Jonathan D. Hodax
Adam E. M. Eltorai
Alan H. Daniels *Editors*

The Orthopedic Consult Survival Guide

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Jonathan D. Hodax
Warren Alpert Medical School
Brown University
Providence, Rhode Island, USA

Alan H. Daniels
Warren Alpert Medical School
Brown University
Providence, Rhode Island, USA

Adam E. M. Eltorai
Warren Alpert Medical School
Brown University
Providence, Rhode Island, USA

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About the Editors and Authors

Editors

Jonathan D. Hodax, MD, MS
Chief Resident, Department of Orthopedic Surgery
Warren Alpert Medical School of Brown University

Adam E. M. Eltorai
MD/PhD Candidate
Warren Alpert Medical School of Brown University

Alan H. Daniels, MD
Assistant Professor, Department of Orthopedic Surgery
Chief, Adult Spinal Deformity Service
Director, Spine Research/Spine Research Fellowship
Co-Director, Spine Surgery Fellowship
Warren Alpert Medical School of Brown University

Authors

Joey P. Johnson, MD
Resident in the Brown University Orthopedic Residency Program pursuing a career in Orthopedic Trauma

J. Mason DePasse, MD
Resident in the Brown University Orthopedic Residency Program pursuing a career in Orthopedic Spine Surgery

Joseph A. Gil, MD
Resident in the Brown University Orthopedic Residency Program pursuing a career in Orthopedic Hand and Upper Extremity Surgery

Andrew D. Sobel, MD
Resident in the Brown University Orthopedic Residency Program pursuing a career in Orthopedic Hand and Upper Extremity Surgery

Seth O'Donnell, MD
Resident in the Brown University Orthopedic Residency Program pursuing a career in Orthopedic Foot and Ankle Surgery

Vincent Alexandre
Senior casting technician at Rhode Island Hospital pursuing further training as a Physician's Assistant

Foreword

For over 25 years, the orthopedic residents of Brown University have been responsible for managing the musculoskeletal consults in the Andrew F. Anderson Emergency Center of Rhode Island Hospital. This system evaluates over 200,000 patient visits per year, including adult, pediatric, and level 1 trauma admissions. The PGY-1 and PGY-2 residents have become extraordinarily efficient in their approach to individual patient evaluation, stabilization, and disposition. Their activities are monitored 24/7 by more senior residents and faculty. Their efforts are reviewed at our morning trauma conference 365 days per year where all emergency department consults (with X-rays) from the prior 24 hours are presented, reductions are critiqued, and soft tissue problems are discussed via digital photography. These morning conferences are a critical time in their training when their efforts, techniques, and results are discussed in an open forum that includes senior faculty, fellows, and all residents. Over the years, consistency of management strategies has been codified and is now available for all to learn from in this volume. It is not intended to be exhaustive, but lays out the basics on how to approach common musculoskeletal consult requests in a clear and well-organized format that will be a welcomed and easily portable resource for junior orthopedic and emergency medicine house officers as well as physician's assistants, nurse practitioners, and medical students on rotation.

Christopher T. Born, MD, FACS, FAAOS
Intrepid Heroes Professor of Orthopedic Surgery
The Alpert Medical School of Brown University
Emeritus Director, Orthopedic Trauma Service
Rhode Island Hospital.

Preface

Patients with acute orthopedic injuries require urgent and sometimes emergent evaluation to stabilize and to evaluate for serious complicating conditions. Such conditions, including any neurovascular injury, often require immediate surgical consultation and intervention. *The Orthopedic Consult Survival Guide* is a concise and user-friendly book covering the most common orthopedic injuries. This quick-reference guide includes bulleted text and easy-to-follow algorithms, protocols, and images, acting as a "pocket consultant" to provide the most up-to-date information when you need it most. Organized anatomically for fast reference, each section is broken down into the most common and most serious injuries with tips on how to evaluate and treat patients from the start of consultation to completion. The contributing authors are chief orthopedic surgery residents at a major level 1 trauma center who have experienced managing a high volume of orthopedic injuries and who have trained many young residents.

