approaches for the treatment of acetabular fractures are you aware of?

The Kocher–Langenbach approach allows access to the posterior aspect of the acetabulum. Access to the anterior aspect can be gained through either an ilioinguinal approach or a Stoppa approach. The former utilizes an incision in the line of the inguinal ligament and provides three windows of access to the anterior column of the acetabulum. The Stoppa approach can be performed through a vertical midline or Pfannensteil incision and also provides access to the anterior column, although a fracture extending higher into the iliac wing may also require use of the outer window of the ilioinguinal approach. There are a number of other extensile approaches, such as the extended iliofemoral approach which allow simultaneous access to anterior and posterior elements. However, the extensive amount of muscle stripping required can lead to significant morbidity and risk of complications, and these techniques are falling out of favour somewhat. In situations where access to both anterior and posterior elements is required, it may be more appropriate to perform two separate approaches, either in one go or as a staged procedure.

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Viva 4 Questions

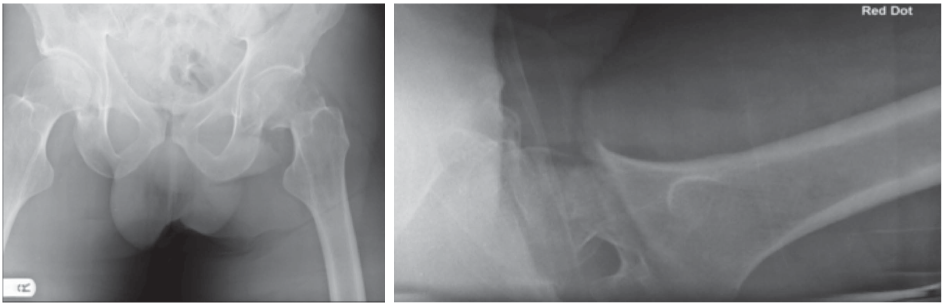

Figure 23.4 Hip AP and Lateral radiograph

Describe what you can see in these radiographs.

How would you manage this patient if he was referred to you by the A&E team?

The patient is a 45-year-old solicitor who sustained this injury whilst mountain biking. He has no other injuries. What would be your management plan for treatment of this fracture?

Could you describe the blood supply to the femoral head?

When consenting this patient for surgery what particular risks would you warn him about?

Can you quote the incidence of these complications and any literature to back this up?

Viva 4 Answers

Describe what you can see in these radiographs.

These radiographs show an anteroposterior view of the hips and a lateral view of the left hip. The anteroposterior film shows a displaced intrascapsular fracture of the left neck of femur, this is supported by the appearance on the lateral view confirming the presence of a fracture with displacement and some posterior angulation of the femoral head.

How would you manage this patient if he was referred to you by the A&E team?

I would take a history and examine him, ensuring that the possibility of any other injuries had been ruled out. I would want to know his age and activity level, any comorbidities, and the mechanism of injury. He should be kept nil by mouth and given intravenous fluids and analgesia. Surgery should be performed on the next available trauma operating list, either on the day of admission or the day following admission, as per national guidelines set out by NICE.

The patient is a 45-year-old solicitor who sustained this injury whilst mountain biking. He has no other injuries. What would be your management plan for treatment of this fracture?

The majority of femoral neck fractures occur in the older population and are the result of low-energy injuries. This is not the case in younger patients who are active and have fewer medical problems and better bone quality than their older counterparts. The goals of treatment are to preserve the femoral head and avoid arthroplasty if at all possible. I would therefore treat this patient with closed reduction, with the caveat that only an anatomical reduction is acceptable. I would be prepared to perform an open reduction if necessary and then internal fixation either with cannulated screws or a two-hole DHS with de-rotation screw.

Could you describe the blood supply to the femoral head?

The femoral head blood supply comes from three main sources: the medial femoral circumflex artery, the lateral femoral circumflex artery, and the obturator artery, although in adults the latter may have little to contribute. The lateral femoral circumflex artery gives off an ascending branch, the inferior metaphyseal artery, and supplies most of the inferoanterior aspect of the femoral head. The largest contributor to the blood supply is the lateral epiphyseal artery, which originates from the medial femoral circumflex artery and courses along the posterosuperior aspect of the femoral neck before supplying the femoral head.

When consenting this patient for surgery what particular risks would you warn him about?

Apart from the risks associated with anaesthetic, the main risks specific to this operation that the patient should be informed about prior to surgery are avascular necrosis (AVN) and non-union.

Can you quote the incidence of these complications and any literature to back this up?

The incidence of non-union has been reported to range from 0% to 45% and that of AVN from 0% to 86%: these figures were quoted in a 2005 paper by Damany et al. in *Injury* on a meta-analysis of

18 studies involving 564 fractures that looked at the incidence of complications after intracapsular hip fractures in young adults. They found that the overall incidence of non-union was 8.9% and of AVN 23%. A second prospective study performed by Loizou and Parker in 2009 looked at 1023 patients who had sustained an intracapsular fracture with subsequent internal fixation. They quoted rates of 20.6% for AVN in the under 60 age group compared with 12.5% in the 60–80 age group. They found an increased risk of AVN with younger age and in females with a displaced fracture. They found no association between the incidence of AVN and the interval between injury and surgery.

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Viva 5 Questions

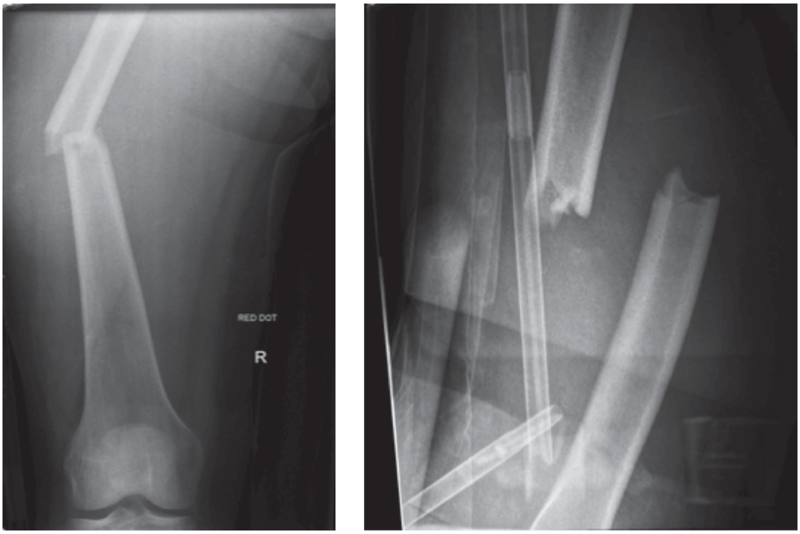

Figure 23.5 Femoral radiographs

A 25-year-old motorcyclist is hit by a car. These are the radiographs taken in the resuscitation bay. How would you manage this patient?

How would you set up the patient? What if any problems would you anticipate?

Are there any situations in which you might consider alternative treatments?

The post-operative films show a fracture of the femoral neck not supported by the interlocking antegrade nail. How has this happened?

Viva 5 Answers

A 25 year-old motorcyclist is hit by a car. These are the radiographs taken in the resuscitation bay. How would you manage this patient?

The radiographs show a displaced midshaft fracture in a high-energy injury. The patient should initially be treated according to ATLS protocols to identify life-threatening injuries first. As an isolated injury, the overlying soft tissue envelope and distal neurovascular status should be examined. A complete set of radiographs to include the ipsilateral hip and knee should be obtained, and the remainder of the limb examined for more distal injuries. Then traction should be applied to give temporary stability to the fracture and reduce blood loss and provide analgesia. Definitive treatment should occur promptly, and I would choose to stabilize this fracture with an antegrade reamed intramedullary nail.

How would you set up the patient? What if any problems would you anticipate?

Assuming the patient is adequately resuscitated and prepared for theatre, I would set the patient up on a traction table, with the affected leg raised and the left leg scissored down to allow access by the image intensifier to both the hip and knee. The patient's hips should be brought to the right side of the table, and the shoulders as far left as is safe to provide the best access for entry point and instrumentation. Looking at the initial radiographs, my first operative concern would be reduction of the fracture, as the injury has led to wide displacement and there is the risk of soft tissue interposition. I would apply sufficient traction to overcome any shortening and assess whether it is possible to reduce the fracture closed either with external pressure, a crutch, or by using an instrument such as the 'F' tool. A Schanz pin could also be used to manipulate either fragment and could safely be inserted from the lateral side. If these techniques do not aid fracture reduction, I would open the fracture site and remove any interposed tissues.

Are there any situations in which you might consider alternative treatments?

In certain situations, largely related to polytrauma, it might be wise to consider a damage control approach involving temporary stabilization of the bone with an external fixator, with a plan to convert this to definitive fixation at a later date. This decision depends on both the physiological status of the patient and the presence of concomitant injuries. In such cases the more prolonged surgery and physiological effects associated with instrumentation of the femoral canal for reamed nailing might prove an unwanted extra physiological hit to the patient and worsen their condition. I would consider alternatives to definitive reamed nailing in instances such as multiple long bone fractures, significant chest injury, and significant closed head injuries. Physiological parameters that might give an indication of the potential need for damage control surgery include serum lactate, which can be easily measured from venous samples on blood gas machines. Bilateral femoral fractures have been shown to be a significant risk factor for the development of systemic inflammatory response syndrome (SIRS) and acute respiratory distress syndrome (ARDS). In polytrauma patients with multiple injuries, I would consider a Damage Control Approach also.

The post-operative films show a fracture of the femoral neck not supported by the interlocking antegrade nail. How has this happened?

This could have been a missed injury from the initial presentation or it may have been a complication of the nailing procedure. Femoral neck fractures may occur in up to 10% of high-energy femoral shaft fractures and are often missed at initial presentation. For patients at risk of this injury combination dedicated imaging of the hip to look for them should be part of the work-up, ideally through a protocol including hip radiographs, fine-cut CT imaging, and intra-operative fluoroscopy.

How would this have changed your treatment if you had known about it initially?

The use of one or two implants to treat both fractures is controversial, but I would have chosen a two-implant approach. Anatomical reduction of the femoral neck fracture is a priority. However, it is easier to apply traction to the femoral neck fracture and achieve a satisfactory reduction if the femoral shaft is one unit. As such I would fix the shaft first with a plate, or retrograde nail—being wary of malrotating the fracture—before attempting to fix the neck fracture, either closed or open with either screws or a DHS.

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Viva 6 Questions

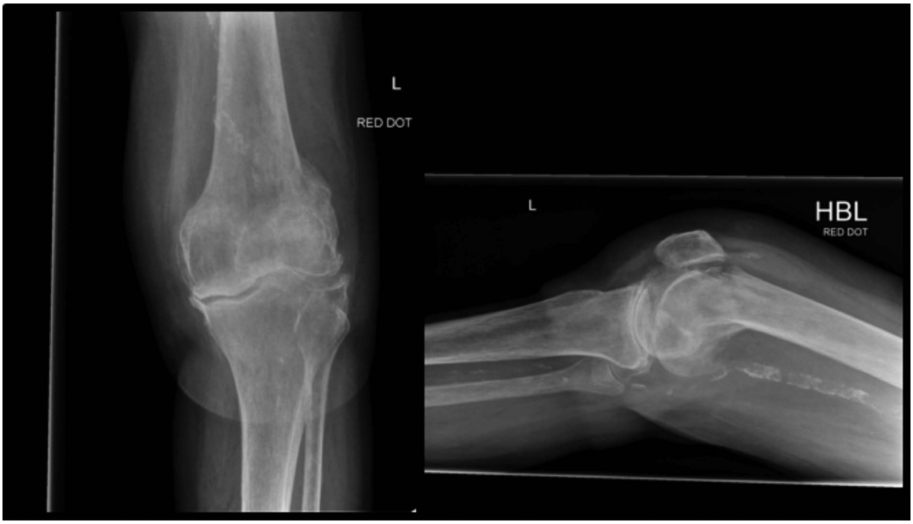

Figure 23.6 AP and Lateral radiograph of knee

Describe these radiographs of a 67-year-old man who fell outside his home on a patch of ice. How are you going to treat him?

What are the challenges and pitfalls of plate fixation?

How would your surgical technique change if you were treating this fracture in a 30-year-old motorcyclist?

Viva 6 Answers

Describe these radiographs of a 67-year-old man who fell outside his home on a patch of ice. How are you going to treat him?

These are anteroposterior and lateral views of a left knee showing a supracondylar fracture of the distal femur. The distal fragment has flexed. In addition there is significant degenerative disease in the knee, and notable calcification in the popliteal vessels.

Provided the patient's general condition does not preclude it, I would elect for surgical intervention. Non-operative treatment would require prolonged immobilization of what is likely an already stiff joint, and in addition to the potential for medical complications there is also a risk that the fracture will continue to displace and potentially threaten the overlying soft tissue envelope. It would also be difficult to control the fracture because the arthrosis in the knee will make the joint stiff and there would be a tendency for any movement to preferentially occur at the fracture site, increasing the risk of both further fracture displacement and non-union.

Broadly speaking, the surgical options here are internal fixation or primary replacement. If this knee had been relatively symptom free prior to the accident I would elect for fixation through a lateral approach with relative stability, using a periarticular locking plate in bridging mode in order to achieve union. Plating would not preclude total knee replacement at a later date if required. However, if the knee had been symptomatic, it may be more appropriate to perform primary arthroplasty. Because of the position of the fracture, this would be likely to involve a distal femoral replacement with a constrained articulation such as a rotating hinge. Thus, this decision should involve a surgeon with the necessary expertise as well as an analysis of the physiological capacity of the patient to withstand this procedure.

What are the challenges and pitfalls of plate fixation?

My preference when plating the femur in fractures in the elderly is to use as long a plate as possible, spanning the whole femur, and to use minimally invasive techniques if appropriate. In this case a small distal incision to allow the plate to be inserted will be needed. It is essential that this allows the iliotibial band to be divided as the plate must sit deep to this—if it is not deep to this layer, the patient will suffer from irritation and prominent metalwork. When plating, it is also essential that the plate is orientated correctly—a 95° wire through the central distal hole of almost all plates should be parallel to the joint on the anteroposterior projection. The plate also sits at an inclined angle on the lateral femoral cortex matching the shape of the native femur; it is important to recognize this otherwise my distal screws will aim anteriorly and penetrate the patellofemoral joint. Proximally it is essential that the plate sits along the mid-axis of the shaft and not too anterior or posterior—this is a common error in percutaneous plating. The number of screws and their configuration are also controversial—distally I prefer to use as many locked screws as possible in my construct, effectively filling the metaphysis with metal. Proximally I prefer a near–far pattern of locked screws, with a total of at least five or six screws. Previous studies suggested a unicortical or non-locked screw at the tip, but in my practice a bicortical screw is preferable.

How would your surgical technique change if you were treating this fracture in a 30-year-old motorcyclist?

In high-energy distal femoral fractures in younger people there is a risk of significant intra-articular involvement, and anatomical restoration of the joint surface is required in addition to fixation to the femoral shaft. Prior to surgery I would obtain a CT scan to allow me to better define the articular fracture fragments and plan my fixation. In this case I would use an extended lazy-S incision beginning midline at the insertion of the patellar tendon and curving laterally over the distal femoral shaft. This would allow me to use a lateral parapatellar arthrotomy to expose the articular surface for reduction and fixation before the addition of a periarticular plate to secure the articular block to the femoral shaft. The Hoffa (coronal) fragment is often present and must be recognized and stabilized prior to plate fixation.

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Viva 7 Questions

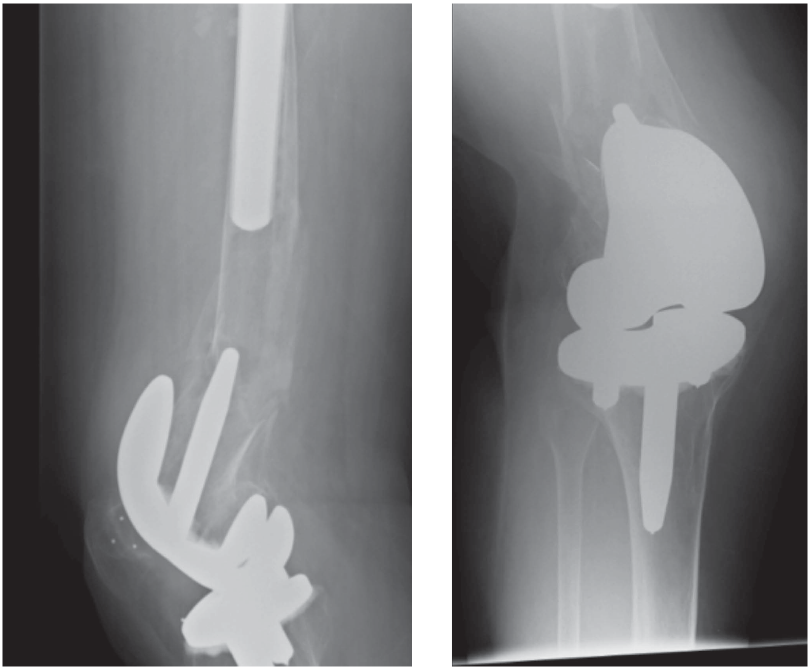


Figure 23.7 AP and Lateral radiograph of knee

What do these radiographs show?

Can you classify this fracture?

Can you describe the Vancouver classification?

How does this classification help the surgeon decide the best intervention for treatment of the fracture?

What are your treatment options for this injury, assuming further imaging shows the femoral component of the total hip replacement to be well fixed?

Are you aware of any literature describing the treatment of periprosthetic fractures?

Viva 7 Answers

What do these radiographs show?

These are anteroposterior and lateral views of the distal femur. There is a long femoral stem visible from a total hip prosthesis but also a short-stemmed total knee prosthesis distally within the femur. The radiographs show that a periprosthetic fracture has occurred within the distal femur from the level of the tip of the stem on the knee prosthesis and extends proximally, it is not possible to tell on these radiographs how far proximally the fracture extends. The bone has an osteopenic appearance.

Can you classify this fracture?

Using the Vancouver classification for periprosthetic fractures around a hip prosthesis this would be a Vancouver B fracture. Periprosthetic fractures around the knee in the supracondylar region of the femur have been classified by Lewis and Rorabeck; this would be a type II fracture using their classification.

Can you describe the Vancouver classification?

This classification system describes fractures around a hip prosthesis. Type A fractures are around the trochanters and are subdivided into groups A_G and A_L for involvement of the greater and lesser trochanters, respectively. Type B fractures are around the stem, with further subdivision depending on solid fixation or not of the implant and whether the bone stock is deficient: B1 is a well-fixed stem, B2 is a loose stem, and B3 is deficient bone stock. Type C fractures are distal to the prosthesis.

How does this classification help the surgeon decide the best intervention for treatment of the fracture?

The Vancouver classification helps the surgeon to focus on the environment in which the fracture has occurred. If the stem is well fixed, as with type B1 injuries, the fracture can generally be treated leaving the prosthesis *in situ* using an onlay cortical strut graft and a suitable plate that enables the use of screws and cables. B2 fractures are around a stem that was not solidly fixed at the time of injury, so the treatment of these fractures would normally require revision of the femoral stem to a prosthesis that bypasses the fracture by two cortical diameters. Type B3 fractures occur in the presence of insufficient bone stock and can be particularly difficult to treat. The literature describes the use of a stem with diaphyseal fit that bypasses deficient proximal bone stock, distally locked stems, or the use of prostheses that replace the proximal femur. Type C fractures can be treated independently of the prosthesis.

What are your treatment options for this injury, assuming further imaging shows the femoral component of the total hip replacement to be well fixed?