Providence, RI, USA

Jonathan D. Hodax
Adam E. M. Eltorai
Alan H. Daniels

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Abbreviations

ABI	Ankle Brachial Index
ACL	Anterior cruciate ligament
AIN	Anterior interosseous nerve
AP	Anterior-posterior
CRP	C-reactive protein
CT	CAT scan
CTS	Carpal tunnel syndrome
CXR	Chest X-ray
DIP	Distal interphalangeal joint
DISH	Diffuse idiopathic skeletal hyperostosis
DP	Distal phalanx
ED	Emergency department
EDC	Extensor digitorum communis
EKG	Echocardiogram
EPL	Extensor pollicus longus
ESR	Erythrocyte sedimentation rate
FDP	Flexor digitorum profundus
FDS	Flexor digitorum superficialis
FPL	Flexor pollicus longus
H&P	History and physical
ICU	Intensive care unit
IO	Interosseous
IV	Intravenous
LCL	Lateral collateral ligament
LUCL	Lateral ulnar collateral ligament
MCL	Medial collateral ligament
MCP	Metacarpal phalangeal joint
MPFL	Medial patellofemoral ligament

MRI	Magnetic resonance imaging
MT	Metatarsal
NPO	*Nil* per os, or “nothing by mouth”
NWB	Non-weight bearing
OPLL	Ossification of the posterior longitudinal ligament
OR	Operating room
PCL	Posterior cruciate ligament
PIN	Posterior interosseous nerve
PIP	Proximal interphalangeal joint
PLC	Posterolateral corner
SEA	Spinal epidural abscess
SI	Sacroiliac joint
SP	Superficial peroneal nerve
TAL	Transverse atlantal ligament
UA	Urine analysis
WBAT	Weight bearing as tolerated
WBC	White blood cell count

Contents

Part I
Special Considerations in Orthopedics

Chapter 1
The Polytrauma Patient

Joey P. Johnson

Keywords Polytrauma • Multiple fractures • Trauma

Overview

Polytrauma patients (Fig. 1.1) are a unique and often challenging population that frequently requires multidisciplinary interventions. Their orthopedic injuries should be viewed with reference to their overall condition and other organ system injuries. A prudent approach should be followed for operative interventions to prevent iatrogenic deterioration of a patient's overall condition. Effective communication between general surgery, ICU, orthopedic surgery, and other consulting services is key to optimizing patient outcomes.

J.P. Johnson, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: joey.johnson12@gmail.com

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FIGURE 1.1 Radiographic examples of polytrauma patients

Evaluation

1. Thorough neurovascular exam of all extremities: These patients have a high rate of missed injury, both due to distracting injuries and often because they present with altered mental status from a shock state and cannot communicate where they are experiencing pain. Any bony step-off, crepitus, laxity, or abnormal motion should be noted.
2. Skin exam: The skin overlying any fracture should be evaluated for dermal violation. Any wound violating the dermis in the area of a fracture should be considered an open fracture until deemed otherwise. Skin with poor perfusion or severely injured skin overlying a fracture should raise concern for a threatened fracture, or one that may progress to being open.
3. Concomitant injuries.

When to Escalate

1. When any of the orthopaedic emergencies are present (See Chapter 5).
2. Neurovascular compromise: As in all injuries, this should be communicated to the orthopedic surgeon on call immediately.
3. If a patient is going to the operative room with another service and has operative orthopedic injuries. The orthopedic surgeon on call may elect to surgically treat the patient under the same anesthesia if possible.

Key Exam Pearls

1. Size and location of open wounds and abrasions
2. Neurovascular status
3. Examine all extremities and the spine

Effective Communication

1. Concomitant injuries
2. Size and location of open wounds
3. Neurovascular status
4. Clearance status for the OR

Follow-Up

1. All fractures should be appropriately immobilized; standard imaging studies should be obtained.
2. Admission to orthopedics, general surgery, or ICU service as dictated by patient condition and hospital practice.