This is an extremely difficult fracture to treat. In my centre these injuries are referred to our regional specialist arthroplasty and complex trauma service. If the femoral stem from the total hip replacement is well fixed it should be left in situ, especially as there appears to be poor bone stock around the stem. The knee prosthesis also appears well fixed. The bone quality between the two prostheses is very poor. The presence of a stem on the femoral component of the knee would make any attempt at extramedullary fixation using a plating system difficult, and proximal fixation will have to rely on cables alone. This would be my preferred choice but I would be worried about fatigue failure of my construct occurring before the bone has healed. Conservative management with a long period in traction would be a difficult but viable option. This risks bed sores, pulmonary complications, and thromboembolic events, and may actually carry a higher risk of morbidity and mortality than surgical management. Other options include total femoral replacement, although this would be a huge undertaking and one that would carry significant risks in an elderly patient. The last option would be a transfemoral amputation. This fracture needs careful consideration as no one treatment option is ideal. All options should be discussed with the patient and his or her family with the seriousness of the injury being explained.

Are you aware of any literature describing the treatment of periprosthetic fractures?

In 2002 Campbell and McWilliams published a comprehensive editorial describing the epidemiology, prevention, classification, and treatment of periprosthetic fractures of the hip and knee. In 2004 Professor Learmonth from Bristol published aspects of current management of fractures around the femoral stem. In the same year Masri et al. from Vancouver published an article on the evaluation and treatment of periprosthetic fractures.

Campbell P, McWilliams TG (2002). Periprosthetic femoral fractures. *Curr Orthop*, 16, 126–132.

Learmonth ID (2004). The management of periprosthetic fractures around the femoral stem. *J Bone Joint Surg Br*, 86, 13–19.

Masri BA, Meek RM, Duncan CP (2004). Periprosthetic fractures evaluation and treatment. *Clin Orthop Relat Res*, Mar(420), 80–95.

Viva 8 Questions

Figure 23.8 Clinical photograph of a left knee injury

This is a photograph of the knee of a 35-year-old woman who has come off her motorcycle on her way to work. What can you see?

How would you manage this injury?

There was a weak pulse prior to reduction, and the foot was pink. You have successfully reduced the tibia; what would you do next?

The pulse is still present. There is no foot drop, but due to head and chest injuries and concerns about the airway the anaesthetists have intubated the patient and she is now fully sedated. The radiograph shows a fibula head avulsion fracture only. What is your major concern and what is your management now?

How would you measure the ABI?

The patient's ABI remains above 0.9 and the foot continues to be well perfused. Three days later the patient is awake. You arrange a MRI scan which shows an almost 'full house' of ligament injuries with only the MCL partially intact. What are your priorities for repair or reconstruction and the timing of these surgeries?

Viva 8 Answers

This is a photograph of the knee of a 35-year-old woman who has come off her motorcycle on her way to work. What can you see?

The left leg is splinted. There is a dislocation of the tibiofemoral joint of the knee with the tibia dislocated anteriorly in relation to the tibia. It appears to be a closed injury.

How would you manage this injury?

This is a high-energy injury and the patient should be appropriately assessed and resuscitated according to the ATLS protocol. While the primary survey is being completed I would assess the neurovascular status of the distal limb, which I would record carefully. If there are no other life-threatening injuries, the patient is stable, and appropriate analgesia is given, I would attempt closed reduction of the knee. I would perform this with gentle in-line traction on the foot and posterior pressure on the anterior part of the proximal tibia.

There was a weak pulse prior to reduction and the foot was pink. You have successfully reduced the tibia; what would you do next?

I would reassess the neurovascular status and document my findings; if I was happy there was distal blood flow I would arrange immobilization of the limb in a backslab or brace and then request radiographs.

The pulse is still present. There is no foot drop, but due to head and chest injuries and concerns about the airway the anaesthetists have intubated the patient and she is now fully sedated. The radiograph shows a fibula head avulsion fracture only. What is your major concern and what is your management now?

Popliteal artery damage is my major concern. There has been a recent shift from routine arteriography to selective arteriography in knee dislocation. Selective arteriography would suggest the need in cases of abnormal distal examination findings. Recent animal and human studies have shown that non-flow-limiting intimal tears rarely progress to occlusive thrombi. In this case it seems that the patient's flow is not occluded as the foot is pink and a weak pulse can be felt, so I would elect for regular measurement of the ankle–brachial index (ABI), which can be done in intensive care.

How would you measure the ABI?

With the patient supine a blood pressure cuff is placed proximal to the ankle of the injured limb. Systolic pressure is determined with a Doppler probe at either the posterior tibial artery or the dorsalis pedis artery. The same measurement is made on the ipsilateral uninjured arm. The ABI is calculated as the systolic pressure of the injured limb divided by the systolic pressure of the uninjured limb. Mills et al. reported 100% specificity; sensitivity, and positive predictive value of a significant arterial injury if this pressure difference is less than 0.9. Other series have suggested a threshold of 0.8.

I would consider arranging an urgent arteriogram and calling a vascular surgeon for advice if the clinical examination changed or the ABI, having been normal, dropped to below 0.9.

The patient's ABI remains above 0.9 and the foot continues to be well perfused. Three days later the patient is awake. You arrange a MRI scan which shows an almost 'full house' of ligament injuries with only the MCL partially intact. What are your priorities for repair or reconstruction and the timing of these surgeries?

My priority in terms of timing is the open repair of the PLC. The literature advises that repair of structures is easiest to perform and has the best outcome if performed within 2 weeks. I would thus liaise with the anaesthetists and plan for this surgery to be performed at a time that is safe for the patient. Elevation and ice can continue to reduce the swelling whilst this is planned.

I would embark on open repair of the PLC with the back up of artificial ligaments, or better still allograft if available. It is hard to predict the need for a graft, thus having one available is my priority. I would bear in mind that both hamstrings (ipsilateral and contralateral) are likely to be required for the ACL and PCL. I would perform open repair or reconstruction of the LCL and PLC, and if the anaesthetist was happy then proceed to arthroscopically assisted reconstruction of the ACL and PCL. If the tourniquet time was long or there was a problem with the anaesthetic I would have no hesitation in staging the reconstruction of the ACL or PCL.

Klineberg EO, Crites BM, Flinn WR, Archibald JD, Moorman CT III (2004). The role of arteriography in assessing popliteal artery injury in knee dislocations. *J Trauma*, 56, 786–790.

Levy BA, Fanelli GC, Whelan DB, et al. (2009). Controversies in the treatment of knee dislocation and multiligament reconstruction. *J Am Acad Orthop Surg*, 17, 197–206.

Mills WJ, Barei DP, McNair P (2004). The value of the ankle-brachial index for diagnosing arterial injury after knee dislocation: a prospective study. *J Trauma*, 56, 1261–1265.

Tzurbakis M, Diamantopoulos A, Xenakis T, Georgoulis A (2006). Surgical treatment of multiple knee ligament injuries in 44 patients: 2–8 years follow-up results. *Knee Surg Sports Traumatol Arthrosc*, 14, 739–749.

Viva 9 Questions

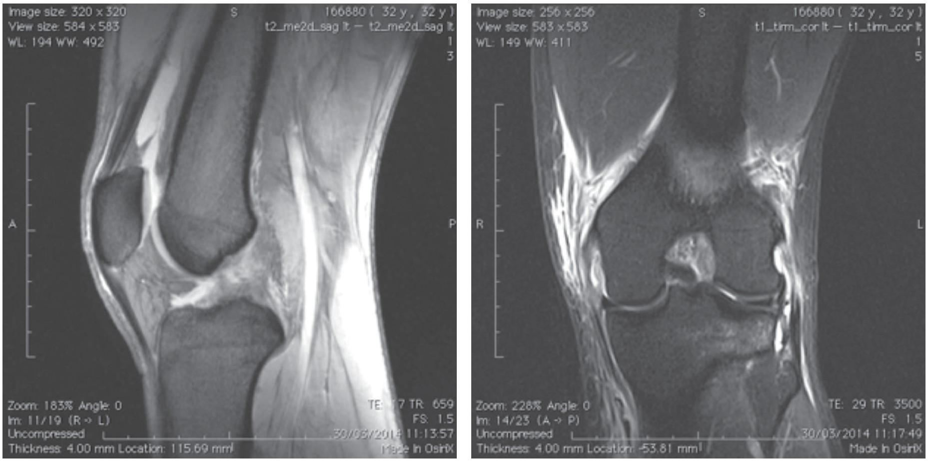


Figure 23.9 Knee MRI

These are MRI scans of the injured knee of an 18-year-old elite junior netball player. She heard a large pop when she tried to change direction. What do the scans show?

How would you treat this injury?

When would you perform reconstruction?

What are the graft choices for ACL reconstruction?

What would be your choice and why?

What are the key steps in performing an ACL reconstruction?

What fixation would you use?

What would your rehabilitation programme be, and when would you allow her to return to playing netball?

Viva 9 Answers

These are MRI scans of the injured knee of an 18-year-old elite junior netball player. She heard a large pop when she tried to change direction. What do the scans show?

These are T_2 MRI scans showing sagittal and coronal views through the knee. I can see a ruptured ACL and a large bone bruise on the posterolateral tibial plateau consistent with the dislocation of the lateral femoral condyle that occurs during this injury. There is some increased signal around the structures of the posterolateral corner and MCL but they look grossly intact.

How would you treat this injury?

I would take a history and examine the patient looking for other ligament injuries, particularly the MCL. If there was no MCL injury I would give the patient crutches but no brace, allow her to bear weight as tolerated, and arrange for a physiotherapist to see her. I would recommend the application of ice twice a day and gentle range-of-movement exercises. I would then discuss reconstruction with her.

When would you perform reconstruction?

Reconstruction should only be performed when the knee is pain free and mobile. It usually takes around 6 weeks for full motion to return.

What are the graft choices for ACL reconstruction?

Autograft in the form of hamstring tendon, bone–patellar tendon–bone, quadriceps tendon. Allograft should preferably be non-irradiated and is usually Achilles tendon, patellar tendon, or tibialis anterior. Artificial ligaments such as the LARS ligament are available.

What would be your choice and why?

I would use a four-strand hamstring tendon. It is a low-morbidity harvest and has excellent 15-year results. Bone–patellar tendon–bone is reliable with good 15-year results too, but some people have concerns over pain in the anterior knee and on kneeling. I would avoid the LARS ligament as some surgeons have serious concerns about the long-term effects on the joint.

What are the key steps to performing an ACL reconstruction?

(1) A low-morbidity harvest, minimizing soft tissue damage. (2) A short arthroscopy time, preserving as best as possible the fat pad and other intra-articular structures. (3) Accurate anatomical tunnel placement including femoral tunnel drilling through the anteromedial portal. (4) Robust fixation devices for the graft.

What fixation would you use?

I would use round cannulated interference (RCI) screws in both femoral and tibial tunnels. They have been shown to be reliable, have low morbidity, and combined with hamstring tendon graft have excellent 15-year results. I would use a suspension device on the femoral side first, however, in order to allow for accurate tensioning of the graft, before additional fixation with the femoral RCI screw.

What would your rehabilitation programme be, and when would you allow her to return to playing netball?

I would not use a brace, and would allow her to fully weight-bear and to begin gentle exercise such as cycling after the first week. Gentle running can begin at 8 weeks, and I would see her at 3 and 6 months with a view to allowing netball training to start at 6 months. She should not return to competition before 9 months, and then only if she had met the rehabilitation goals.

Bourke HE, Gordon DJ, Salmon LJ, Waller A, Linklater J, Pinczewski LA (2012). The outcome at 15 years of endoscopic anterior cruciate ligament reconstruction using hamstring tendon autograft for 'isolated' anterior cruciate ligament rupture. *J Bone Joint Surg Br*, 94, 630–637.

Viva 10 Questions

Figure 23.10 Lateral radiograph of knee

What does this radiograph show?

This is a closed isolated injury in a 45-year-old male patient. What is your management?

Talk me through your fixation technique, concentrating on the biomechanical principles.

What is your on-going management following this procedure?

What are the potential complications of this procedure?

Viva 10 Answers

What does this radiograph show?

This radiograph demonstrates a completely displaced transverse patella fracture in a skeletally mature patient.

This is a closed isolated injury in a 45-year-old male patient. What is your management?

This injury requires operative fixation to restore the extensor mechanism of the knee joint. I would immobilize the patient in a cast or brace for comfort and provide adequate analgesia. I would then arrange to admit the patient for surgery on the next available trauma list.

Talk me through your fixation technique, concentrating on the biomechanical principles.

[THE EXAMINER WILL OFTEN VOLUNTEER A PENCIL AND PAPER AT THIS POINT. IF HE OR SHE DOES NOT, THEN REACH FOR THE PENCIL AND PAPER (IF AVAILABLE) FOR THE BEST DESCRIPTION OF TENSION-BAND WIRING.]

I would utilize a tension-band wiring technique. In an appropriately consented and anaesthetized patient, exposure to the patella should be achieved through a midline longitudinal incision. Fracture haematoma should be thoroughly washed to clearly expose the fracture fragments. All interposing soft tissue should be removed from the fracture edges. Two 1.6-mm K-wires with points at both ends should be drilled into the fracture side of the superior bone fragments, evenly spaced and in parallel in an axial direction until the tips just disappear into the bone. With the knee in full extension the patella can then be reduced anatomically and temporarily held with large pointed reduction forceps with their tips on the inferior and superior poles. The K-wires can then be driven through the inferior poles and out of the soft tissue. Figure-of-eight tension-band wiring can then be achieved with 1.25-mm thick steel wire, keeping the wire as close to the bone as possible. This can be achieved with the help of a curved large-bore injection needle to pass the wire through the soft tissue. Tensioning is achieved through a single loop which should be buried in the medial or lateral retinacular tissue as best as possible to minimize later discomfort. I would bend the superior ends of the K-wires over and bury them in the patella and then cut the inferior ends flush with the soft tissue of the patellar tendon.

The biomechanical principles of this technique are that the greatest tension through the fracture occurs on the most anterior aspect while the quadriceps muscle exerts a force on the tendon and the patella within. The tension band lies on the anterior aspect of the patella. Steel wire, which is strong in tension, resists this force and transfers the energy via the fixation from the K-wires at the superior and inferior poles and to the posterior aspect of the patella, where it acts as a compressive force at the articular surface. Compression forces across a fracture stimulate direct bone healing.

It is also essential to augment the tension band with a strong repair of the extensor retinaculum. This is almost always torn in these cases, and repairing this will protect my fixation and allow for improved outcomes.

What is your on-going management following this procedure?

I would immobilize this patient's knee in a hinged knee brace locked from 0–45° and allow full weight-bearing as tolerated. The brace should stay on for a minimum of 6 weeks. Following this I would repeat the radiographs, and subject to satisfactory progress, ask a physiotherapist to begin range-of-movement exercises to avoid stiffness. I would perform a second procedure to remove the wires at 6 months, as symptomatic hardware is among the most common complications of this procedure.

What are the potential complications of this procedure?

Early complications include infection, wound breakdown, rapid failure of fixation, and VTE. Intermediate complications include symptomatic hardware, quadriceps weakness, knee stiffness, and non-union (rare). Late issues would be conditions such as extensor lag and late-onset osteoarthritis of the patellofemoral joint from inadequate reduction.

AO Foundation. *AO Surgery Reference*. Patella 34–C1.3. Open reduction; tension band wiring. https://www2.aofoundation.org/wps/portal/surgery?showPage=redfix&bone=Knee&segment=Patella&classification=34-C1.3&treatment=&method=ORIF%20-%20Open%20reduction%20internal%20fixation&implantstype=Tension%20band%20wiring&approach=&redfix_url=1285238823429&Language=en

Melvin JS, Mehta S (2011). Patellar fractures in adults. *J Am Acad Orthop Surg*, 19, 198–207.

Viva 11 Questions

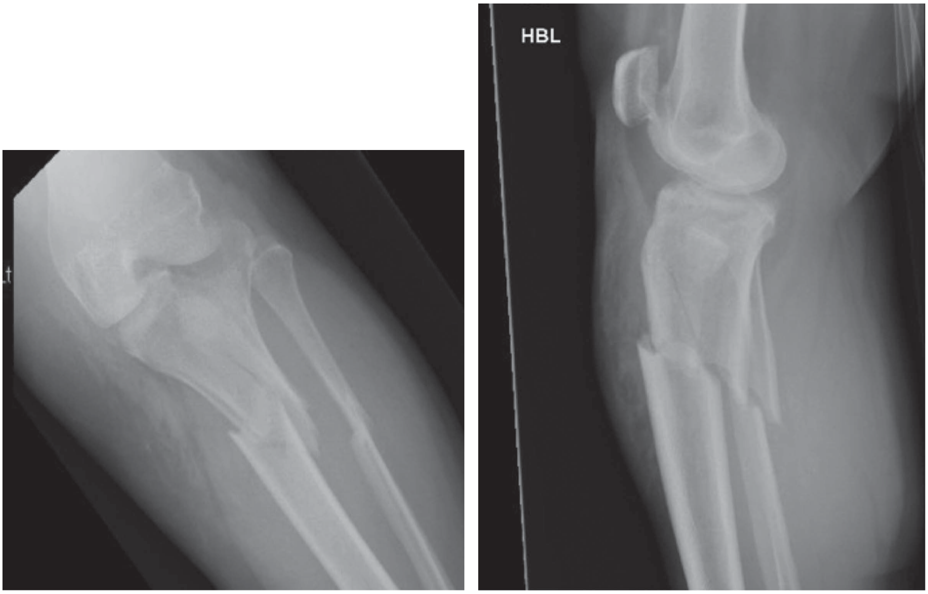


Figure 23.11 AP and lateral radiograph of proximal tibia

These radiographs are of the knee of a man who fell from the seventh rung of a ladder, landing awkwardly on his left knee. A&E has assessed him, and his injury is isolated and closed. Tell me what you can see.

How would you manage this patient's isolated injury?

The knee is grossly swollen and the depression of the joint surfaces has not improved with simple splintage. You decide to perform external fixation. Describe how you would do this.

The CT scan confirms a significant depression laterally, minimal joint involvement medially, and large amounts of comminution in the metaphysis. What is your plan for definitive management?

Describe your operative plan.

What will you tell your patient regarding the likely outcome and need for knee replacement in the future?

Viva 11 Answers

These radiographs are of the knee of a man who fell from the seventh rung of a ladder, landing awkwardly on his left knee. A&E has assessed him, and his injury is isolated and closed. Tell me what you can see.

These are anteroposterior and lateral views showing a displaced bicondylar tibial plateau fracture. There is no intact communication between the articular surface and the tibial diaphysis, so this is a Schatzker VI pattern injury or a type C3 fracture in the AO terminology, indicating both metaphyseal and articular comminution. There is significant depression of the lateral articular surface. The fibula is fractured at the same level as the diaphyseal–metaphyseal dissociation of the tibia.

How would you manage this patient's isolated injury?

This is a high-energy injury. Although it is a closed injury I would have concerns regarding the soft tissue envelope and would assess the patient's limb for distal neurovascular deficit or signs of compartment syndrome. Initial management would include appropriate analgesia and immobilization of the limb in an above-knee backslab. The patient requires admission and, depending on the degree of soft tissue injury and the position of the knee on a radiograph, he might also benefit from bridging external fixation.

The knee is grossly swollen and the depression of the joint surfaces has not improved with simple splintage. You decide to perform external fixation. Describe how you would do this.

I would prepare the patient for surgery by gaining informed consent, ensuring he is starved, and by arranging the theatre and anaesthetic support. Once supine and prepared for operation, with no tourniquet, I would place two anteroposterior Schanz pins in the distal femoral diaphysis. This can be done percutaneously. I tend to start the pin on power and then complete it manually to optimize feedback on the far cortex. In the tibia I would place my pins distal to the zone of injury, aiming anterior-to-posterior with my entry at the lateral aspect of the palpable tibial crest. This ensures the pins will not impede the later placement of plates if internal fixation is proposed. The frame is built off these pins and the fracture reduced manually under fluoroscopic control before the construct is tightened with the knee in slight flexion. I would add bars and pins as needed to ensure a stable construct, and ideally use a system that offers 11- or 12-mm bars for optimal stability. Postoperatively I would again check the neurovascular status of the limb, begin DVT prophylaxis, and monitor for compartment syndrome. I would arrange a fine-slice CT scan with reconstructions to plan definitive surgery. It may take several days for the soft tissues to settle, so I would anticipate performing definitive fixation a week or more after injury.

The CT scan confirms a significant depression laterally, minimal joint involvement medially, and large amounts of comminution in the metaphysis. What is you plan for definitive management?

The best option for fixation in these high-grade injuries remains controversial. Outcomes appear to be comparable between circular frame fixation and internal fixation. The key determinant for success is restoration of the mechanical axis. The key feature to aid decision-making about what implant to use is the state of the soft tissues. In this case, in my practice, the pattern would be amenable to limited internal fixation of the articular surface with screws, and circular frame fixation for the meta-diaphyseal component. This allows wires to be kept away from the joint, but avoids the risks of plating through traumatized soft tissues. The circular fixator is excellent at aligning the axis of the limb.

Describe your operative plan.

Assuming the patient is adequately prepared for theatre, I would remove the fixator under clean conditions. The prepared patient would then be set up supine with a radiolucent bolster behind the thigh to flex the knee by about 40°. I would have the C-arm approach from the opposite side and use a radiolucent table. I would use a tourniquet for the joint fixation, and release this before applying the circular frame. I would centre my incision for the joint reduction over the anterolateral fracture line which is normally just medial to Gerdy's tubercle. This fracture line can be used to allow a punch or elevator to be inserted below the depressed fragments, and elevate them gradually under image control. It is important to use the lateral film to gauge the need for anterior or posterior joint elevation. Once the articular surface has been sufficiently elevated, I would support it in position with one or two K-wires. I would then apply a large pelvic reduction clamp across the articular block to reduce the condylar width and compress the articular fracture lines. I would then use two to four 3.5-mm screws to support the articular surface. If the articular surface does not reduce I would extend my incision proximally, allowing me to open the joint and release any entrapped meniscus. On completion of this step I would release the tourniquet and apply my circular fixator. This construct would be a three- to four-ring frame. I would use a ring just below the articular screws and a double ring block in the tibial diaphysis, allowing me to restore the axis of the tibia. If the knee was unstable after this (on examination under anaesthesia), I would cross the knee with the ring fixator and plan to remove the femoral ring at 6–8 weeks. I would then dress the pin sites accordingly.

What will you tell your patient regarding the likely outcome and need for knee replacement in the future?

Assuming I have restored the joint line and mechanical axis and achieved good fixation, I would explain to him that although the cartilage surface of the joint was damaged at the time of injury he is likely to achieve a good return of function. Rademakers and colleagues studied 109 patients for post-traumatic arthritis from tibial plateau fractures over 5–2 years: if good alignment was achieved, the incidence of osteosrthritis was 9% (versus 27% if the axis deviation is >5°). Weigel and Marsh looked at outcome of high-grade injuries and found a low rate of symptomatic joint arthrosis even if there was some articular incongruity. Other structures in the knee can also be injured, most commonly the menisci, but sometimes the cruciate ligaments (the incidence in Schatzker VI injury is approximately 25%). If his knee is symptomatically unstable on examination at 6 weeks post-injury, I would perform a MRI to assess the ligaments and menisci. The need for meniscal resection will increase the risk of arthrosis, as will instability from cruciate dysfunction.

Rademakers, MV, Kerkhoffs, GM, Sierevelt, IN, Raaymakers, EL, Marti, RK (2007). Operative treatment of 109 tibial plateau fractures: five to 27-yr follow-up results. *J Orthop Trauma*, 21, 5–10.

Wiegel DP, Marsh JL (2002). High-energy fractures of the tibial plateau: knee function after longer follow-up. *J Bone Joint Surg Am*, 84, 1541–1551.

chapter 24

LOWER LIMB—DISTAL TIBIA, FOOT, AND ANKLE

Viva 1 Questions

Figure 24.1 AP and Lateral ankle radiograph

Describe what these radiographs show.

How would you proceed?

This represents the main injury in a stable patient. How would you manage this fracture?

This is a closed injury with no gross neurovascular concerns but significant soft tissue injury. How would you proceed?

Is CT scanning necessary given the pre-operative films and fluoroscopic examination?

What external fixator configuration would you use? Are there alternatives?

What are the principles of definitive fixation?

What are the outcomes of pilon fractures?

Viva 1 Answers

Describe what these radiographs show.

These are anteroposterior and lateral views of the distal tibia and ankle joint. There is a complex, intra-articular, multifragmentary fracture extending proximally into the metaphysis. There is significant proximal migration of the talus. There is no obvious air in the soft tissues, indicating that this is an open injury, although the soft tissue component and zone of injury will be extensive. This is a pilon fracture.

How would you proceed?

This is a high-energy injury. I would proceed following ATLS protocols to identify immediately life-threatening injuries and deal with these in a logical hierarchal sequence using the ABCDE (airway, breathing, circulation, disability, exposure) approach. I would initiate a trauma call to summon help.

This represents the main injury in a stable patient. How would you manage this fracture?

I would take full history and examination, concentrating on important risk factors, for example smoking, diabetes, and peripheral vascular disease. Examination would assess soft tissue integrity and neurovascular status with full documentation.

This is a closed injury with no gross neurovascular concerns but significant soft tissue injury. How would you proceed?

This injury requires reduction and skeletal stabilization to allow resolution of soft tissue before definitive fixation. If the patient remains stable and there are no concerns about anaesthesia I would take the patient to theatre to apply an external fixation, focusing on correction of length, alignment, and rotation. I would then obtain a CT scan in order delineate the fracture further. Once soft tissues have recovered I would consider definitive fixation depending upon the fracture configuration. This is the staged management protocol described by Sirkin, and represents the gold standard management algorithm for complex intra-articular fractures of the tibial plafond.

Is CT scanning necessary given the pre-operative films and fluoroscopic examination?

Yes, CT scanning is necessary. The scan improves recognition of fracture fragments as described by Topiliss, and helps in planning incisions to minimize additional trauma to soft tissues and maintain their viability. CT scans change management in approximately two-thirds of cases and reduce operating time in three-quarters of cases.

What external fixator configuration would you use? Are there alternatives?

I would use a simple 'A' frame, two pins in the tibia away from the zone of injury, and a pin through the calcaneus. There are many alternatives, including fixation in calcaneus and talus, supplemental first metatarsal fixation to avoid equinus problems, quadrilateral frame, hybrid frames, and fine wire frames.

What are the principles of definitive fixation?

The principles are anatomical reduction and rigid fixation of the articular components, and restoration of length, alignment, and rotation of the meta-diaphyseal components, in order to restore anatomy and function. Careful technique is essential to preserve blood supply to fracture fragments.

What are the outcomes of pilon fractures?

After the initial success of Rüedi and Allgöwer and their principles of fixation the complication rate rose significantly in the hands of non-experts. Multiple studies reported high complication rates (30% non-union, malunion, infection). However, the evidence is beginning to suggest that in appropriate centres with experienced surgeons and appropriate techniques (staged, early intervention, limited reduction) the complication rate is improving, with excellent clinical outcomes (2.7% complication in closed fractures).

Boraiah S, Kemp TJ, Erwteman A, et al. (2010). Outcome following open reduction and internal fixation of open pilon fractures. *J Bone Joint Surg Am*, 92, 346–352.

Liporace FA, Yoon RS (2012). Decisions and staging leading to definitive open management of pilon fractures: where have we come from and where are we now? *J Orthop Trauma*, 26, 488–498.

Tornetta P III, Gorup J (1996). Axial computed tomography of pilon fractures. *Clin Orthop Relat Res*, Feb(323), 273–276.

White TO, Guy P, Cooke CJ, et al. (2010). The results of early primary open reduction and internal fixation for treatment of OTA 43. C-type tibial pilon fractures: a cohort study. *J Orthop Trauma*, 24, 757–763.

Viva 2 Questions

Figure 24.2 AP and Lateral ankle radiograph

Describe these radiographs.

This is an isolated injury that is closed and neurovascularly intact. How would you manage it?

What is the mechanism of the injury? Can you classify the injury?

What is the difference between SER II and IV injuries, and how can you diagnose this?

What is your definitive management for this patient and why?

Do you know the current literature on the gravity stress view?

Viva 2 Answers

Describe these radiographs.

These are anteroposterior and lateral views of a skeletally mature left ankle. There is a trimalleolar fracture with talar shift approaching 50%. The fibular is a spiral fracture starting at the level of, and extending below the level of, the syndesmosis and the medial side is a transverse fracture. There is a posterior malleolar fragment—this only carries a small part of the articular surface but probably confers significant instability in this instance due to the attachment of the posterior inferior tibiofibular ligament (PITFL).

This is an isolated injury that is closed and neurovascularly intact. How would you manage it?

This injury needs immediate reduction in the emergency department under appropriate analgesia or sedation to prevent compromise of the medial side. I would stabilize the reduction in a below-knee plaster of Paris cast, obtain radiographs to confirm adequate reduction, and arrange admission for definitive fixation.

What is the mechanism of the injury? Can you classify the injury?

There are several classifications for ankle factures based on either the mechanism (Lauge-Hansen) or anatomical description (Weber) of the injury. The Weber classification relates to the fibular with type A below the syndesmosis, type B at the level of the syndesmosis, and type C above. A more detailed system is that proposed by Lauge-Hansen based upon cadaveric work. The first term represents the position of the foot and the second to the force placed upon the foot and talus in the ankle mortise. There are four main types: supination–adduction, supination–external rotation (SER), pronation–abduction and pronation–external rotation (PER). Dorsiflexion patterns are also described and relate more to Pilon fractures than ankle injuries.

In this case, the fibula has a spiral pattern, indicating a rotational force, so this could be PER or SER. However, the fibula fracture runs from the anterior inferior to posterior superior direction, which would be more in keeping with a SER pattern. In a PER pattern the spiral starts anterior superior to the posterior inferior position. The supination–adduction pattern tends to have a vertical orientation to the medial malleolus and pronation–abduction tends to have a fibular fracture above the syndesmosis and a transverse or short oblique fibular fracture due to the bending force. Supination external rotation injuries begin anteriorly, with rupture of the anterior inferior tibiofibular ligament (AITFL), then the fibula fractures followed by either a posterior malleolus fracture or PITFL rupture. The last structure to fail is the deep deltoid or medial malleolus. Therefore this fracture is a SER IV injury.

What is the difference between SER II and IV injuries, and how can you diagnose this?

The difference is essentially whether the medial structures, i.e. the deep deltoid and the medial malleolus, are intact; these structures play a significant part in the stability of the ankle joint. The absence of pain and tenderness on the medial side is a poor indicator of the integrity of these structures. The gravity stress view has been developed to help confirm the integrity of the deltoid, with a medial clear space of more than 5 mm being suggestive of medial injury. Furthermore, the presence of a posterior injury (SER III) means this has to be more than an SER II.

What is your definitive management for this patient and why?

Given no contraindications to surgery, my definitive management would be operative. I would perform ORIF, either before swelling has occurred or allow swelling to reduce, as long as the fracture is in a satisfactory position. Using a tourniquet, and with antibiotic prophylaxis, I would fix the posterior malleolus and the lateral side though a posterolateral approach. The posterior fixation would be a buttress plate and additional screw, with an anti-glide plate plus supplementary interfragmentary screws for the fibula. I would address the medial side ideally using two short (40 mm) partially threaded cancellous screws. I would protect the soft tissues in plaster of Paris for 2 weeks and then begin protected weight-bearing for a further 4 weeks. My indications for operative intervention are that this fracture would be very difficult to maintain in position in plaster of Paris due to instability, and for a shift of more than 1 mm in contact area the forces in the ankle joint change significantly, predisposing to post-traumatic osteoarthritis.

Do you know the current literature on the gravity stress view?

Currently, the role of the deep deltoid is being investigated further. Stress views may over-diagnose injuries and partial tears of the deep deltoid may result in positive stress views, but could be successfully treated non-operatively. Weight-bearing mortise views or MRI scans may be more sensitive predictors of instability than stress views.

van den Bekerom MP, Mutsaerts EL, van Dijk CN (2009). Evaluation of the integrity of the deltoid ligament in supination external rotation ankle fractures: a systematic review of the literature. *Arch Orthop Trauma Surg*, 129, 227–235.

Koval KJ, Egol KA, Cheung Y, Goodwin DW, Spratt KF (2007). Does a positive ankle stress test indicate the need for operative treatment after lateral malleolus fracture? A preliminary report. *J Orthop Trauma*, 21, 449–455.

Lloyd J, Elsayed S, Hariharan K, Tanaka H (2006). Revisiting the concept of talar shift in ankle fractures. *Foot Ankle Int*, 27, 793–796.

Ramsey PL, Hamilton W (1976). Changes in tibiotalar area of contact caused by lateral talar shift. *J Bone Joint Surg Am*, 58, 356–357.

Viva 3 Questions

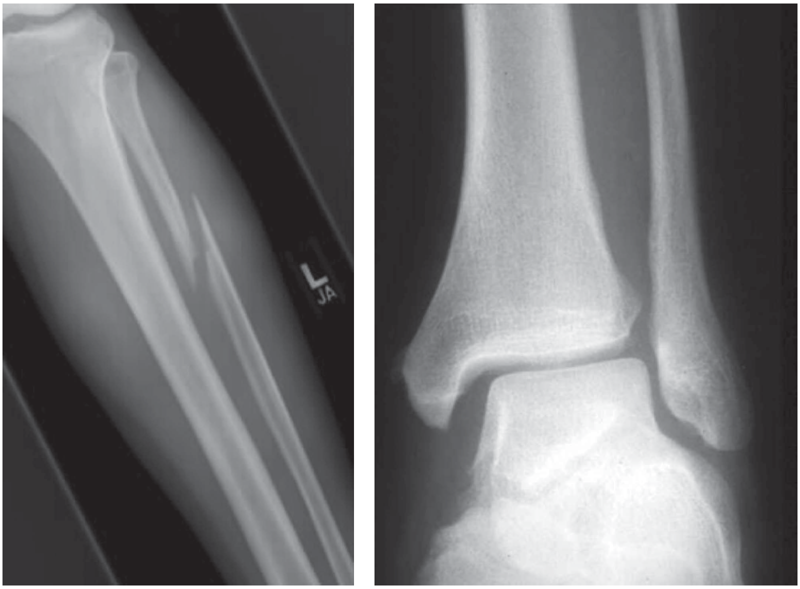


Figure 24.3 AP radiographs of lower limb

A 28-year-old female aerobics instructor twisted her ankle in a nightclub, sustaining an isolated injury to the right lower limb. What do her radiographs show?

How would you classify this injury?

How would you treat this injury initially?

What is your preferred method for syndesmosis fixation and why?

Viva 3 Answers

A 28-year-old female aerobics instructor twisted her ankle in a nightclub, sustaining an isolated injury to the right lower limb. What do her radiographs show?

These anteroposterior views of the left lower limb demonstrate a proximal third spiral fibula fracture, and an ankle mortise with widening of the medial and superior clear spaces leading to significant talar shift.

How would you classify this injury?

This injury is a Weber type C fibular injury with associated deltoid and syndesmotic ligament ruptures. It is also called a 'Maisonneuve' fracture as per the original description. It can also be classified according to the Lauge-Hansen system as a PER injury, which implies an external rotational force applied to a pronated foot. This leads to a medial injury first—in this instance the disruption of the deltoid ligament—followed by anterior syndesmosis, interosseous membrane to the level of a fracture of the fibula, or to the disruption of the proximal tibiofibular joint followed by the posterior syndesmosis in type IV injury. This fracture would represent a type III or IV PER injury.

How would you treat this injury initially?

The injury pattern is unstable, and therefore in all but extremely unfit patients surgical fixation would be my preferred management. Initial treatment would include analgesia and splintage, a thorough history, examination and documentation of neurological and vascular status, and pre-operative investigations such as blood tests and ECGs as needed.

This fracture configuration typically requires stabilization of the syndesmosis. In this instance, under tourniquet and image control, and with a sandbag under the ipsilateral buttock, I would attempt closed reduction of the syndesmosis using a large pelvic reduction clamp between the malleoli. Although the position of the foot was once thought to be important it has since been shown that there is no need to dorsiflex the foot with this manoeuvre. However, I would place a bolster, such as a kidney dish, under the Achilles tendon to avoid resting the heel on the bed and driving the talus forward. As the fibula fracture is very proximal it is not suitable for plate fixation which can make it difficult to achieve correct length and rotation of the fibula. In order to be sure of an accurate reduction I would check the level of the fibular tubercle on the mortise view to ensure the fibular length and rotation were accurate.

If the syndesmosis did not reduce it would require further open reduction to clear any fragments that could block the reduction. There is no need to repair the deltoid in most cases provided the fibula and syndesmosis have been accurately reduced. However, to allow for adequate deltoid healing the patient should be put in a cast for 6–8 weeks.

What is your preferred method for syndesmosis fixation and why?

Controversy exists around the choice of implant and technique for syndesmotic stabilization in the ankle. While there are many options, I prefer to use two small-fragment 3.5 cortical screws, over four cortices. I prefer the small-fragment screws as the heads are less prominent than the large-fragment screws, and they have been shown to be sufficiently strong. I prefer four cortices—although there may be a slightly increased incidence of screw breakage, they are easier to remove from the medial side if this is the case. I am aware that tightrope fixations are an option, but have no experience of these. After fixation, I splint the limb but allow early range of motion from about

2 weeks after the wound has healed. I keep the patient non-weight-bearing for 8 weeks and plan for elective screw removal at 12 weeks. I will explain to the patient that there is a small chance the screws may break before then as they start to bear weight from weeks 8 to 12. Removal of the screws has been shown to allow any malreduction in the syndesmosis to correct itself, as does screw breakage.

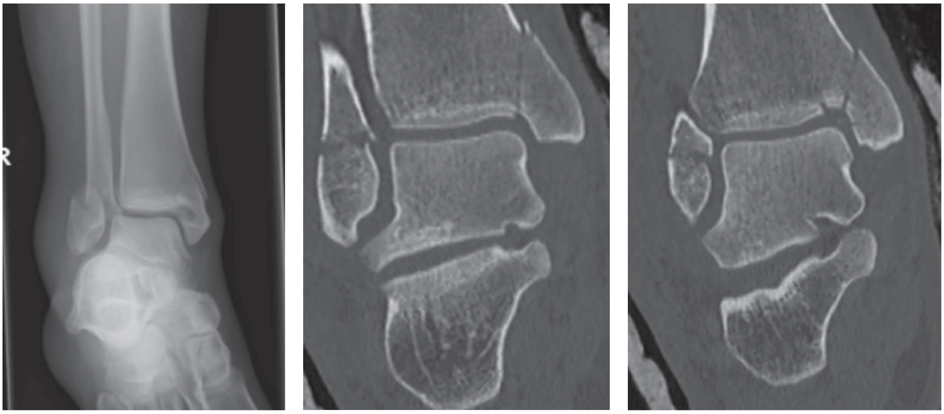
Jelinek JA, David A. Porter DA (2009). Management of unstable ankle fractures and syndesmosis injuries in athletes. *Foot Ankle Clin*, 14, 277–298.

Manjoo A, Sanders D, Tieszer C, MacLeod M (2010). Functional and radiographic results of patients with syndesmotic screw fixation: implications for screw removal. *J Orthop Trauma*, 24, 2–6.

Markolf K, Jackson S, McAllister D (2013). Syndesmosis fixation using dual 3.5 mm and 4.5 mm screws with tricortical and quadricortical purchase—a biomechanical study. *Foot Ankle Int*, 34, 734–739.

Walling AK, Sanders RW (2007). Ankle fractures. In: MJ Coughlin, RA Mann, CL Saltzman (eds) *Surgery of the Foot and Ankle*, 8th edn, pp.1973–2016. Mosby Elsevier, Philadelphia, PA.

Viva 4 Questions



(a) (b) (c)

Figure 24.4 Right ankle (a) radiograph; (b), (c) coronal CT

You are called to the review a young woman who has slipped down a few steps. This is an isolated injury in a healthy young adult. Please describe what the imaging shows.

What is the likely mechanism and what are you definitive options?

What are your principles of fixation and how would you go about it?

What is the prognosis for ankle fractures?

Viva 4 Answers

You are called to the review a young woman who has slipped down a few steps. This is an isolated injury in a healthy young adult. Please describe what the imaging shows.