Chapter 2
Open Fractures

Joey P. Johnson

Keywords Open fracture • Compound fracture • Antibiotics

Overview

Open fractures (Fig. 2.1) are common orthopedic injuries with potentially serious sequelae. Approximately 8–10% of all open fractures result in amputation, and various studies have shown that infection rates following open fractures are as high as 24%. Even if you are not at the center that is going to be definitively treating a patient with an open fracture, you can assist in their care and improve the outcome. The *most important factor* in terms of decreasing infections related to open fracture is the time taken to administer antibiotics. Studies suggest that greater than 65 min from injury to antibiotics is an independent risk factor for developing an infection.

J.P. Johnson, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: joey.johnson12@gmail.com

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Figure 2.1 Example of an open fracture presenting to our emergency department

Evaluation

1. Thorough neurovascular exam: Any fracture high enough injury to break the skin should be thoroughly examined to determine if intervening neurovascular structures are injured.
2. Skin examination: Skin overlying every fracture should be evaluated for dermal violation.
3. If a wound violating the dermis is present, it should be considered an open fracture until deemed otherwise.
4. Concomitant injuries should be ruled out.

Antibiosis

1. Timing: Intravenous antibiotics should be given when an open fracture is suspected.
2. Cefazolin: Weight-based cefazolin should be given to every patient with open fracture unless the patient has a known allergy.

3. Gram-negative coverage: Guidelines are currently debated. In severe open fractures, an aminoglycoside in weight-based dosing is given (e.g., gentamicin); some hospitals have moved on to fluoroquinolones, because of the better side effect profiles, or piperacillin-tazobactam; for severe open fractures (described as Gustilo IIIA-C), be aware of your hospital's policy.
4. Penicillin: Given for farm, barnyard, and heavily contaminated injuries.
5. Fluoroquinolones: Usually given for injuries occurring in standing water.

When to Escalate

1. Immediately! The orthopedic surgeon on call should be made aware of patients with open fractures.
2. Neurovascular compromise: As in all injuries, this should be communicated to the orthopedic surgeon on call immediately.

Key Exam Pearls

1. Size and location of open wounds
2. Neurovascular status

What to Bring

1. Splinting materials appropriate for suspected injuries
2. Normal saline for copious irrigation
3. Bulky gauze dressing

Reduction

Prior to reduction, any visible debris should be gently removed from the wound bed. The visible bone should also be rinsed with an isotonic solution (normal saline). The general goals in reduction of open fractures are to return bone ends underneath the skin[1] and prevent skin necrosis from pressure of bony spikes. Early anatomic reduction of open fractures is generally not necessary in the ER setting, as these patients will require urgent surgery. However, effective closed reduction can prevent further skin injury and decrease swelling by restoring normal alignment.

Effective Communication

1. The Gustilo-Anderson classification is often used to describe these fractures, though the Orthopedic Trauma Association Open Fracture Classification (OTA-OFC) is gaining popularity among surgical providers because of its descriptive nature and its interobserver reliability.
2. Size and location of open wounds.
3. Neurovascular status.
4. Contaminant amount/type.
5. Clearance status for the OR.

Follow-Up

1. These fractures should be appropriately immobilized; standard imaging studies should be obtained.
2. Admission to orthopedics, general surgery, or ICU service as dictated by patient condition and hospital practice is essential.
3. Urgent operative intervention is required.

[1] An important caveat: If you encounter a patient who had a bone spike delivered through the skin that is grossly contaminated (mud, feces, etc.), contact the orthopedic surgeon on call prior to attempting a reduction, as any reduction may seed clean tissue with contaminant.