The images are an anteroposterior radiograph and coronal CT slices of a skeletally mature right ankle. The radiograph shows a low fibula fracture and a medial malleolar fracture. The CT scans confirm this and show the orientation of the fibula fracture to be predominantly transverse and the medial side injury to be vertical—a shearing fracture. There is also a small segment of depressed articular surface in the medial corner of the tibial plafond.

What is the likely mechanism and what are you definitive options?

The mechanism here is supination–adduction force. In this mechanism the injury starts on the lateral side with failure in tension of the fibula or lateral ligament complex—hence the low transverse fibula fracture. As the talus then undergoes an adduction force this classically pushes off the medial malleolus, resulting in a shear fracture line that is oblique or vertical in nature. Depression of the medial corner of the tibial plafond has occurred as the talus has continued to be adducted after the malleolus has sheared off. I prefer to use the Lauge-Hansen classification here as the Weber system would simply classify this as an 'A' fracture and underestimate the severity and instability of the injury.

What are your principles of fixation and how would you go about it?

The main principle is that this is an intra-articular fracture and it therefore needs anatomical reduction with absolute stability to allow early range of motion and restoration of function. The medial side represents a shear force with comminution of the medial malleolus. Therefore I would tend to favour a plate to withstand the shear forces after reduction of the intra-articular fragment. This is tricky and requires planning as the plate is applied through a direct medial approach which does not allow visualization of the joint or the depressed fragment. This fragment may be able to be reduced percutaneously through a mini anterior incision in the plane of the fracture line to allow in a narrow instrument to push the fragment down. The fibula requires an anti-glide plate posteriorly. I would utilize a posterolateral approach or a standard lateral approach, although this needs to be longer than the plate to allow for safe retraction of the skin edge and access.

What is the prognosis for ankle fractures?

The prognosis for ankle fractures is variable. The majority have good or excellent outcomes at 2 years, but with some limitations. Simple fracture patterns have superior outcomes. Removal of metalwork can improve lateral pain in 50% of cases, but is not routinely recommended.

Fifty per cent of bimalleolar ankle fractures will have good or better outcomes at 10 years, with 24% having a poor outcome with evidence of post-traumatic degenerative changes. Posterior malleolus fracture is associated with deteriorating outcomes, particularly if joint congruity is not restored.

Bhandari M, Sprague S, Hanson B, et al. (2004). Health-related quality of life following operative treatment of unstable ankle fractures: a prospective observational study. *J Orthop Trauma*, 18, 338–345.

Lash N, Horne G, Fielden J, Devane P (2002). Ankle fractures: functional and lifestyle outcomes at 2 years. *Aust NZ J Surg*, 72, 724–730.

Lauge-Hansen N (1954). Fractures of the ankle III. Genetic roentgenologic diagnosis of fractures of the ankle. *Am J Roentgenol Radium Ther Nucl Med*, 71, 456–471.

Viva 5 Questions

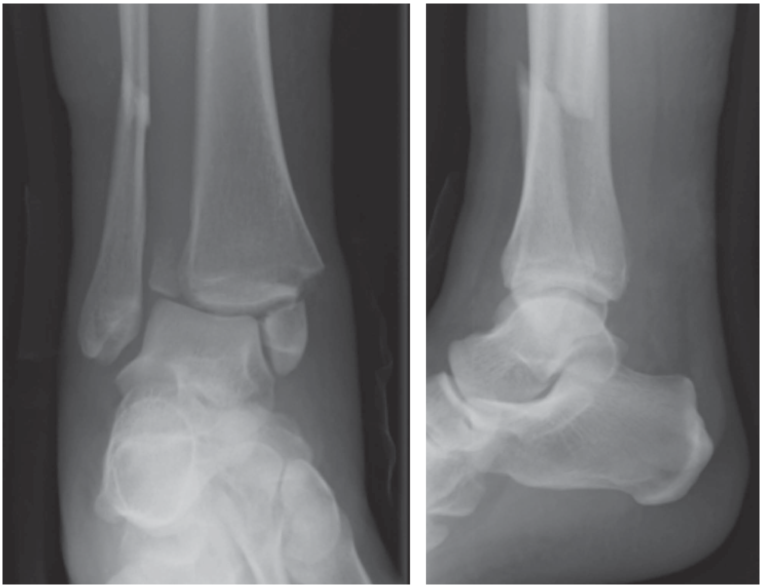


Figure 24.5 AP and Lateral ankle radiograph

What do these radiographs demonstrate?

How would you classify this injury?

What would you definitive management be?

What techniques can you use in comminuted fibula fractures to ensure superior outcomes?

Viva 5 Answers

What do these radiographs demonstrate?

These are anteroposterior and lateral views of a skeletally mature patient. They show a Weber type C transverse/short oblique fibula fracture, a 'pull-off' of the medial malleolus, and a small posterolateral fragment, with significant talar shift.

How would you classify this injury?

The simplest system by Weber would classify this as type C. Lauge-Hansen's more comprehensive system would classify this as a pronation–abduction injury. The foot is pronated at the time of injury (i.e. everted) with an abduction force applied to the talus. This leads to the characteristic pull-off injury on the medial side, with a bending pattern injury to the fibula above the syndesmosis. The syndesmosis is disrupted, in this instance with a pull-off of the tibial side of the PITFL. This injury is sometimes described as a Dupuytren's fracture dislocation.

What would you definitive management be?

Assuming no contraindications I would recommend ORIF. I would plan for fixation on the next available list as long as there is no significant soft tissue swelling; if there were I would delay until this subsided.

My preference is to fix the posterior malleolus, even if small, when there is such obvious instability in the ankle; however, in this instance, the fibula is fractured reasonably proximally so it may not be possible to fix this through a combined posterolateral approach. I would therefore fix the fibula through a lateral approach, being aware that the superficial peroneal nerve is likely to cross my incision. I would aim for anatomical reduction and rigid internal fixation of the fibula—a compression plate in this case, as it is a simple fracture pattern. This would require me to use a small-fragment locking compression plate because a third tubular plate would not be strong enough. After this I would certainly screen the ankle for external rotation instability and be prepared to use syndesmosis screws. I would prefer to put them through the plate, using two 3.5-mm screws over four cortices. The plate would need to be long enough to accommodate these. I would then address the medial side with ORIF. This looks to be a sizeable fragment and I should be able to get two small-fragment 40-mm partially threaded screws across the fracture. If the fragment was too small or comminuted I would consider a tension band wire technique or even just a stout 2-mm K-wire or two.

What techniques can you use in comminuted fibula fractures to ensure superior outcomes?

With the fibula the key is to accurately restore the length and the rotation; this becomes difficult in comminuted fractures. One technique is to stabilize the medial side first, which tensions the lateral ligaments helping to ensure the correct length and rotation. Fixation of the fibula with a lag screw and a one-third tubular plate is often impossible with comminution, therefore I would tend to use a thicker plate to withstand bending forces, either a reconstruction plate or a pre-contoured locking plate. However, one must use locking plates with caution because they are associated with an increased rate of wound complications. Radiographic parameters include the talocrural angle formed by two lines, one from the tip of the fibular to the tip of the medial malleolus and a second along the tibial plafond which is around 83°. Another feature is Shenton's line running from the lateral process on the talus to the tip of fibular; a disruption in this represents shortening and rotation malreduction.

Schepers T, Van Lieshout EM, De Vries MR, Van der Elst M (2011). Increased rates of wound complications with locking plates in distal fibular fractures. *Injury*, 42, 1125–1129.

Viva 6 Questions

Figure 24.6 Lateral ankle radiograph

This patient fell from their horse. Can you describe the radiograph?

This patient has been managed according to ATLS principles. Their injury appears to be an isolated closed injury. How would you manage the patient in A&E?

How would you classify this injury?

How would you treat this patient definitively?

How would you manage this patient post-operatively?

How would you counsel the patient regarding their prognosis?

Viva 6 Answers

This patient suffered a high energy injury. Can you describe the radiograph?

This is a high-energy injury. The lateral view shows a significantly displaced fracture through the neck of the talus with an associated dislocation of the subtalar joint. I suspect there is a degree of comminution as I cannot delineate the fracture line very easily. There is also a fracture of the anterior process of the calcaneus—up to 89% of these types of injuries have an associated fracture elsewhere in the foot. I would like to see further views.

This patient has been managed according to ATLS principles. Their injury appears to be an isolated closed injury. How would you manage the patient in A&E?

I would take a thorough history—asking the patient about the mechanism of injury, significant medical history, drugs and allergies, smoking status, and employment. My examination would focus on a documented assessment of distal neurological and vascular status and an assessment of the soft tissues. I would splint the limb in a backslab and arrange for further imaging in the form of a CT scan to detail the anatomy of the fracture, especially any comminution, to allow for planning of surgery. While waiting for the scan I would elevate the limb and ask the nursing team to alert me should the patient's pain not be controlled by simple analgesia, because this patient is at risk of foot compartment syndrome. In the absence of neurovascular compromise there is no urgency in this situation to fix the fracture out of hours, and getting the CT would be vital. Recent studies have dismissed the fact that delay to ORIF is associated with an increased risk of AVN.

How would you classify this injury?

This is a type II fracture according to the Hawkins classification.

Hawkins classified these fractures in 1970, and gave specific focus to the risk of developing AVN. Type I fractures are non-displaced. They are rare and have a very low chance (<13%) of proceeding to AVN. The classification then looks at associated joint dislocations. Type II fractures have an associated subtalar dislocation, as in this case. The risk of AVN here is 20–50%. Type III have a dislocation of the entire body of the talus (subtalar and tibiotalar joint dislocation), while type IV also have a dislocation of the talar neck at the talonavicular articulation. Type III and IV injuries have reported AVN rates of up to 100%.

How would you treat the patient definitively?

All displaced articular fractures require anatomical reduction and rigid internal fixation. In this case, assuming the patient is adequately prepared for theatre and the soft tissue envelope is in good condition, I would offer ORIF as this allows for direct visualization of the reduction. Generally I perform this using a two-approach technique, with an anteromedial incision between the anterior and posterior tibialis tendons, avoiding any dissection of the deep deltoid which carries the blood supply to the body. My anterolateral approach is in line with the fourth ray, so the superficial peroneal nerve may need to be mobilized. I would elevate the belly of the extensor digitorum brevis and clear the fat pad from the sinus tarsi to expose the talus. It can be very difficult to reduce the dislocated talar body, and if required I would use an external fixator to provide distraction. Depending on the amount of comminution, I would be prepared to fix the talus with screws, plates, or both. The medial side is often comminuted and a plate may be best here to avoid late varus collapse.

How would you manage this patient postoperatively?

Initially I would place the limb in a below-knee backslab and maintain elevation to reduce swelling. The surgery is likely to have taken some time. Therefore, given that the patient will be non-weight-bearing for at least 6–8 weeks, thromboembolism prophylaxis will be required in the form of a calf compression device on the contralateral limb during surgery and until mobile, and chemical prophylaxis for at least 2 weeks until the patient is mobile on crutches. If all is well at the 2-week wound check I would consider mobilizing the patient in a removable boot without bearing weight. This decision would depend on how strong the fixation is, because it has been shown that non-weight-bearing range-of-movement exercises can generate up to 1200 N of force across the talar neck. Two anteroposterior screws are not sufficient to allow for this but two posteroanterior 6.5-mm screws are strong enough. If plates are used then I would not mobilize the patient in this manor as the use of plates would suggest comminution. After 6–8 weeks I would remove all support and allow for 25–50% weight-bearing until the 12-week mark.

How would you counsel the patient regarding their prognosis?

Patients with this type of injury need to be followed up for 2–3 years—the revascularization process can take that long, or longer, depending on the development of complications. Potential complications include neurological deficit, infection, AVN, non-union, malunion, and degenerative joint disease involving the ankle, subtalar joint, or both. At 3 months it would be reasonable to perform a MRI to identify any AVN as a prognostic indicator. Otherwise I would look out for Hawkins' sign denoting revascularization in the form of subchondral linear radiolucency of the talar dome, usually on the medial side. Relative sclerosis of the talus would suggest a failure of revascularization and AVN.

Halvorson JJ, Winter SB, Teasdall RD, Scott AT (2013). Talar neck fractures: a systematic review of the literature. *J Foot Ankle Surg*, 52, 56–61.

Swanson TV, Bray TJ, Holmes GB Jr (1992). Fractures of the talar neck. A mechanical study of fixation. *J Bone Joint Surg Am*, 74, 544–551.

Viva 7 Questions

Figure 24.7 AP and lateral ankle radiographs

A young man who had been playing football is brought into the emergency department These are his radiographs. What can you see?

This is an isolated injury in a young healthy man with no relevant medical history. How would you manage him initially and what is this type of injury?

The emergency department has tried a closed reduction but failed. What are your concerns? How would you proceed?

Once the dislocation is reduced how would you manage the patient and what would his prognosis be?

Viva 7 Answers

A young man who had been playing football is brought into the emergency department These are his radiographs. What can you see?

This is an anteroposterior view centred on the left ankle. I can see a normal relationship between the talus and the tibia. The calcaneus is translated medially and posteriorly in relation to the talus, and the talonavicular articulation is also dislocated. This is a subtalar dislocation. For all intents and purposes, the whole foot is no longer articulating with the talus.

This is an isolated injury in a young healthy man with no relevant medical history. How would you manage him initially and what is this type of injury?

I would take a full history and examine the patient, concentrating in particular on whether this is an open injury and the neurovascular status. This needs urgent reduction, either under sedation or general anaesthesia. This is a medial subtalar dislocation, the commonest type (80%), followed by lateral dislocation (15%), with anterior or posterior dislocations occurring rarely. Medial dislocation is also described as acquired clubfoot and lateral dislocation as acquired flat foot. The calcaneonavicular ligaments remain intact, with the force rupturing the talonavicular ligaments and the talocalcaneal ligaments. Medial dislocations tend to be associated with low-energy injuries (e.g. basketball), whilst lateral dislocations tend to be higher-energy injuries. This needs urgent reduction to prevent tissue necrosis or neurovascular compromise.

The emergency department has tried a closed reduction but failed. What are your concerns? How would you proceed?

Assuming a good standard of technique was employed, my concern now would be that something was blocking reduction, such as an osteochondral fragment, an unrecognized fracture, or soft tissue interposition (extensor tendons or retinaculum, dorsalis pedis, deep peroneal nerve). I would arrange theatre urgently for closed reduction/open reduction. In the interim I would perform a CT scan to identify missed fractures or osteochondral lesions that could be blocking reduction. Closed reduction would entail relaxing the Achilles tendon (by flexing the knee), then exaggerating the deformity, and then reducing the deformity. If this failed I would open anteriorly, allowing exposure to both sides of the talar head to facilitate reduction. If the CT scan demonstrated associated fractures I would be prepared to supplement the reduction with fixation of these.

Once the dislocation is reduced how would you manage the patient and what would his prognosis be?

The management of these injuries remains controversial. In the absence of associated injuries (e.g. open fractures, neurological injury), the joint is usually stable post-reduction. I would allow a short period of immobilization so soft tissues can recover before commencing range-of-motion exercises to prevent stiffness, as that is the main problem post-injury. With more complex injuries the rehabilitation would be delayed. In the long term up to 80% of patients with these injuries will have stiffness in the subtalar joint and 50% will have evidence of degenerative changes; however, osteonecrosis is seen much less often. The majority of patients will still have good function in the long term. High-energy injuries are associated with increased stiffness, degenerative changes, and a worse outcome.

Bibbo C, Anderson RB, Davis WH (2003). Injury characteristics and the clinical outcome of subtalar dislocations: a clinical and radiographic analysis of 25 cases. *Foot Ankle Int*, 24, 158–163.

Heck BE, Ebraheim NA, Jackson WT (1996). Anatomical considerations of irreducible medial subtalar dislocation. *Foot Ankle Int*, 17, 103–106.

Monson ST, Ryan JR (1981). Subtalar dislocation. *J Bone Joint Surg Am*, 63, 1156–1158.

Waldrop J, Ebraheim NA, Shapiro P, Jackson WT (1992). Anatomical considerations of posterior tibialis tendon entrapment in irreducible lateral subtalar dislocation. *Foot Ankle*, 13, 458–461.

Viva 8 Questions

Figure 24.8 Lateral ankle radiograph

What does this radiograph show?

Can you classify this fracture?

What are the principles of management for this type of injury?

What are the short- and long-term consequences of calcaneal fractures?

Are you aware of any literature showing a difference between non-operative and operative management of calcaneal fractures?

Viva 8 Answers

What does this radiograph show?

This is a lateral view of the ankle and hindfoot of a skeletally mature patient with a significantly displaced calcaneal fracture. The majority of the posterior tuberosity is split and displaced and I suspect the fracture extends into the subtalar joint.

Can you classify this fracture?

This is a severe tongue-type fracture (also known as a beak fracture).
Calcaneal fractures can be broadly classified as extra-articular or intra-articular. Extra-articular fractures (25%) include tuberosity fractures, anterior process sustentacular fractures, and fractures of the body not involving the joint. Intra-articular fractures (75%) can be classified by the Essex–Lopresti system. This distinguishes those intra-articular fractures that do not involve the subtalar joint from those that do. Fractures involving the subtalar joint can broadly be classified as tongue type or joint depression type according to whether the fracture line on the lateral radiograph exits posterior (tongue) or anterior (joint depression) to the proximal insertion of the Achilles tendon at the posterior tuberosity. A further classification by Sanders, based on coronal CT slices through the subtalar joint, allows for operative planning and prognosis of intra-articular fractures involving this joint.

What are the principles of management for this type of injury?

Some calcaneal fractures can be treated non-operatively, but almost all tongue-type fractures necessitate operative intervention due to their threat to the skin on the posterior heel. In my department these injuries may get referred on to the specialist trauma centre, but the principles of management in this case revolve about two issues: soft tissue management and fracture management. The soft tissues posteriorly may be in peril. I would assess the tissues for signs of breakdown or necrosis, and if there is any concern I would ask a plastic surgeon to review the skin at the time of the index operation. Tongue-type fractures often need reducing to allow the soft tissues to settle, unlike joint depression types, which can afford to wait. If skin coverage was not achievable after fixation I would use a vacuum-assisted closure device before getting the plastic surgery team to provide definitive cover. After a CT scan to better visualize the fracture lines and comminution, my operative plan in this case would be to reduce the fracture under image control with a large clamp and stabilize the fracture with two screws from posterosuperior to anteroinferior through a minimal-access incision adjacent to the Achilles tendon on the lateral side. The reduction of the tongue fragment should reduce the majority of the subtalar joint; however, if I am unsure of the reduction I could assess it through an open visualization via a sinus tarsi approach. I am aware that the tension band principle has been described but it has high complication and metalwork removal rates.

What are the short- and long-term consequences of calcaneal fractures?

Calcaneal fractures are often the result of axial compression. There is an association with tibial pilon and plateau fractures, as well as spinal injuries. These can be high-energy injuries, so immediate issues include haemodynamic compromise from other fractures or visceral injury.

Early complications include swelling—one often needs to wait 10 days or more before fixation in joint-depression-type fractures. Neurovascular compromise is rare. Early post-operative wound breakdown is an early complication seen in up to 10% of patients who have an extended lateral incision. Meticulous tissue handling should reduce this. Later issues include subtalar arthrosis, either from initial comminution or malreduction. The need for potential fusion should be discussed early with every patient. Heel shape in terms of height and width can also be altered, leading to difficulties with footwear.

Are you aware of any literature showing a difference between non-operative and operative management of calcaneal fractures?

In the Canadian Orthopaedic Trauma Society (COTS) study of 2002, Buckley et al. looked at over 500 fractures. They showed that operative treatment as a whole provides no improvement over non-operative treatment of displaced intra-articular calcaneal fractures. However, careful subgroup analysis of the patient population and information on clinical outcome highlighted that women, patients who were not receiving workers' compensation (industrial injury compensation), younger men, patients with a higher Böhler angle, patients with a lighter workload, and those with a single, simple displaced intra-articular calcaneal fracture had better results after operative treatment than after non-operative treatment. Anatomical reduction enhances outcome, while comminuted reductions or fractures without reduction produce long-term outcomes that are less satisfactory. Non-operative care more commonly leads to late arthrodesis. The best patients to treat non-operatively are those who are aged 50 years or more, men, and those who are receiving workers' compensation and have an occupation involving a heavy workload. The results after a higher-energy fracture (a lower Böhler angle and more comminution) are not as good as those after a low-energy injury. Early operative intervention has also been shown to have a cost benefit over non-operative management.

Buckley R, Tough S, McCormack R, et al. (2002). Operative compared with nonoperative treatment of displaced intra-articular calcaneal fractures: a prospective, randomized, controlled multicenter trial. *J Bone Joint Surg Am*, 84, 1733–1744.

Brauer CA, Manns BJ, Ko M, Donaldson C, , Buckley R (2005). An economic evaluation of operative compared with nonoperative management of displaced intra-articular calcaneal fractures. *J Bone Joint Surg Am*, 87, 2741–2749.

Sanders R (2000). Current concepts review: displaced intra-articular fractures of the calcaneus. *J Bone Joint Surg Am*, 82-A, 225–250.

Viva 9 Questions

Figure 24.9 AP and oblique foot radiographs

What does this radiograph show?

What is the usual mechanism of injury?

What are the clinical and radiographic features of this injury?

Do you know any classifications for this type of injury?

Can this injury happen without a fracture, i.e. ligamentous injury?

How would you treat this injury?

What are the short- and long-term complications?

Viva 9 Answers

What does this radiograph show?

These anteroposterior and oblique views of the right foot show a Lisfranc fracture dislocation This predominantly involves the second and third tarsometatarsal (TMT) joints, although the fourth joint appears to have mild incongruity. On the anteroposterior view the second metatarsal is laterally subluxed and its medial border does not line up with the medial border of the middle cuneiform. On the oblique view the third metatarsal is not in line with the lateral cuneiform. There is also a flake of bone at the calcaneocuboid joint, although this may be old. I would like to see a lateral view to assess for any dorsal subluxation of the metatarsals.

What is the usual mechanism of injury?

Lisfranc was a French surgeon who originally described this injury in Napoleonic soldiers who had fallen from a horse with a foot trapped in the stirrup. Two distinct mechanisms of injury are now described. (1) A direct injury in which the foot is often crushed, leading to a midfoot 'break' or loss of arch, with a disruption of the tarsometatarsal joints. (2) An indirect injury, in which the foot is subject to a torsional force, such as being retained in the stirrup as the rider falls from a horse, or an axial and rotational load to a plantarflexed foot.

What are the clinical and radiographic features of this injury?

Any patient with suspected 'midfoot sprain' should be carefully assessed for Lisfranc injury. The mechanism of injury should be elicited by thorough history-taking, which often leads to the diagnosis. Swelling of the midfoot disproportionate to the mechanism of injury, plantar ecchymosis, and pain should raise the suspicion. Radiological signs include the 'fleck sign' at the TMT joint, dorsal subluxation of metatarsal base in lateral view, misalignment of the second TMT joint in anteroposterior view, and sometimes misaligned third and fourth TMT joints in oblique view. A high index of clinical suspicion, weight-bearing radiographs of both feet, CT or MRI scan, and at times examination under anaesthetic may be needed to diagnose this injury, especially in subtle cases.

Do you know any classifications for this type of injury?

Quenu and Kuss's original classification, as modified first by Hardcastle and then by Myerson, is the most widely used. It consists of three patterns of injury. Type A (total incongruity, homolateral, or complete) injuries involve all five TMT articulations displacing dorsolaterally as a unit. Type B (partial incongruity, homolateral, or incomplete) injuries involve one or more, but not all, of the metatarsals. The pattern of injury usually involves medial displacement of the first metatarsal or dorsolateral displacement of one or more of the lateral metatarsals. Myerson's modification divided type B injuries into those affecting the medial articulation alone (type B1) and those involving one or more lateral metatarsals (type B2). Type C (divergent, total, or partial displacement) injuries occur when the lateral and medial metatarsals are displaced in opposite directions and in different planes. It is difficult to establish a more useful classification because significant variation exists in potential fracture patterns. Furthermore, the pattern of injury and degree of displacement are less significant for poor outcome than the quality of the reduction or the extent of soft tissue injury to the foot. Therefore the simple distinction between direct and indirect injuries is more useful for prognosis.

Can this injury happen without a fracture, i.e. ligamentous injury?

Purely ligamentous injury to the Lisfranc ligament is possible and is seen in patients with usually subtle injuries. The disability and complications are still significant. There have been reports of primary fusion of Lisfranc joints for pure ligamentous instability, with good results in the medium term being described by Coatzee, although more recent research has suggested that simple fixation may prove to give results that are as good.

How would you treat this injury?

The mid foot should be realigned and stabilized appropriately. Due to the nature of the injury, the foot develops significant swelling, and it often 7 to 10 days before surgery can be performed. ORIF with screws or bridging plates can be used. In essence, the steps for fixation are, first and foremost, to reduce the keystone second metatarsal base to its correct position. Occasionally it is necessary to first reduce the first TMT articulation to allow for the second to reduce adequately. Once the second TMT articulation is correctly reduced and held, the reduction of the rest of the foot can proceed in a sequential fashion. If the injury involves the fourth to fifth TMT joints, without shortening, simple temporary K-wire fixation is preferred as these joints have significant range of movement

What are the short- and long-term complications?

Delay in diagnosis and appropriate treatment can unfortunately still happen. As the second TMT joint is an important part of the Lisfranc joint, it is often compared to the cornerstone of a Roman arch: any weakness of this joint leads to abnormal biomechanics and early midfoot arthritis. Even with early treatment, 25–50% of patients can develop mid-foot pain and arthritis, requiring further procedures. Surgical fixation will reduce but not obliterate this risk.

Hardcastle PH, Reschauer R, Kutscha-Lissberg E, Schoffmann W (1982). Injuries to the tarsometatarsal joint: incidence, classification and treatment. *J Bone Joint Surg Br*, 64, 349–356.

de Palma L, Santucci A, Sabetta SP, Rapali S (1997). Anatomy of the Lisfranc joint complex. *Foot Ankle Int*, 18, 356–364.

Viva 10 Questions

Figure 24.10 AP and oblique foot radiographs

What do these radiographs show?

How would you manage the patient?

This is an isolated injury—the foot was run over. How would you proceed?

During admission, but prior to fixation, you are informed that this patient's pain is resistant to opioids and increasing in severity. How would you proceed?

How will you manage this?

How do you decompress compartments in the foot?

Viva 10 Answers

What do these radiographs show?

These are anteroposterior and oblique views of a skeletally mature left foot showing a dislocation through the Chopart joint. The talonavicular and calcaneocuboid joints are dislocated, with plantar displacement of the distal foot. There is a small fragment of bone at the level of the talonavicular joint. I cannot see any other fractures but would like further imaging to confirm this.

How would you manage the patient?

This is clearly a high-energy trauma. I would therefore manage this patient following ATLS protocols, which deal with life-threatening injuries in a logical hierarchal sequence. For the foot, a thorough and documented neurological and vascular examination, with an assessment of the soft tissues, is mandatory. Analgesia and splintage are required. I would plan to reduce the foot in theatre under anaesthetic on the first available trauma list. I would only do this overnight if I was concerned about the viability of the foot or if there was obvious vascular compromise.

This is an isolated injury—the foot was run over. How would you proceed?

I would still take a full history and examination of the patient. Concentrating on the foot I would assess the degree of soft tissue injury, swelling, and neurovascular status. The patient would need to be admitted for definitive management following a CT scan to delineate fracture patterns and to plan surgical reduction and fixation.

During admission, but prior to fixation, you are informed that this patient's pain is resistant to opioids and increasing in severity. How would you proceed?

The concern here is that compartment syndrome of the foot may be developing. This requires immediate assessment and management. Pain that increases despite opioids and pain on passive stretch of the muscle compartments is characteristic, with evolving neurological and vascular compromise being late signs.

How will you manage this?

If the diagnosis was clinically confirmed I would proceed to surgical decompression. If there was doubt I would try and measure compartment pressure, with a value of greater then 30 mmHg being highly suggestive of compartment syndrome.

How do you decompress compartments in the foot?

Compartment syndrome of the foot has been described in the last 20–30 years but still generates some debate. Up to nine compartments have been described, but these may not all be functional because some have been demonstrated to communicate with other compartments at low pressure. The nine compartments are five in the forefoot (four interosseous and the adductor hallucis) and four in the hindfoot (medial, lateral, superficial central, and calcaneal compartments). Others have disagreed, stating there may be up to six compartments with only four compartments being functionally important. Current opinion in the UK is that the morbidity associated with decompressions (nerve injury, the need for skin grafts, infection) may be greater than the sequalae of an untreated compartment syndrome, and it may be best left alone, the only real indication for decompression being intractable pain.

The compartments of the foot are: medial—flexor halluces brevis and abductor hallucis; lateral—flexor digitorum brevis (fifth only), abductor digit mini and opens; central—flexor digitorium brevis, lumbricals quadratus plantae, and adductor halluces; and the interosseous compartments containing the interosseii muscles. All of these can be released if indicated. The technique I use is two dorsal incisions centred over M2 and M4 passing either side to decompress the interosseous and lateral compartments. A medial incision beneath and parallel to the first metatarsal will allow decompression of the medial compartment and lateral progression will release the central compartment. To complete release of the central compartment and the calcaneal compartment an incision is made from the posterior tuberosity of the calcaneus on the medial side to the inferior portion of the first metatarsal. The abductor is retracted superiorly to allow access through the intramuscular septum to the calcaneal compartment. The medial incisions alone are usually sufficient for calcaneal midfoot injuries. The additional dorsal incisions are for Lisfranc or metatarsal injuries.

Guyton GP, Shearman CM, Saltzman CL (2001). The compartments of the foot revisited. Rethinking the validity of cadaver infusion experiments. *J Bone Joint Surg Br*, 83-B, 245–249.

Ling ZX, Kumar VP (2008). The myofascial compartments of the foot. A cadaver study. *J Bone Joint Surg Br*, 90-B, 1114–1118.

Myerson M (1990). Diagnosis and treatment of compartment syndrome of the foot. *Orthopedics*, 13, 711–714.

Viva 11 Questions

Figure 24.11 AP and oblique foot radiographs

Describe the injury shown in this radiograph.

Can you classify fifth metatarsal fractures?

What is the mechanism of injury?

What are the management options?

How would you treat a Jones fracture surgically?

What are the complications?

Viva 11 Answers

Describe the injury shown in this radiograph.

These are anteroposterior and oblique views of a skeletally mature right foot. There is a minimally displaced transverse fracture of the fifth metatarsal at the proximal diaphyseal–metaphyseal junction.

Can you classify fifth metatarsal fractures?

Injuries of fifth metatarsal can be grouped into neck, shaft, and proximal fractures. Fractures of the neck of the fifth metatarsal are uncommon and often associated with injuries of multiple metatarsals. Diaphyseal fractures can be oblique/spiral with significant displacement. Fractures of the proximal fifth metatarsal are common and are classified by zones: tuberosity avulsion fracture, metaphyseal–diaphyseal junction (Jones fracture), and diaphyseal stress fractures.

What is the mechanism of injury?

It is not clear, but is thought to be either inversion with a fixed forefoot or adduction of the forefoot with rapid application of forces to the proximal metatarsal.

What are the management options?

I prefer to manage the majority of these fractures non-operatively. The options vary between a simple Tubigrip (compression) bandage, boot and plaster cast, or functional brace. Most heal in 3–4 weeks although diaphyseal fractures can take much longer. The proximal metaphyseal–diaphyseal (Jones) fracture is known for an increased risk of delayed/non-union, possibly due to poor blood supply. It is recommended that a non-weight-bearing plaster cast should be tried for 6 weeks first, unless in athletes or patients who wish to have it fixed surgically. This is often performed using a screw placed percutaneously. Some fractures of the fifth metatarsal occur in diaphysis, often as a result of repetitive stress in runners and athletes. These range from an undisplaced fracture to established fracture with sclerosis at the fracture site and in the cortex. The treatment often is surgical with intramedullary screw fixation with or without bone grafting as there is a high rate of non-union in this group.

How would you treat a Jones fracture surgically?

I would like to discuss this with a foot and ankle specialist in our department, although I am confident of dealing with these fractures. The general preference is to fix these fractures using a partially threaded screw, either cannulated or simple, under radiological control. It is important to use a tap to reduce the risk of fracture of the shaft. The screw should be long enough to pass the fracture line with good purchase in the bone—a 4.5-mm screw or larger is often required. The surgical risks are minimal, rehabilitation is enhanced, and healing is often achieved with internal fixation. Recovery takes about 4–6 weeks. There are reports of using tension band wiring and small plates with or without bone graft.

What are the complications?

The common risk is of delayed or non-union, but infection, intra-operative fracture, sural nerve injury, and complications related to metal work can also occur.

Dameron TB (1995). Fractures of the proximal fifth metatarsal: selecting the best treatment option. *J Am Acad Orthop Surg*, 3, 110–114.

Glasgow MT, Naranja RJ, Glasgow SG, et al. (1996). Analysis of failed surgical management of fractures of the base of the fifth metatarsal distal to the tuberosity: the Jones fracture. *Foot Ankle Int*, 17, 449–457.

Kelly IP, Glisson RR, Fink C, Easley ME, Nunley JA (2001). Intramedullary screw fixation of Jones fractures. *Foot Ankle Int*, 22, 585–589.

Nulle JA (2002). Jones fracture technique. *Tech Foot Ankle Surg*, 1, 131–137.

chapter 25

PAEDIATRIC TRAUMA

Viva 1 Questions

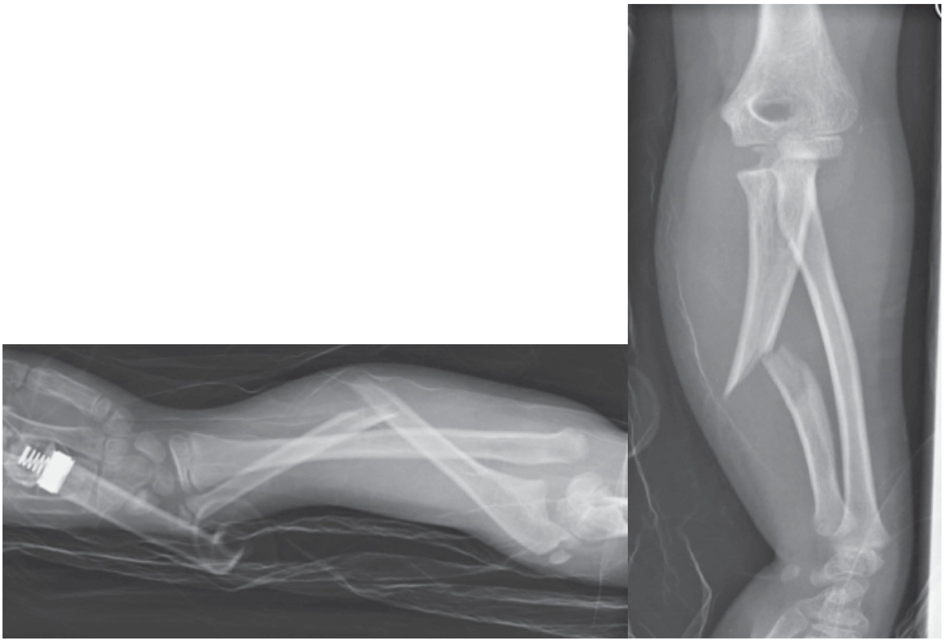


Figure 25.1 Forearm radiographs

An 8-year-old girl has fallen from a trampoline, injuring her forearm. There is a bleeding puncture wound dorsally and she is neurovascularly intact. Describe her radiographs.

How would you classify this injury?

How would you manage this patient?

What would you do if, following this, the radial head was not fully reduced?

How would you reduce the radial head?

How would you manage the patient post-operatively?

Viva 1 Answers

An 8-year-old girl has fallen from a trampoline, injuring her forearm. There is a bleeding puncture wound dorsally and she is neurovascularly intact. Describe her radiographs.

There is a dorsally and radially severely angulated midshaft ulna fracture with an associated anterior dislocation of the radiocapitellar joint. This is a Monteggia fracture dislocation.

How would you classify this injury?

An open fracture may be classified according to the Gustilo–Anderson system after debridement. The Monteggia fracture is classified by the Bado system. This is a Bado type I injury where there is a fracture of the ulna with an anterior dislocation of the radial head.

How would you manage this patient?

The goal of treatment is to achieve anatomical restoration of the length, alignment, and rotation of the ulna. On doing this the radial head invariably reduces. I would therefore debride and extend the skin wound to allow delivery of the fracture ends followed by meticulous debridement of any unviable tissue. I would reduce the fracture anatomically and, because this is a simple fracture pattern, aim for absolute stability which I would achieve by using a lag screw and 3.5 mm dynamic compression plate, with the screw being placed either through or separate from the plate.

What would you do if, following this, the radial head was not fully reduced?

I would first re-check my ulna fixation, as that is the most common reason why this might occur. If this was OK I would be worried about soft tissue interposition, most likely the annular ligament. I would radiograph the opposite elbow to be sure the patient did not have a congenital radial head dislocation (this can occur) before proceeding to open reduction of the radial head.

How would you reduce the radial head?

I would perform a Kocher's approach to the lateral elbow between the anconeus and extensor carpi ulnaris. The annular ligament is typically intact and flipped into the joint. It may be possible to flip it out but it may need to be divided then repaired after reduction has been achieved.

How would you manage the patient post-operatively?

I would discontinue antibiotics after a maximum of 72 hours and follow the patient up every week for at least the first 3 weeks to ensure there is no late subluxation of the radial head. I would use an above-elbow plaster for 6 weeks as this is a child and stiffness will not be a major issue. Contact sports are not allowed for at least 3 months.

Edwards SG, Weber JP, Baecher NB (2013). Proximal forearm fractures. *Orthop Clin North Am*, 44, 67–80.

Ring D (2013). Monteggia fractures. *Orthop Clin North Am*, 44, 59–66.

Viva 2 Questions

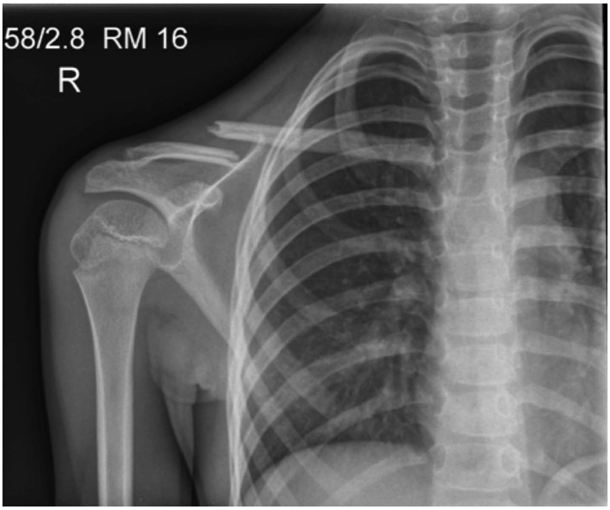


Figure 25.2 AP radiograph of right shoulder

Look at this radiograph of a 14-year-old child and tell me what you see.

Are you aware of any classification systems for this type of fracture?

How would you manage this injury?

Are you aware of any evidence in the literature to support your management?

Viva 2 Answers

Look at this radiograph of a 14-year-old child and tell me what you see.

This is an anteroposterior view of the right clavicle of a skeletally immature patient showing a simple fracture in the midshaft of the clavicle with over 100% displacement and shortening. I would like to look at another view (45°Cephalic tilt) to assess the degree of apposition and overlap of the fracture ends.

Are you aware of any classification systems for this type of fracture?

Paediatric fractures are broadly classified into physeal or extraphyseal injuries. This is an extraphyseal injury and the classification is similar to that used in adults—the Allman classification. Group 1 (85%) comprises middle-third fractures. Group 2 (10%) comprises lateral third fractures. (Group 2 has been further subdivided by Neer into three subtypes based on the location of the fracture in relation to the coracoclavicular ligaments.) Group 3 (5%) comprises medial-third fractures. This would therefore be a Group 2 fracture.