Chapter 3
High-Energy Trauma

Joey P. Johnson

Keywords Fall from height • Motor vehicle accident • Polytrauma

Overview

High-energy trauma (Fig. 3.1) patients are a unique and often challenging population. Most commonly, they present following motor vehicle collisions, being struck by a motor vehicle, and falls from a significant height. These patients are at risk for periarticular fractures (e.g., Pilon, tibial plateaus, etc.), long bone fractures, and potentially life-threatening axial skeleton injuries.

Evaluation

1. Thorough neurovascular examination of all extremities: These patients have a high rate of missed injury, both due to distracting injuries and because of limited

J.P. Johnson, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: joey.johnson12@gmail.com

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FIGURE 3.1 Examples of high-energy trauma

communication due to altered mental status from a state of shock.

2. Skin examination: The skin overlying any fracture should be evaluated for dermal violation, if present; any laceration violating the dermis should be considered an open fracture until deemed otherwise.
3. Concomitant injuries: These patients are at high risk for intracranial, intrathoracic, and intra-abdominal injuries.

When to Escalate

1. When any of the orthopaedic emergencies are present (See Chapter 5).

2. Neurovascular compromise: As in all injuries, this should be communicated to the orthopedic surgeon on call immediately.
3. If a patient is going to the operating room with another service and has operative orthopedic injuries, the orthopedic surgeon on call may elect to surgically treat the patient under the same anesthesia if possible.

Key Exam Pearls

1. Size and location of open wounds
2. Neurovascular status
3. Examine all extremities and the spine

Effective Communication

1. Concomitant injuries
2. Size and location of open wounds
3. Neurovascular status
4. Clearance status for the OR

Follow-Up

1. All fractures should be appropriately immobilized; standard imaging studies should be obtained.
2. Admission to orthopedics, general surgery, or ICU service as dictated by patient condition and hospital practice.

Chapter 4
Penetrating Trauma

Joey P. Johnson

Keywords Shooting • Stabbing • Open fracture • Gunshot

Overview

Treating penetrating trauma (Fig. 4.1) patients often presents a treatment challenge. The majority of penetrating trauma is caused by bullet and stab wounds. Typically, in the community setting, if a fracture's characteristics would allow it to be treated nonoperatively and it is caused by a gunshot wound, it can be treated as a closed fracture. If a fracture's characteristics require operative intervention, then the fracture should be treated as an open fracture. These principles hold true for "low-velocity" gunshot injuries, however, "high-velocity" injuries such as rifle, assault weapon, or low-distance shotgun injuries should be treated differently due to increased energy transferred to the surrounding tissues.

J.P. Johnson, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: joey.johnson12@gmail.com

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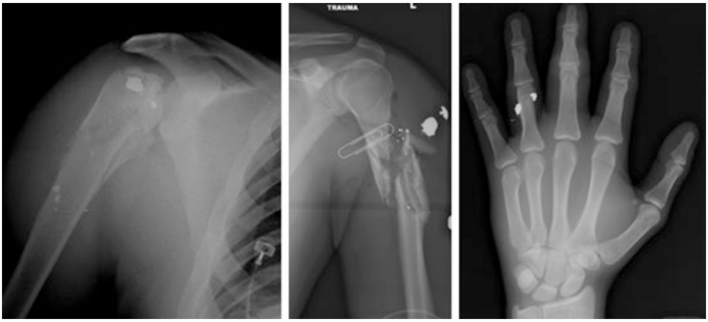

FIGURE 4.1 Examples of penetrating trauma (in these cases low-velocity gunshot wounds)

Evaluation

1. A thorough neurovascular exam: The zone of injury of a bullet wound is defined by the cone of energy dissipation surrounding the bullets path, not just the linear path of the bullet. This makes the tissue injury much larger than the caliber of the bullet, often, and the energy imparted to surrounding tissues can cause neurapraxia or vascular injury.
2. Skin examination: Entrance and exit wounds should be examined; if there is no exit wound, the location of the bullet must be identified. Intra-articular bullets or fragments are indications for surgical irrigation and debridement.
3. Concomitant injuries should be ruled out.