How would you manage this injury?

I would manage this injury by first taking a full history and making an examination of the child. I would follow this by plain radiographs (anteroposterior and 45°Cephalic tilt), ensuring that they are all consistent with the injury pattern (i.e. to rule out non-accidental injury). The other pertinent points I would note are the presence of any open wounds, whether skin integrity is compromised, whether this is an isolated injury (polytrauma or floating shoulder), and the presence of neurovascular injury—all of which would be indications for operative stabilization. In this scenario, I would opt for conservative management in a broad arm sling with progression to mobilization as pain allows.

Are you aware of any evidence in the literature to support your management?

In children, the periosteal sleeve is thick and has great propensity to remodel, especially considering the clavicle is last bone to fully ossify (at about 25 years old). Complications from clavicle fractures are therefore very rare; hence they have traditionally been treated conservatively. Non-unions have only been cited as case reports in the literature. Calder's study in 2002, involving two local UK district general hospitals, also supports this low complication rate and even suggests that follow-up for such fractures is unnecessary.

I am aware, however, that displaced midshaft clavicle fractures have recently gained attention in the literature. The Canadian Orthopaedic Trauma Society's multicentre randomized trial on adult clavicle fractures indicated a higher incidence of poor functional outcomes, non-union, and symptomatic malunion following non-operative management compared with operative fixation. The same is thought to be true in adolescents who do not possess the same remodelling potential as younger children: most heal with some degree of malunion. Surgery has therefore been recommended as an option for older children who have displaced fracture of more than 2 cm.

Calder JD, Solan M, Gidwani S, Allen S, Ricketts DM (2002). Management of paediatric clavicle fractures—is follow-up necessary? An audit of 346 cases. *Ann R Coll Surg Eng*, 84, 331–333.

Canadian Orthopaedic Trauma Society (2007). Nonoperative treatment compared with plate fixation of displaced midshaft clavicular fractures. A multicenter randomized clinical trial. *J Bone Joint Surg Am*, 89, 1–10.

McKee RC, Whelan DB, Schemitsch EH, McKee MD (2012). Operative versus nonoperative care of displaced midshaft clavicular fractures: a meta-analysis of randomized clinical trials. *J Bone Joint Surg Am*, 94, 675–684.

Pandya NK, Namdari S, Hosalkar HS (2012). Displaced clavicle fractures in adolescents: facts, controversies, and current trends. *J Am Acad Orthop Surg*, 20, 498–500.

Vander Have KL Perdue AM, Caird MS, Farley FA (2010). Operative versus nonoperative treatment of midshaft clavicle fractures in adolescents. *J Pediatr Orthop*, 30, 307–312.

Viva 3 Questions

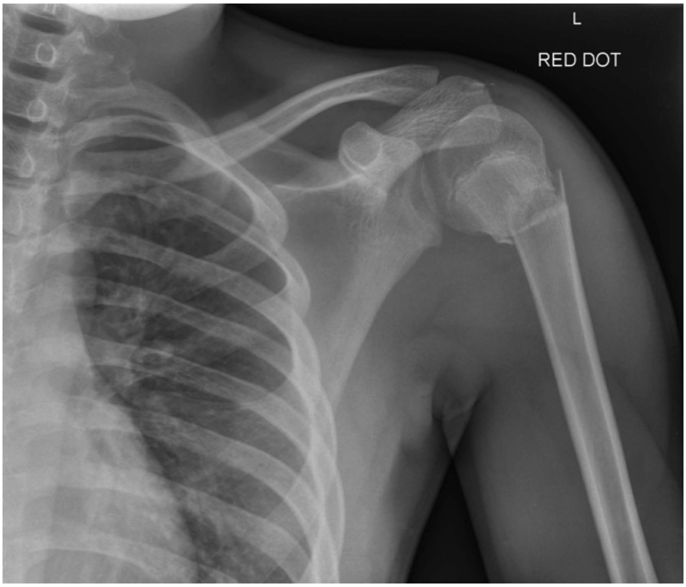


Figure 25.3 AP radiograph of left shoulder

Look at this child's radiograph and describe what you see.

Are you aware of any classification systems for this type of fracture?

How would you manage this injury?

How would you manage this fracture operatively in a 15-year-old?

If you were to manage this fracture surgically in a 15-year-old, how would you do this?

Viva 3 Answers

Look at this child's radiograph and describe what you see.

This is an anteroposterior view of the left shoulder of a skeletally immature patient showing an extraphyseal fracture of the proximal humerus. The fracture is through the metaphysis of the proximal humerus and it is angulated approximately 20° into varus. I would like to look at other views of a shoulder trauma series, specifically a scapular Y-view and an axillary view, to further assess the degree of displacement and to rule out dislocations.

Are you aware of any classification systems for this type of fracture?

Paediatric fractures can be broadly classified as physeal or extraphyseal. Physeal injuries can be further classified based on the Salter–Harris classification: for the proximal humerus type II is the most common in older children and type I the most common in neonates and younger children.

Specifically for the proximal humerus, the Neer–Horowitz classification grades the fracture by the amount of displacement: grade I, <5 mm displacement; grade II, displacement less than a third of the width of the shaft; grade III, displacement one-third to two-thirds the width of the shaft; grade IV, displacement greater than two-thirds the width of the shaft. In this case, this child has an extraphyseal fracture and I would grade this as Neer–Horowitz grade II.

Data from Neer CS and Horowitz BS (1965). Fractures of the proximal humeral epiphyseal plate. *Clinical Orthopaedics and Related Research*, 41, 24–31.

How would you manage this injury?

I would manage this injury by first taking a full history and examination of the child, in particular the neurological status of the limb (axillary nerve/brachial plexus) followed by plain radiographs (full shoulder trauma series) and ensuring that they are all consistent with the injury pattern (i.e. to rule out non-accidental injury). The other pertinent points I would elicit are the presence of any open wounds, whether this is an isolated injury (or polytrauma), and the presence of a vascular injury. All of which would be indications for operative stabilization. Other indications for surgical treatment would be a displaced Salter–Harris type III or IV fracture (these are very rare injuries but require anatomical reduction and stabilization) and severe fracture displacement in an adolescent.

In this scenario, based on the age of the child and the minor degree of displacement, I would opt for conservative management with a collar and cuff sling with progression to mobilization as pain allows, usually within 3 weeks.

If this was an older child, say a 15-year-old, would you manage it any differently?

If this injury occurred in a 15-year-old I would still aim to manage it conservatively with a sling. There is no controversy in the management of proximal humeral fractures in younger children (<10 years)—regardless of the degree of displacement, they uniformly do well with non-operative management as there is tremendous remodelling potential and a wide functional arc of motion of the shoulder. However, I am aware of recent changes in thinking that suggests that an older child may benefit from operative intervention. Previous studies advocating universal conservative management of paediatric proximal humeral fractures tended to include younger children, with very few adolescents in the cohort. A recent systematic review of over 550 cases suggests that children aged over 13 may benefit from open reduction and fixation due to poorer outcomes with conservative management (shortening, varus malunion), particularly for those fractures with more displacement.

How would you manage this fracture operatively in a 15-year-old?

My treatment goal would be to achieve an acceptable alignment, for which there is no absolute consensus in the literature; I would aim for <30° angulation and <50% translation. I would ensure the child is appropriately consented and marked and that that the WHO theatre checks are made. Then I would place the child in the supine position with a sandbag between the scapula, and using intra-operative fluoroscopy attempt closed reduction with gentle traction, 90° of flexion, then 90° of abduction and external rotation. If this fails, then I would proceed to open reduction via a deltopectoral approach. Studies by Pandya et al. and Bahrs et al. showed in the majority of cases the periosteum or biceps tendon was a block to reduction. Other impediments to reduction include the deltoid or the presence of comminution. Very often, there is more than one structure blocking reduction. Percutaneous reduction techniques are therefore less likely to be successful. Once the fracture is reduced adequately, I would stabilize it with percutaneous K-wires. I am aware of other techniques involving cannulated screws and elastic nails. A recent study comparing flexible intramedullary nails with percutaneous pinning showed both to be effective in stabilizing severely displaced fractures, with nails having fewer complications but requiring a longer surgical time and higher blood loss, and they need subsequent surgical removal.

Bahrs C, Zipplies S, Ochs BG, et al. (2009). Proximal humeral fractures in children and adolescents. *J Pediatr Orthop*, 29, 238–242.

Hutchinson PH, Bae DS, Waters PM (2011). Intramedullary nailing versus percutaneous pin fixation of pediatric proximal humerus fractures: a comparison of complications and early radiographic results. *J Pediatr Orthop*, 31, 617–622.

Pahlavan S, Baldwin KD, Pandya NK, Namdari S, Hosalkar H (2011). Proximal humerus fractures in the pediatric population: a systemic review. *J Child Orthop*, 5, 187–194.

Pandya NK, Behrends D, Hosalkar HS (2012). Open reduction of proximal humerus fractures in the adolescent population. *J Child Orthop*, 6(2), 111–118.

Sarwark JF, King EC, Janicki JA (2010). Proximal humerus, scapula, and clavicle. In: JH Beaty, JR Kasser (eds) *Rockwood and Wilkins' Fractures in Children*, 7th edn, pp.1873–1889. Lippincott, Williams and Wilkins, Philadelphia, PA.

Viva 4 Questions

Figure 25.4 Lateral radiograph of left elbow

What does this radiograph show?

Can you classify this fracture?

What is Baumann's angle and why is it used

What are the principles of management for this type of injury?

What is the brachialis sign and how does it affect management?

What biomechanical factors are involved in fixation of the fracture?

How would you assess a patient who had a radiograph as above but with absent radial and ulnar pulses?

Viva 4 Answers

What does this radiograph show?

This lateral radiograph shows a displaced supracondylar humeral fracture in a paediatric patient. The distal fragment is in extension and is rotated when compared with the long axis of the humeral shaft. There is some comminution and, looking at the soft tissue shadows, I am suspicious that the distal humeral shaft has buttonholed through the brachialis. I would like to see further views if possible.

Can you classify this fracture?

Paediatric supracondylar distal humeral fractures are classified into extension type, which account for 95% of injuries, and flexion type.

The Gartland system classifies extension injuries. Type I are a non-displaced fractures. Type II are displaced fractures with an intact posterior cortex—subdivided into those with and those without rotation. Type III are displaced fractures with no cortical contact. A recent modification of the system has included a type IV injury, which has no periosteal hinge and is significantly more unstable in both flexion and extension than a type III injury where there is still some periosteum in continuity posteriorly. This is an extension-type injury and most probably type III or IV.

What is Baumann's angle and why is it used

Baumann's angle is the angle between the long axis of the humerus and a line subtending the capitellar physis. It is normally in the 80–85° range, but should be compared with the opposite side. Fixing the fracture with an angle any more than 5° greater than normal causes significant varus malunion—the so-called gunstock deformity

What are the principles of management for this type of injury?

First and foremost, a history should be taken to include pertinent medical information and assess the risk of non-accidental injury or neglect. A through documented neurological examination, specifically to include the anterior interosseous, ulnar, and radial nerves, is mandated. Vascular assessment is also essential. The fracture should be splinted in a position of comfort and appropriate analgesia administered.

Historically, cast treatment of supracondylar fractures led to significant rates of malunion. Later, these fractures were treated as surgical emergencies, often being fixed out of hours. More recently the view with regard to timing of surgical intervention has changed from surgical emergency to surgical urgency. The rationale behind this is that if the fracture is splinted in 30–40°Flexion then it has been found that it is no more difficult to obtain an acceptable reduction with 'next day' treatment. However, it is important to be aware of warning signs that would require emergency treatment. These include severe elbow swelling, bruising, dimpling of the skin, neurological deficit, and a diminished or absent radial pulse.

Gartland type I fractures can be treated non-operatively with a collar and cuff applied in such a way than they cannot be removed, with the elbow flexed beyond 90°. Gartland type II and III fractures ideally need to be stabilized using K-wires. There are many options regarding the best configuration for the K-wires, and more recently there has been a move towards the wires being lateral entry only because of the potential for damage to the ulnar nerve, which ranges from 0% to 4%.

Data from Gartland JJ (1959). Management of supracondylar fractures of the humerus in children. *Surgery, Gynecology and Obstetrics*, 109, 145–154.

What is the brachialis sign and how does it affect management?

Bruising with puckering of the skin and the ability to feel the subcutaneous proximal fragment all imply that the proximal fragment has buttonholed the brachialis muscle. The significance of the sign is that it is associated with a more difficult reduction and also that there may well have been significant soft tissue injury to both the brachial artery and the anterior interosseous nerve.

What biomechanical factors are involved in fixation of the fracture?

When fixing supracondylar fractures, I prefer to use wires with a minimum thickness of 2.0 mm. I aim for maximal separation of pins at the fracture site, and engagement of both columns proximal to the fracture. If using crossed wires, I consider the possibility of further lateral entry pins if there is any concern regarding stability. I have no worries about crossing the olecranon fossa and engaging four cortices if that allows for an optimal wire trajectory.

How would you assess a patient who had a radiograph as above but with absent radial and ulnar pulses?

The first thing to establish is whether or not there is distal perfusion—a pink hand implies this while a white hand suggests otherwise. The pathology of a white hand is that there is a disrupted brachial artery and the associated collateral circulation is inadequate. The implication of this is that once the fracture has been stabilized there should be a vascular team available to either repair or reconstruct the brachial artery, so I would have alerted them prior to going to theatre. In a patient with a pink hand it is important to ensure that the artery is not contained within the fracture, and therefore there should be no gap on the post-operative film after fixation. In the majority of cases the vessel is in spasm and the collaterals are providing distal circulation. Opinions differ as to what happens when a patient has a pink hand after the fracture has been reduced. If the pulse returns the patient needs to be observed. There is controversy about what to do if the pulse does not return. Choi et al. state that many advocate an exploration of the artery, but if there is evidence of a pulse at the wrist on Doppler the patient can be observed with particular attention being paid to swelling and active finger motion. If the patient loses the pulse after closed reduction and pinning, the implication is that it has an iatrogenic cause and open reduction is required to assess the artery.

Choi PD, Melikian R, Skaggs DL (2010). Risk factors for vascular repair and compartment syndrome in the pulseless supracondylar humorous fracture in children. *J Pediatr Orthop*, 30, 50–56.

Kocher MS, Kasser JR, Waters PM, et al. (2007). Lateral entry compares with medial and lateral entry and fixation for completely displaced supracondylar humeral fractures in children: a randomised clinical trial. *J Bone Joint Surg Am*, 89, 706–712.

Schmidt AH, Teague DC (eds) (2010). *Orthopaedic Knowledge Update 4: Trauma*. American Academy of Orthopaedic Surgeons, Rosemont, IL.

Skaggs DL, Cluck MW, Mostofi A, Flynn JM, Kay RM (2004). Lateral entry pin fixation in the management of supracondylar fractures in children. *J Bone Joint Surg Am*, 86, 702–707.

Viva 5 Questions

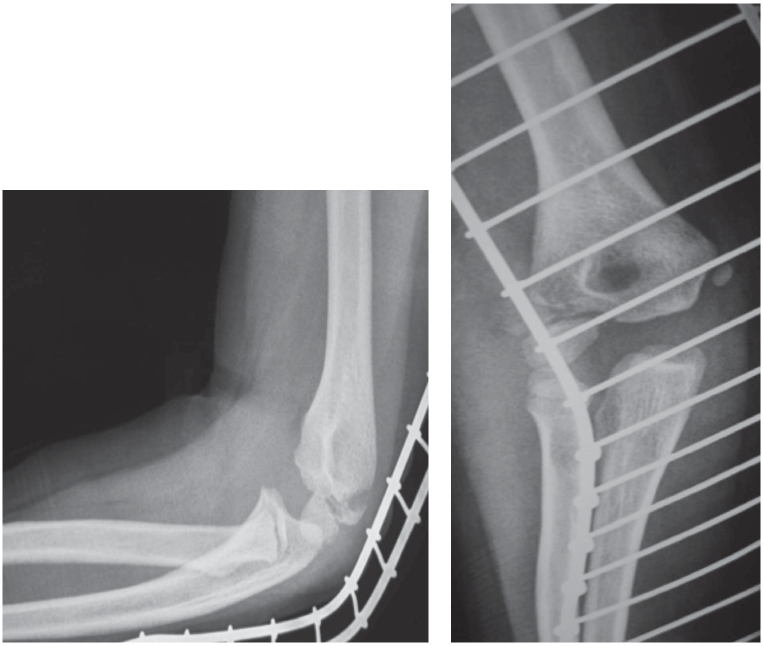


Figure 25.5 AP and lateral elbow radiographs

What do these radiographs show?

Can you classify this fracture?

What are the principles of management for this type of injury?

What are the long-term complications of lateral condyle fracture?

Are you aware of any literature supporting or opposing late open reduction?

Viva 5 Answers

What do these radiographs show?

These are anteroposterior and lateral views of the elbow of a child in a splint, showing a displaced lateral condyle fracture.

Can you classify this fracture?

The fracture line extends medially into the trochlear groove. The fragment is completely displaced and rotated, leaving the elbow unstable. Lateral condyle fractures can be classified according to the position of the fracture line and the degree of displacement. The Milch classification system differentiates between rare type I fractures that pass through the capitellar centre of ossification (equivalent to Salter–Harris type IV) and type II fractures which extend into the trochlear groove which is more likely to be displaced and cause instability of the elbow. A Milch type II fracture can be equivalent to a Salter–Harris type II or IV depending on the proximal fracture line.

What are the principles of management for this type of injury?

A displaced fracture (>2 mm) is most commonly managed operatively. There are very few contraindications to performing fixation in the properly selected patient. As the fragment is rotated and displaced, ORIF is indicated in preference to percutaneous techniques. The aims in the surgical management of this fracture are minimal disruption to the blood supply and periosteum and to achieve anatomical reduction of the articular surface. Through a curved incision over the lateral condyle the approach is between the brachioradialis and triceps muscles, directly entering the fracture haematoma to visualize the fragment. The fixation can be secured with wires, screws, or absorbable pins.

What are the long-term complications of lateral condyle fracture?

The complications of lateral condyle fracture can include both a cosmetic deformity and functional loss. The complications can be divided to biological and technical. Biological problems occur as a result of the healing process, even if a perfect reduction is obtained. These problems include spur formation with pseudo-cubitus varus or a true cubitus varus. Technical problems usually arise from management errors and result in non-union or malunion, with or without valgus angulation, and osteonecrosis secondary to surgical dissection of the posterior tissues of the capitellar fragment.

Are you aware of any literature supporting or opposing late open reduction?

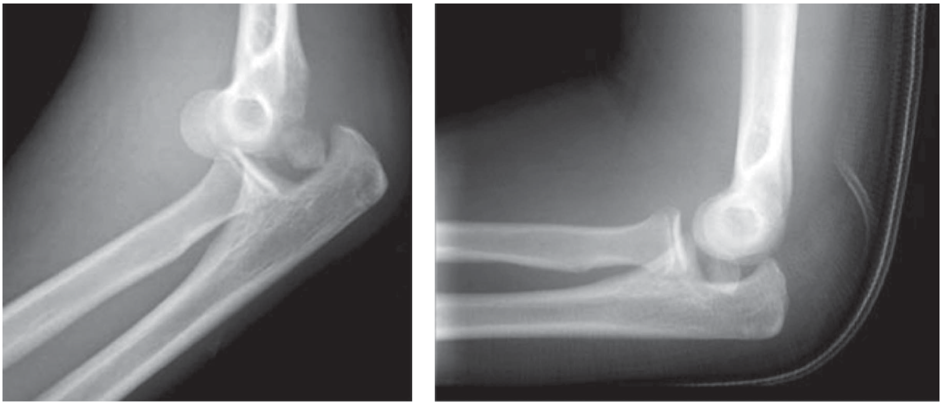
Controversy exists as to whether elbow function can be improved by late ORIF of the fracture fragment. Delayed open reduction has been shown to be complicated by osteonecrosis and further loss of elbow motion. Roye et al. demonstrated successful treatment by means of open reduction, cleaning the bony surfaces, inserting a cancellous screw, and making use of bone grafting. With surgical intervention, the stability of the elbow was improved and the risk of cubitus valgus reduced. Jakob and Fowles reported that patients treated later than 3 weeks after the fracture did no better than those who received no treatment at all. They found that early callus and fibrous tissue made it extremely difficult to obtain a satisfactory open reduction without performing considerable soft tissue dissection. All their patients treated after 3 weeks lost range of motion (at least 34° on average), and osteonecrosis, premature physeal closure, and valgus deformity were common.

Jakob R, Fowles JV (1975). Observations concerning fractures of the lateral humeral condyles in children. *J Bone Joint Surg*, 40, 430–436.

Roye DP, Bini SA, Infosino A (1991). Late surgical treatment of lateral condylar fractures in children. *J Pediatr Orthop*, 11, 195–199.

Sullivan JA (2006). Fractures of the lateral condyle of the humerus. *J Am Acad Orthop Surg*, 14, 58–62.

Viva 6 Questions



(a) (b)

Figure 25.6 Lateral elbow radiographs before (a) and after (b) closed reduction

What does radiograph (a) show?

Radiograph (b) was taken following a closed reduction of the elbow. What does it show?

What are the principles of management for this type of injury?

What are the complications of medial epicondyle fracture?

Are you aware of any controversy in the literature regarding the management of medial epicondyle fractures?

Viva 6 Answers

What does radiograph (a) show?

This is a lateral radiograph of a skeletally immature elbow showing a dislocated joint and a fracture, most likely the medial epicondyle.

Radiograph (b) was taken following a closed reduction of the elbow. What does it show?

This lateral radiograph demonstrates an incarceration of the medial epicondyle in the joint and incomplete reduction of the elbow joint.

What are the principles of management for this type of injury?

Treatment of most medial epicondyle fractures is non-surgical. Absolute indications for surgical intervention include only open fractures and a fragment incarcerated in the joint, which is the case here. Surgical treatment involves open reduction and removal of the incarcerated fragment from the joint. The fixation can be suture repair, K-wire fixation, or screw fixation. Alternatively, if the patient is young and the fragment is very small, the epicondylar fragment can be excised and the soft tissues of the flexor origin can be sutured to the periosteum of the medial elbow.

What are the complications of medial epicondyle fracture?

Loss of motion, cubitus valgus, and bony non-union are complications of the fracture. Septic arthritis, myositis ossificans, wound infection, pin-tract infections, and even radial nerve injury have been reported following surgical treatment. The incidence of these complications is low.

Are you aware of any controversy in the literature regarding the management of medial epicondyle fractures?

Management of this type of fracture is controversial. Management has traditionally been non-surgical—immobilization in a long arm cast with the elbow flexed to 90°. Several studies have reported that non-surgical management of elbow dislocations and of severely displaced medial epicondyle fractures yields results similar to or better than those of surgery, even when healed with fibrous union. No consensus exists in the literature as to the amount of fracture displacement that warrants surgical intervention. Advocates of surgery stress the importance of the medial soft tissues in maintaining joint stability. Another factor that should be considered is the high-level athletic demands that some adolescents place on their elbows. Most studies recommend surgical fixation in the following settings—open fractures, incarcerated fragments with elbow dislocation, and fractures with displacement of more than 5 mm—and consider patients who place a high level of stress on the elbow during sporting activities.

Farsetti P, Potenza V, Caterini R, Ippolito E (2001). Long-term results of treatment of fractures of the medial humeral epicondyle in children. *J Bone Joint Surg Am*, 83, 1299–1305.

Gottschalk HP, Eisner E, Hosalkar HS (2012). Medial epicondyle fractures in the pediatric population. *J Am Acad Orthop Surg*, 20, 223–232.

Josefsson PO, Danielsson LG (1986). Epicondylar elbow fracture in children: 35-year follow-up of 56 unreduced cases. *Acta Orthop Scand*, 57, 313–315.

Viva 7 Questions

Figure 25.7 AP radiograph of the elbow

What does this radiograph show?

Do you know of a classification system for paediatric radial neck fractures?

What are the principles of management for this type of fracture?

What are the indications for, and can you describe the technique of, open reduction of a radial neck fracture?

What are the complications associated with open reduction?

Can you quote any evidence for the principles of management you have previously described?

Viva 7 Answers

What does this radiograph show?

These are anteroposterior and lateral views of the elbow in an immature skeleton showing a Salter–Harris type II injury to the radial neck. The proximal fragment is angulated by more than 30° and there is approximately 80% translation. The ulnohumeral articulation appears congruent.

Do you know of a classification system for paediatric radial neck fractures?

Jeffery described two main mechanisms of injury, leading to different radial neck fracture morphologies. In the more common type I a radial neck fracture occurs after a fall on the outstretched hand with the elbow in extension and valgus strain on the elbow, resulting in a fracture with valgus angulation. In the rare type II, the proposed mechanism is a fall on the hand with the elbow flexed, which causes temporary posterior dislocation of the elbow joint. The fracture and displacement occur during spontaneous reduction of the dislocation, leaving the completely displaced radial head in the posterior aspect of the joint. Perhaps the more commonly used classification is that of Judet. This classifies radial neck fractures according to angulation and translation: grade I, undisplaced fractures; grade II, <30° angulation, <50% translation; grade III, 30–60° angulation, <100% translation; grade IV, 60—90° angulation, >100% translation. This fracture would be a Judet grade III fracture.

Data from Judet R et al. (1964). Fractures of the acetabulum: classification and surgical approaches for open reduction. *The Journal of Bone and Joint Surgery*, 46, 1615–1675.

What are the principles of management for this type of fracture?

Fractures with less than 30° angulation (Judet grades I and II) can be treated non-operatively. Grade III fractures require closed reduction and can be reduced and fixed using the technique of elastic-stable intramedullary nailing (ESIN) as described by Métaizeau or K-wire fixation. Grade IV fractures require a closed reduction but the Métaizeau technique is less likely to work here. Occasionally an open reduction may be necessary.

What are the indications for, and can you describe the technique of, open reduction of a radial neck fracture?

If there is a gap at the fracture site after reduction, or if the radial head is not able to be reduced into an acceptable position using the above techniques, there is likely to be soft tissue interposition that is preventing reduction (periosteum, annular ligament, or capsule). Open reduction is then recommended through a lateral approach: with the arm in pronation (to protect the PIN), the incision starts at the lateral epicondyle and extends distally and obliquely to the proximal ulna. The fascia over the anconeus and extensor carpi ulnaris is opened. The fibres are split in line with the extensor carpi ulnaris down to the joint capsule. Usually the injury has opened the capsule; if not, the capsule can be opened anterior to the radial humeral ligamentous complex. The radial head, radial shaft, and annular ligament should now be visible. If necessary, the annular ligament can be cut to allow reduction, but this must be repaired after reduction.

What are the complications associated with open reduction?

The proximal radial epiphysis is mainly supplied by periosteal blood vessels running distal to proximal. The fracture itself or the dissection required for open reduction may disturb the blood supply and may lead to AVN of the radial head or premature physeal closure. Proximal synostosis, heterotopic ossification, infection, and loss of range of motion are higher than after closed reduction.

Can you quote any evidence for the principles of management you have previously described?

In a study by Tibone and Stoltz the outcome was classified as good or excellent in 80% of cases after closed reduction and in 62.5% after open reduction of radial head or neck fractures. Métaizeau reported excellent results in 100% of Judet type III fractures treated using closed intramedullary pinning; however, with conservative treatment 50% of results were excellent while open reduction resulted in only 25% of results being excellent (40% of results were bad). In Judet type IV fractures, Métaizeau described poorer outcomes. In those fractures, 74% of results with closed intramedullary pinning were excellent and 23% bad; open reduction gave excellent results in 25% of cases and bad results in 45%.

Jeffery CC (1950). Fractures of the head of the radius in children. *J Bone Joint Surg Br*, 32-B, 314–324.

Klitscher D, Richter S, Bodenschatz K, et al. (2009). Evaluation of severely displaced radial neck fractures in children treated with elastic stable intramedullary nailing. *J Pediatr Orthop*, 29, 698–703.

Métaizeau JP (2005). Reduction and osteosynthesis of radial neck fractures in children by centromedullary pinning. *Injury*, 36 (Suppl. 1), A75–A77.

Pring ME (2012). Pediatric radial neck fractures: when and how to fix. *J Pediatr Orthop*, 32 (Suppl. 1), S14–S21.

Stiefel D, Meuli M, Altermatt S (2001). Fractures of the neck of the radius in children. Early experience with intramedullary pinning. *J Bone Joint Surg Br*, 83, 536–541.

Schmittenbecher PP, Haevernick B, Herold A, Knorr P, Schmid E (2005). Treatment decision, method of osteosynthesis, and outcome in radial neck fractures in children: a multicenter study. *J Pediatr Orthop*, 25, 45–50.

Tibone JE, Stoltz M (1981). Fractures of the radial head and neck in children. *J Bone Joint Surg Am*, 63, 100–106.

Viva 8 Questions

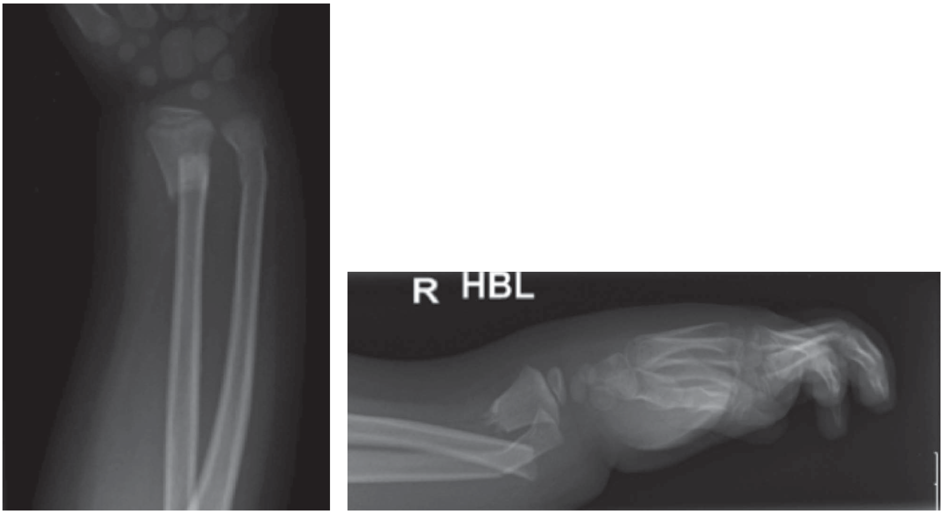


Figure 25.8 AP and lateral wrist radiographs

What do these radiographs show?

You used the term 'greenstick' to describe the ulna injury. Can you explain to me what a greenstick fracture is?

How does this differ from a torus fracture?

Could you describe your initial management of this child?

What would you tell theatre you were going to do?

Can you describe to me your decision for using either a long-arm or a short-arm cast and any evidence to support your decision?

Viva 8 Answers

What do these radiographs show?

These are AP and lateral views of an immature skeleton. There is a completely displaced, dorsally angulated, and translated fracture of the distal radius with an associated greenstick fracture of the distal ulna which is also angulated in a dorsoradial direction.

You used the term 'greenstick' to describe the ulna injury. Can you explain to me what a greenstick fracture is?

The term greenstick is used to describe an incomplete fracture in children that exhibits failure of the cortex on the tension side and plastic deformation on the concave side of a bone. It is given the name for its comparison with young twigs that are still 'green' and do not snap readily when bent.

How does this differ from a torus fracture?

A torus fracture is described when there is failure of the cortex on the compression side with intact cortex opposite this. A torus fracture is essentially a variant of a greenstick fracture in the sense that it is a feature of the way immature bone fails under loading.

Could you describe your initial management of this child?

I would take a history and examine the child with the parent present if possible, ruling out any issues relating to non-accidental or neglectful injury. Adequate analgesia should be administered and the child assessed to ensure this is a closed injury and that there is no neurological or vascular compromise. A plaster splint should be applied for pain relief and the child kept nil by mouth and a consent form completed. Theatre should be informed and the child booked for surgery. No attempt at manipulation and reduction is required in A&E as it will not be accurate enough.

What would you tell theatre you were going to do?

I would tell theatre that I was planning to perform a closed reduction by manipulation, but that occasionally an open reduction is necessary, and image intensification would be required. If I obtained a reduction that was stable I would then apply a well-moulded cast. If the reduction was not anatomical or was unstable I would plan to use K-wires prior to application of a cast. I may also need to plate the fracture and would ask for both a 2.7-mm and 3.5-mm system to be available.

Can you describe to me your decision for using either a long-arm or a short-arm cast and any evidence to support your decision?

Various risk factors have been described for re-displacement of distal radial fractures in children. Complete displacement of the fracture and an ipsilateral ulna fracture are the most significant. Non-anatomical reduction and plaster moulding are other significant factors, with the padding index being the most significant radiological index described. This fracture is at high risk of re-displacement if manipulation alone is performed based on these criteria. Bohm has shown that below-elbow casts perform as well as above-elbow casts in maintaining reduction of fractures in the distal third of the forearm in children. These findings were supported by Webb, who concluded that a well-moulded short-arm cast can be used as effectively as a long-arm cast to treat fractures of the distal third of the forearm in children aged 4 and older, and they interfere less with daily activities. I think, therefore, that on the basis of this evidence a short-arm well-moulded cast in an anatomically reduced distal radial fracture would be adequate.

Bohm ER (2006). Above and below-the-elbow plaster casts for distal forearm fractures in children. A randomized controlled trial. *J Bone Joint Surg Am*, 88, 1–8.

Hang JR, Hutchinson AF, Hau RC (2011). Risk factors associated with loss of position after closed reduction of distal radial fractures in children. *J Pediatr Orthop*, 31, 501–506.

Kamat AS, Pierse N, Devane P, Mutimer J, Horne G (2012). Redefining the cast index: the optimum technique to reduce redisplacement in pediatric distal forearm fractures. *J Pediatr Orthop*, 32, 787–791.

Proctor MT, Moore DJ, Paterson JM (1993). Redisplacement after manipulation of distal radial fractures in children. *J Bone Joint Surg Br*, 75, 453–454.

Webb GR (2006). Comparison of short and long arm plaster casts for displaced fractures in the distal third of the forearm in children. *J Bone Joint Surg Am*, 88, 9–17.

Zamzam MM, Khoshhal KI (2005). Displaced fracture of the distal radius in children: factors responsible for redisplacement after closed reduction. *J Bone Joint Surg Br*, 87, 841–843.

Viva 9 Questions

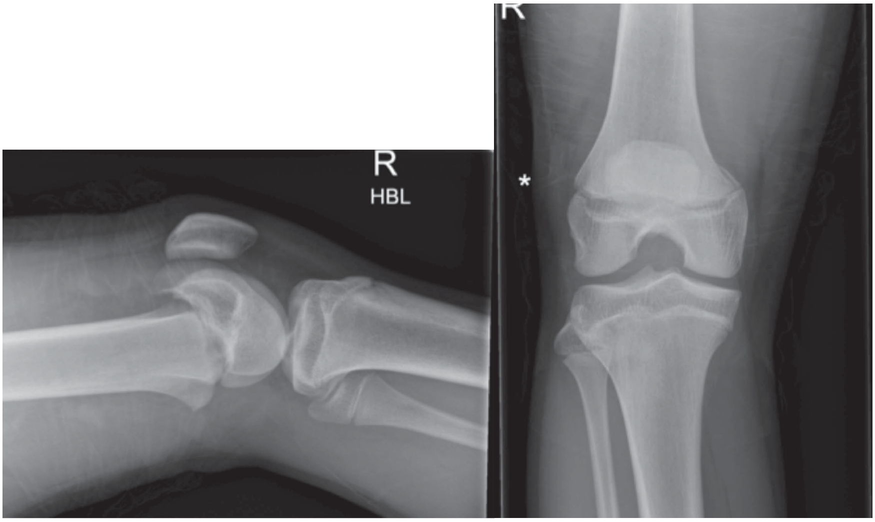


Figure 25.9 AP and lateral knee radiographs

What do these radiographs show?

This boy is 14 years old and is an elite junior footballer. He plays in goal and sustained this fracture in a collision with another player. You are the consultant on call and he presents to your department. What is your management?

What are you concerns about the fracture, and what are your plans for surgery?

How would you place your wires?

What are the potential consequences of leaving wires across the physis?

What is your management now and how would you follow this patient up?

Are you aware of any literature that reports outcomes on this type of injury?

What are your options for (1) emerging angular deformity and (2) total growth arrest if they were to occur?

Viva 9 Answers

What do these radiographs show?

These are anteroposterior and lateral views showing a displaced Salter–Harris type II fracture of the distal femur in a child with open growth plates. The metaphyseal fragment on the medial side is very small.

This boy is 14 years old and is an elite junior footballer. He plays in goal and sustained this fracture in a collision with another player. You are the consultant on call and he presents to your department. What is your management?

I would examine the patient immediately to rule out neurovascular compromise. If there were none present I would make the patient as comfortable as possible with immobilization and analgesia and I would request compartment syndrome observations. I would then arrange admission for operative fixation on the next available trauma list.

What are you concerns about the fracture, and what are your plans for surgery?

Although a large number of Salter–Harris type II fractures in this area can be managed non-operatively, in this case the angulation of the fracture is too great to accept non-operative management in a child aged 14. His remodelling potential is limited, and combined with his sporting ambitions I would not accept this deformation. My aim would be to perform a closed reduction under anaesthetic and if there was residual instability I would stabilize the fracture with wires.

How would you place your wires?

In fractures with a large Thurston-Holland fragment, screw fixation through this fragment into the opposite metaphysis, keeping parallel to but staying well away from the physis, is appropriate. However, in this case the metaphyseal fragment is small and this would not be possible. I would therefore use crossed 1.6 or 2.0-mm K-wires if needed. These would be directed from distal to proximal, one from each side, with the procedure performed under fluoroscopic control to allow for a single pass. I would aim to insert them from just adjacent to, but not through, the articular cartilage of the femur. I would cut and bury the wires.

What are the potential consequences leaving wires across the physis?

The greatest linear growth in the lower extremity occurs at the distal femoral growth plate. This physis will grow at approximately 1.2 cm/year contributing 70% of the total growth of the femur. Partial or total growth arrest by can be caused by either the initial insult or during surgery by overzealous reduction, by wires or screws, or both. This trauma could lead to leg-length discrepancy and/or angular deformity. Wires have a small footprint and cross-sectional area so are unlikely to lead to growth disturbance, although I would avoid multiple passes—hence the use of image control. In this case the wires cross the physis obliquely making them more likely to injure a greater area of growth plate.

What is your management now and how would you follow this patient up?

I would allow active and passive movement at the knee but insist strictly on no weight-bearing with crutches. At 1 week I would check the radiograph and wound to ensure no loss of position. I would then follow up at 6 weeks for repeat radiograph and planned removal of the wires. I would see him again for radiographs after another 6 weeks and then at 6 months. At each appointment I would carefully assess the leg clinically and radiologically for range of movement, angular deformity, and leg-length discrepancy.

Are you aware of any literature that reports outcomes on this type of injury?

In 2002 Eid and Hafez reported on a retrospective case series of 151 of these injuries. In Salter–Harris type II fractures the outcomes were as follows: 46% of patients suffered some degree of shortening, 25% suffered some form of growth arrest, and 63% had some angular deformity. The fractures that were reduced and fixed fared slightly better than those that weren't. In addition this paper highlighted a considerable complication rate with these fractures, including laxity of the knee ligaments, loss of normal range of movement, Volkmann's ischaemic contracture, and compartment syndrome.

What are your options for (1) emerging angular deformity and (2) total growth arrest if they were to occur?

Angular deformity from partial growth arrest may be managed by osteotomy or by hemi-epiphysiodesis. When an osseous bridge is present, resection may be considered in children who have at least 2 years of growth remaining and whose lesions occupy less than 50% of the growth plate. Osteotomy combined with concomitant epiphysiodesis may be indicated in children who have larger physeal bridges or who are approaching skeletal maturity. Complete growth arrest without angulation in a child with a contralateral open growth plate would be best managed by a contralateral epiphysiodesis if predicted to be less than 5 cm. I would use an Eastwood–Cole chart to time my surgery. Discrepancy of more than 5 cm may require ipsilateral lengthening.