Antibiosis

1. Timing: If a patient has an operative fracture, it will be treated as an open fracture—provide antibiotics immediately.
2. Agent: Weight-based cefazolin should be given. Often this is the only antibiotic that is required.

When to Escalate

1. Neurovascular compromise
2. Intra-articular/intrathecal fragments
3. Bullet tracks that may communicate with gastric contents

Key Exam Pearls

1. Size and location of open wounds
2. Neurovascular status
3. Location of fragments (intra-articular/intrathecal?)

What to Bring

1. Splinting materials
2. Normal saline irrigation
3. Bulky gauze dressing

When to Get the Bullet

Often patients will expect you to offer surgery to get the bullet out. This is often unnecessary and may expose them to undue risk. There is some evidence that lead can leach into the blood stream if the person has open physes; however, such scenarios are exceedingly rare.

Retrieval of the bullet/fragments is appropriate if (1) it is located subcutaneously and you can palpate it on exam; (2) it is in, or communicating with, a synovial joint; (3) it is located within the canal of the lumbar spine; or (4) it is located within the thoracic or cervical spinal canal and the patient has an operative fracture or neurological deficit.

Neurologic Deficits and Stab Injuries

It should be assumed that the nerve is lacerated. This is an indication for surgical exploration and potential nerve repair/interposition.

Effective Communication

1. Size and location of open wounds
2. Standard description of fractures
3. Neurovascular status
4. Contaminant amount/type
5. Clearance status for the OR

Follow-Up

1. All of these fractures should be appropriately immobilized; standard imaging studies should be obtained.
2. Admission to orthopedics, general surgery, or ICU service as dictated by patient condition and hospital practice, if patient has operative fractures or a bullet in or communicating with a synovial joint.
3. Urgent operative intervention when appropriate.
4. If a patient has a nonoperative fracture, their wounds should be dressed and reduced/splinted as per standard care. These patients can often be discharged with follow-up in the office/clinic.

Chapter 5
Never-Miss Conditions

Jonathan D. Hodax

Keywords Compartment syndrome • Cauda equina syndrome • Open fracture • Dislocation

Overview

A number of musculoskeletal injuries are considered emergent. Missing these injuries is likely to lead to significant disability, and in some instances possibly death. While many such topics are covered throughout this book, it is important to take a moment to cover some of the most significant topics that warrant special attention.

Open Fractures

Delayed diagnosis of an open fracture leads to an increased risk of infection, morbidity including possible loss of limb, and even possible mortality. Any wound in conjunction with a fracture should be considered an open fracture if the dermis

J.D. Hodax, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: JDHodax@gmail.com

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is violated. Early treatment with antibiotics is a key factor, and the first line is typically cefazolin, a first-generation cephalosporin. This can be augmented per institutional protocols in the setting of contaminated wounds or severe soft tissue injury. By being quick to refer to a fracture as "open," and letting the definitive exploration take place during an irrigation and debridement in a formal operating room, fewer missed injuries are likely to occur.

Compartment Syndrome

In the event that tissue pressures increase beyond local venous pressures, compartment syndrome occurs. While typically associated with the leg, thigh, and forearm, compartment syndrome may occur anywhere that a fascial compartment exists (paraspinal muscles, gluteus, pectoralis, etc.). The carpal tunnel, the deltoid, the hand, and the foot are all other sites of possible compartment syndrome leading to significant loss of function. The five "P"s are often taught (pain out of proportion, pallor, paresthesia, poikilocytosis, and pulselessness); however, these should not be relied upon for diagnosis. In the clinical setting, patients often present with pain out of proportion, followed by paresthesia. Pain with passive stretch is an excellent examination maneuver when possible (motion of the first toe in leg compartment syndrome or of the digits in forearm compartment syndrome) but is not available anatomically in all settings, and sometimes fractures themselves may lead to some pain with passive stretch. Be aware that by the time a body part is pulseless, pale, and/or cold, your diagnosis is already too late to prevent disability. In addition, tissues feeling "firm" or "tense" should not be relied upon, as subcutaneous fat and deep muscle compartments often limit palpation.

Scapulothoracic Dissociation and Traumatic Internal Hemipelvectomy

While both these conditions are rare, it is important that emergency and orthopedic practitioners understand and recognize the possibility and presentation of these life-threatening injuries. Scapulothoracic dissociation is a closed separation of the entire forequarter from the thorax. Fractures of the scapula and clavicle may or may not be associated. Neurologic injury, particularly to the brachial plexus, is common. Vascular injury may occur and is potentially life threatening. A traumatic internal hemipelvectomy is the equivalent injury in the lower extremities and is often fatal. In both cases, the earliest hints are high-energy mechanisms, sensory/motor/vascular disability in the extremity, and asymmetries on the extremity on initial trauma films (AP chest, AP pelvis).

Septic Arthritis

The presence of bacteria within a joint space can quickly lead to devastating and permanent loss of articular cartilage. Early diagnosis is again critical. A good history is helpful, particularly in the setting of immunocompromised, intravenous drug use, or recent surgery. Pain with motion and inability to bear weight are the hallmarks of physical examination, in addition to a swollen and tender joint. While a number of differential diagnoses may present in a similar manner (gout, pseudogout, transient synovial reactions, and even arthritis), a septic joint should be at the top of a differential unless it can be confidently ruled out. Essential factors in dealing with suspected septic arthritis include taking a sterile aspiration PRIOR to the administration of any antibiotics and following the aspiration with a copious lavage of sterile isotonic fluid.

Specific Dislocations

1. *Hip*: Dislocations of a native hip can devastate the vascular supply to the femoral head and cause irreversible injury to the sciatic nerve. Hip dislocations are a true orthopedic emergency and should be reduced as soon as safely possible. An early reduction with adequate sedation will limit the risk of devascularization and collapse.
2. *Knee:* Knee dislocations often spontaneously reduce. Any multiligamentously injured knee or equivalent (such as a tibial plateau fracture with medial involvement) should be considered a knee dislocation equivalent, carefully evaluated for neurologic and vascular injury.
3. *Wrist:* Lunate and perilunate dislocations of the wrist are commonly overlooked, especially in the polytrauma patient. A methodical evaluation of wrist X-rays to identify any incongruence should be standard practice.

Cauda Equina Syndrome

As discussed in the axial skeleton section, cauda equina is the result of critical compression to the lumbar and sacral nerve roots within the spinal canal. New onset of incontinence, perianal anesthesia, or loss of motor function should be evaluated with emergent imaging and quick decompression.

The Injury That You Can Make Worse

Mistaking a complex injury for a simpler one is a common error and can lead to significant iatrogenic injury. Always carefully evaluate your films to ensure you have not overlooked something, particularly before performing a reduction. A common hip dislocation can be made much worse if a nondisplaced femoral neck fracture suddenly becomes displaced when traction is applied. A common distal radius fracture when combined with a tight cast molded over the carpal tunnel may rapidly lead to irreversible injury to the median nerve. Always look for a snake in the grass!

Part II
Skills and Techniques for Diagnosing and Treating Musculoskeletal Injuries

Chapter 6
Splinting and Casting Techniques

Vincent Alexandre and Jonathan D. Hodax

Keywords Cast • Splint • Immobilization • Stabilization

Overview

The initial treatment of many orthopedic injuries relies upon casting and splinting of the affected limb to mitigate pain, maintain reduction, and prevent further damage to soft tissues. However, these tools are not without their associated caveats. A poorly applied splint can cause further injury to the patient including pressure sores and thermal burns. The following should serve as general guidelines; however, institutional variance may apply.