Eid AM, Hafez MA (2002). Traumatic injuries of the distal femoral physis. A retrospective review of 151 cases. *Injury*, 33, 251–255.

Zionts LE (2002). Fractures around the knee in children. *J Am Acad Orthop Surg*, 10, 345–355.

Viva 10 Questions

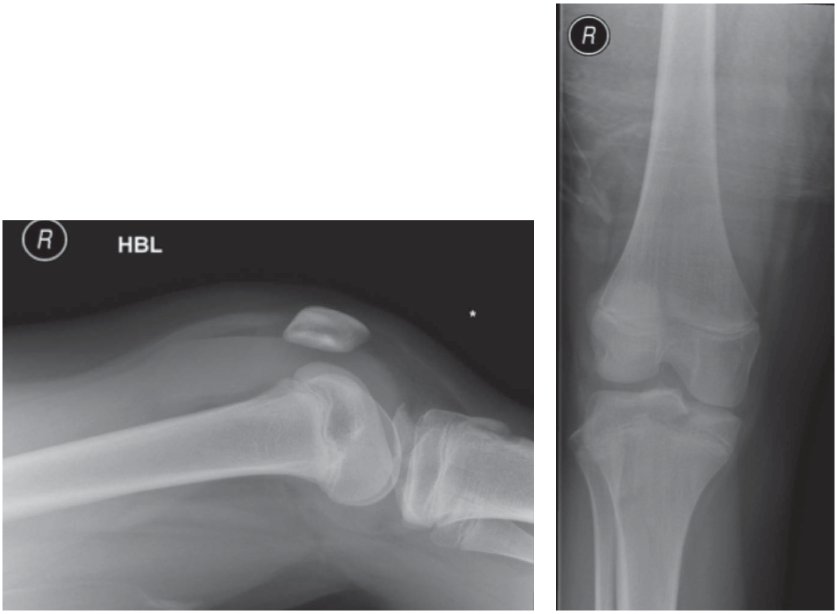


Figure 25.10 AP and lateral knee radiographs

What do these radiographs show?

Can you classify this fracture?

Why does this fracture occur?

How would you manage this injury?

Which surgical technique would you therefore choose and what rehabilitation?

What are the potential complications of this procedure?

Viva 10 Answers

What do these radiographs show?

These are anteroposterior and lateral views of a skeletally immature knee showing a large lipohaemarthrosis and a tibial eminence (or spine) fracture. The fracture is displaced but not fragmented, and there are no associated bony injuries such as osteochondral lesions of the femoral condyles.

Can you classify this fracture?

In 1959 Meyers and McKeever described three main types of fracture pattern. Type I is non-displaced and does not interfere with knee extension. The type II fracture has an intact posterior hinge with the anterior portion being elevated. In this type, knee extension is generally limited, and there is a possibility that the intermeniscal ligament is caught under the anterior fracture fragment and blocks reduction by closed means. A type III fracture is fully displaced, usually with the knee held in a mildly flexed position. In 2005 Lubowitz et al. published a subclassification of type III fractures based on CT findings: it describes type IIIa as involving only the ACL footprint and type IIIb as involving the entire tibial eminence. In 1977 Zaricznyj added a type IV fracture to the original classification; this type describes a comminuted fracture.

The fracture in the radiographs is a Meyers and McKeever type II fracture.

Why does this fracture occur?

It is analogous to rupture of the anterior cruciate ligament (ACL) in an adult, but in the skeletally immature the bone often fails under tension before the ACL, leading to an avulsion of the tibial origin of the ligament.

How would you manage this injury?

This type II fracture requires reduction and immobilization to allow direct bone-to-bone healing. Occasionally, manipulation into extension can reduce the fracture and this should be followed by brace or cast immobilization in as close to extension as possible. Repeat radiography can then be performed. If satisfactory reduction is achieved then the patient can be discharged home with a 1-week fracture clinic appointment. If reduction is not achieved then surgical intervention is required. According to Kocher et al., soft tissue interposition occurs in 54% of cases. The soft tissue interposing between the fracture fragments can be the anterior horn of the lateral meniscus, the anterior horn of the medial meniscus, or the intermeniscal ligament.

Which surgical technique would you therefore choose and what rehabilitation?

I would choose to perform an arthroscopically assisted reduction and fixation. I would aim to remove the impingement to reduction—usually by hooking the intermeniscal ligament anteriorly and pulling it out of the way. Extending the knee often allows for reduction of the fragment, but I may an additional high medial or lateral portal in order to utilize a pusher on the fragment before holding it in place with a percutaneous K-wire. I would then use cannulated screw fixation after the soft tissue interposition has been removed. This can be performed through a high anteromedial portal with the knee flexed to 90° and a single pass of the guidewire from a superoanterior to an inferoposterior direction through the proximal tibial physis. A partially threaded screw without a washer can then be passed over the guidewire to hold the reduction. A single passage of a screw or wire across the physis in a vertically orientated direction does not risk growth disturbance. Alternative techniques such as suture lassoes around the ACL can also be used, especially if the fragment is small or comminuted. Respect for the growth plate, hardware placement, and potential complications must be borne in mind at all times.

For rehabilitation the child can partially weight-bear on crutches with no brace and begin gentle range-of-movement exercises with the physiotherapist after 2 weeks. The screw should be removed at approximately 12 weeks, but not before.

What are the potential complications of this procedure?

The potential complications are all those associated with fracture surgery, and in this case growth plate disturbance (which is rare for this procedure), extensor lag owing to an impinging screw head, or on-going instability as a result of incomplete reduction and a lax ACL.

Kocher MS, Micheli LJ, Gerbino P, Hresko MT (2003). Tibial eminence fractures in children: prevalence of meniscal entrapment. *Am J Sports Med*, 31, 404–407.

Lubowitz JH, Elson WS, Guttmann D (2005). Part II: arthroscopic treatment of tibial plateau fractures. Intercondylar eminence avulsion fractures. *Arthroscopy*, 21, 86–92.

Meyers MH, McKeever FM (1959). Fracture of the intercondylar eminence of the tibia. *J Bone Joint Surg*, 41-A, 209–222.

Zaricznyj B (1977). Avulsion fracture of the tibial eminence: treatment by open reduction and pinning. *J Bone Joint Surg Am*, 59, 1111–1114.

Viva 11 Questions

Figure 25.11 AP radiograph of the tibia

What does this radiograph show?

How would you manage this injury?

Can you describe some of the common deformities to be expected?

One week later the check radiograph shows 10° of valgus. What will you do?

Viva 11 Answers

What does this radiograph show?

This is an anteroposterior view of a skeletally immature patient demonstrating a tibia and fibula facture at the same level. The fibula is a greenstick fracture whereas the tibia is a complete fracture. There is 10° valgus angulation.

How would you manage this injury?

I would first take a full history and examine this patient. If there were any suggestion of significant trauma I would manage this along ATLS guidelines. The majority of tibial fractures in children can be managed non-operatively with excellent results. The fracture is in an unacceptable position and I would attempt a closed reduction to improve the position and maintain an acceptable position using an above-knee cast. If a satisfactory position were achieved I would want further radiographs within a week to monitor reduction. I would aim to use an above-knee cast for 3–4 weeks and a below-knee cast for another 3–4 weeks.

Can you describe some of the common deformities to be expected?

There are three main types of tibial fracture: those of the proximal metaphysis, the diaphysis, and the distal diaphysis/metaphysis. Proximal metaphyseal fractures tend to deform into valgus—the Cozen fracture. There is no clear understanding of why this occurs but it is thought to be the result of periosteal interposition in the fracture medially. Diaphyseal fractures, if associated with a plastic deformity of the fibular, tend to drift into valgus. Isolated diaphyseal tibial fractures are prone to drift into varus due to the splinting effect of the fibula. Isolated comminuted tibial fractures are less prone to varus deformity. Fractures at the junction of the middle and distal third are likely to drift into valgus.

One week later the check radiograph shows 10° of valgus. What will you do?

The anteroposterior radiograph demonstrates loss of positioning, with the tibia drifting into valgus of approximately 10°. This represents an unacceptable position and I would attempt to improve this using a wedging technique. Using markers placed upon the cast I would establish the level of the fracture. I would then mark out the level for an opening to be cut into the cast of less than 90% of the circumference, with the intact portion at the apex of the deformity. Then I would use laminar spreaders to open the cast and place cork wedges or ready-made wedges to correct the valgus angulation. A further radiograph would show whether adequate reduction has been achieved.

Jackson DW, Cozen L (1971). Genu valgum as a complication of proximal tibial metaphyseal fractures in children. *J Bone Joint Surg Am*, 53, 1571–1578.

Jordan SE, Alonso JE, Cook FF (1987). The aetiology of valgus angulation after metaphyseal fractures of the tibia in children. *J Pediatr Orthop*, 7, 450–457.

Viva 12 Questions

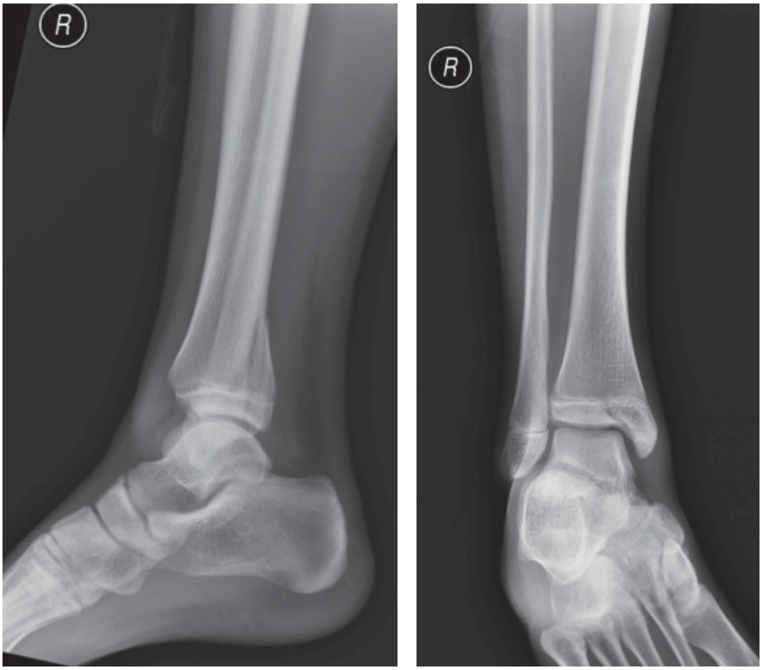


Figure 25.12 AP and lateral ankle radiographs

What do these radiographs show?

How would you manage this isolated injury?

What is the aetiology and classification of this injury?

What are you indications for operative intervention, and what would you do?

What are the short- and long-term outcomes associated with these injuries?

Viva 12 Answers

What do these radiographs show?

These are anteroposterior and lateral views of the right ankle in a skeletally immature patient. There is a fracture of the distal tibia which appears as a Salter–Harris type II fracture on the lateral view and Salter–Harris type III on the anteroposterior view. It is a triplane fracture.

How would you manage this isolated injury?

Initial management would consist of history and examination. If this was a closed and neurovascularly intact injury and there were no contraindications to operative intervention I would place this in a temporary backslab, offer appropriate analgesia, admit the patient, and organize a CT scan to establish the pattern of injury and degree of displacement. The CT will allow me to plan screw trajectories once the fracture plane orientation is clear. I would ensure the patient is marked and consented and adequately prepared for theatre.

What is the aetiology and classification of this injury?

Triplane fractures are complex fractures that occur in children between the ages of 10 and 16. They are either lateral or medial and occur in two or more parts. Lateral two-part fractures are the most common. They represent both an articular injury and a growth plate injury. The cause of these fractures is still controversial; some authors believe they represent different energy levels whilst others feel they are due to unequal closure of the physis. The latter is the more popular theory: since closure of the distal tibial physis occurs last in the anterolateral corner it is common for this fragment—the Chaput–Tilleaux segment—to displace. The triplane fracture is so-called as there are fractures in the coronal, sagittal, and axial planes.

What are you indications for operative intervention, and what would you do?

A displacement of more than 1–2 mm is unacceptable as it has been shown to be associated with a worse outcome. The goals of surgery are to anatomically reduce the articular surface with overall satisfactory alignment (no varus, a small amount of valgus, posterior or anterior angulation). I would attempt a closed reduction under image control. If a satisfactory position can be achieved I would then consider percutaneous fixation of the epiphyseal component, either with cannulated screws if epiphysis is large enough or smaller-diameter screws if necessary. The screws would be orientated from the lateral to medial direction. I would supplement this fixation with a further anteroposterior screw above the physis to reduce the Thurston–Holland fragment which is a Salter–Harris type II component.

What are the short- and long-term outcomes associated with these injuries?

For those that have no internal fixation the main short-term problem is loss of position. I would radiograph routinely at short intervals for the first 3 weeks to ensure no loss of position. The long-term outcomes depend on the accuracy of reduction, with a low rate of osteoarthritis in anatomical reductions of less than 10% and good functional outcomes.

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Viva 13 Questions

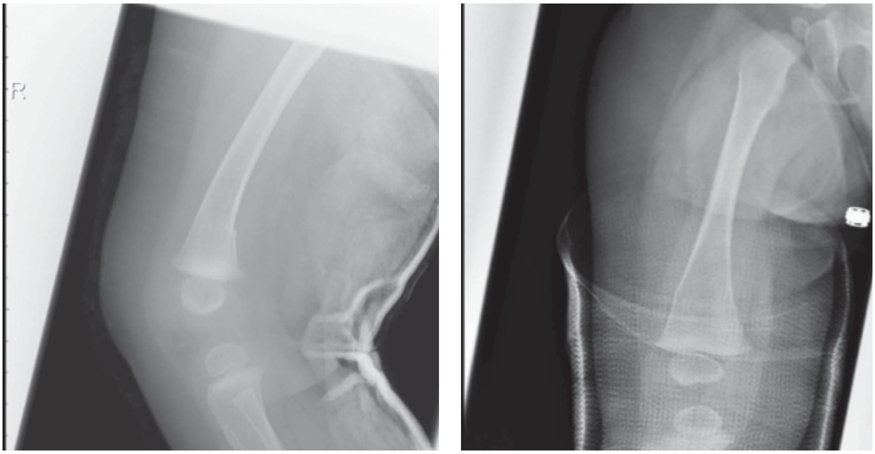

Figure 25.13 AP and lateral knee and femur radiographs

Describe what these radiographs show.

How would you manage the patient?

The child is 6 months old and the father describes a fall when the child was attempting to walk. What do you think?

What are the principles of diagnosing suspected non-accidental injury (NAI)?

What is your role in managing suspected NAI?

Viva 13 Answers

Describe what these radiographs show.

These are anteroposterior and lateral plain radiographs of the femur of a skeletally immature child. It demonstrates a minimally displaced transverse metaphyseal fracture of the femur, and the limb is in a backslab. Depending on the age of the child, this fracture raises my suspicions for NAI, especially if the child is of non-walking age.

How would you manage the patient?

I would first like to take a thorough history from the parents/carers and examine the child. In my history the key points I would focus on are the age of the patient, the mechanism of injury (looking for inconsistencies or improbability between the mechanism and injury pattern, as well as any delay in presentation), antenatal and developmental history (as prematurity is a known risk factor for NAI), past medical history (e.g. known osteogenesis imperfecta, osteopenia of prematurity, bone dysplasia, or previous fractures as well as any other previous visits to hospital), and interaction between parents and the child (e.g. child fearful of the parent, or an evasive or aggressive parent).

I would ensure that I was meticulous with documentation in the child's medical notes. I would also look out for any visual codes on the child's medical notes (depending on each hospital's policy) that indicate they are known to social services or are on the child protection register.

In my examination of the child, I would be certain to fully examine the child from head to toe, as next to fractures soft tissue injuries like bruises and burns are the most common presentation of NAI. In particular, I would look for signs of neglect, bruises with a semblance to hand or finger prints or implements used to harm the child, or cigarette burns.

In addition to the above, the child's distal femoral fracture still requires appropriate management. In this case, the limb requires splintage (in a Pavlik harness if the child is younger than 6 months old, or a spica cast if older). Ultimately, if I have any concerns regarding the welfare of the child, I would inform the named or designated nurse or doctor for safeguarding children, or an experienced colleague. My priority would be to ensure the child is in a safe environment.

The child is 6 months old and the father describes a fall when the child was attempting to walk. What do you think?

I would be suspicious about the history and the mechanism described and concerned about the possibility of non-accidental injury, as a child of 6 months should not be able to walk independently. A large comparative review of NAI cases in a Level 1 paediatric trauma centre in the USA (Pandya et al. 2009) and a systematic review published in the *British Medical Journal* (Kemp et al. 2008) have shown that fractures from NAI are most common in children under 18 months of age (i.e. those who are not walking), with femoral fractures occurring nearly twice as often in those who have been abused compared with those resulting from accidental injury.

What are the principles of diagnosing suspected non-accidental injury (NAI)?

The principles involve several key areas. Initially, the history: looking for delay in presentation, multiple attendances, inconsistent descriptions, unlikely mechanisms of injury, and unusual times of presentation. Risk factors include low socioeconomic status, parents with mental health or substance-misuse issues, exposure to domestic violence, vulnerable and unsupported parents, twins, developmental delays, pre-term infants, and chronic illness. Examination should be from top to tail to identify any other injuries (as detailed in previous answers). If there are any alerting features that prompt me to consider NAI, then I would discuss my concerns with a more experienced colleague or a named or designated professional for safeguarding children. I would also gather collateral information from other agencies like social services (if within office hours). In more highly suspicious cases, I would directly refer the child to children's social care, following local safeguarding children board (LSCB) procedures.

Radiographic investigations should be performed in consultation with an appropriate radiologist (one who has expertise in reading such films). This would involve a skeletal survey, especially in children aged under 2; this would include plain films of the skull, chest, abdomen, spine, and limbs. Other investigations to exclude medical, skeletal, and biochemical abnormalities and differential diagnoses should also be considered.

What features on radiographs are suggestive of NAI?

There is no one fracture pattern or location that is specific for NAI—fractures resulting from abuse have been described in virtually every bone in the body. It is more important to consider the age and developmental stage of the child as there is a strong inverse relationship between the age of the child and likelihood of a fracture being caused by abuse. However, certain radiological findings could raise suspicions, including the presence of multiple fractures, rib fractures (particularly posteromedial which have a 71% probability of being caused by NAI), fractures of different ages, radiographic evidence of occult fractures (i.e. fractures identified on radiographs that were not clinically evident), metaphyseal corner (bucket handle) fractures, humeral fractures (a 50% chance of NAI), femoral fractures in children under 18 months old (a 33% chance), and skull fractures.

What is your role in managing suspected NAI?

It is a legal responsibility for all clinicians to initiate child protection procedures if child abuse is suspected, and we must all have a high index of suspicion for NAI. For orthopaedic surgeons this is even more pertinent, as most cases of maltreatment present with soft tissue injury or fractures; hence we are likely to be the first doctors to see such children. To ensure good medical practice, I am obliged to adhere to The General Medical Council's published guidance, 'Protecting children and young people: the responsibilities of all doctors', on cases of suspected abuse. NICE has also published guidelines on 'When to suspect child maltreatment'. It is also my responsibility as a healthcare professional to ensure that I have received the relevant training (minimum level 2 training) to recognize child maltreatment. This is a difficult problem and must be managed sensitively as part of a multidisciplinary team including paediatricians, orthopaedic surgeons, social workers, and allied health professionals. It is important to have a working knowledge of local procedures for protecting children and young people. In general, as an orthopaedic surgeon my role is to consider the safety and welfare of children and young people and to be aware of risk factors and look out for signs of abuse or neglect. Out of hours cases should be discussed with the paediatric registrar and/or consultant, often necessitating admission for investigation. During hours each hospital will have a named nurse or doctor for child protection issues through whom advice can be sought. The patient should not be allowed to leave the hospital if there are any concerns.

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