In general, the joint "above and below" (or proximal and distal) to the fracture site should be immobilized when possible in order to maintain adequate control over the fracture site. In the emergent setting, splinting is preferred to casting

V. Alexandre (✉)
Casting Technician, University Orthopedics, Providence, RI, USA
e-mail: vincentalexandre@gmail.com

J.D. Hodax, MD
Department of Orthopedics, Brown University,
Providence, RI, USA

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as splints can more readily accommodate swelling. If casting must be performed on acute fractures, bivalving (cutting the cast in order to allow for expansion) should be seriously considered as this will reduce the risk of cast-induced compartment syndrome.

The padding applied beneath a splint is of crucial importance, as it is the part of a cast or splint that directly interfaces with the patient. For "slab"-type splints, no less than six layers of padding on the upper extremity and eight on the lower with additional padding on bony prominences are appropriate. For circumferential wrapping, padding should be applied in a 50% overlapping pattern from the most distal portion of the splint to the most proximal. Circumferentially wrapped padding should be a minimum of 3–4 layers with additional padding applied to any prominences. In both splints and casts, wrinkles can lead to pressure points and skin breakdown and should be carefully avoided.

When it comes to splinting material, there are generally two choices, fiberglass or plaster. Fiberglass is faster to harden and less messy to deal with; however, fiberglass does not shape to the patient as closely as plaster. Plaster is generally messier and takes longer to harden; however, it shapes more closely to the patient if applied while wet and arguably holds unstable reductions better. With both materials, the risk of thermal injury is very real as the curing of both plaster and fiberglass is highly exothermic. Splints and casts should be kept in open air while hardening to allow the heat to escape.

Upper Extremity Splinting Techniques

Sugar Tong Splint

A sugar tong splint (Fig. 6.1) is one that wraps around the elbow and onto the volar and dorsal aspects of the forearm, extending beyond the wrist but leaving the MCP joints free.

FIGURE 6.1 Sugar tong splint after padding (*left*) and application of splint (*middle*, *right*)

1. *Indications*: For any fractures of the radius/ulna or in conjunction with long-arm posterior splint for unstable elbow fractures or dislocations. Consider immobilizing the forearm in pronation for unstable elbow dislocations.
2. *How to*: Wrap the arm with cast padding from metacarpal heads to the proximal arm. Take care to use additional padding at the medial and lateral epicondyle, olecranon, and over the posterior arm where the edge of the splint rests. Place a "U"-shaped piece of plaster or fiberglass from the dorsal hand, around the forearm and elbow, and back to the palm. Overwrap with an elastic wrap. The splint should be long enough to immobilize the wrist but just short enough to allow full motion of the fingers.

Volar Splint

A single slab of splint material is placed on the volar aspect of the forearm (Fig. 6.2).

1. *Indications*: For stable fractures of the distal radius and mild carpal injuries. May be used for immobilization of infections or soft tissue injuries as well.
2. *How to*: Wrap the arm with cast padding from the metacarpal heads to the proximal forearm. Place a sheet of plaster

Figure 6.2 Volar splint

or fiberglass over the volar palm to the mid-forearm. If the fingers are to be immobilized, both the padding and the plaster should extend beyond the fingertips. Overwrap with an elastic wrap.

Posterior/Ulnar Long-Arm Splint

A slab of splint material is placed along the posterior aspect of the arm from the level of the axilla to the metacarpophalangeal joints, with the elbow flexed to 90° (Fig. 6.3).

1. *Indications*: Stable fractures or dislocations of the elbow. It can also be used as part of a coaptation splint or in conjunction with a sugar tong splint, when more stability is required.

Figure 6.3 Posterior/ulnar long-arm splint padding (*above*) and after application of splint (*below*)

2. *How to*: Wrap the arm with cast padding from the metacarpal heads to the proximal arm. Take care to use additional padding at the medial and lateral epicondyle and the olecranon. Place a long slab of plaster or fiberglass from the posterior proximal arm, along the posterior elbow, and around the ulnar forearm. Overwrap with an elastic bandage.

Figure 6.4 Thumb spica splint

Thumb Spica Splint

A radially based splint that begins on the forearm, crosses the wrist, and wraps around the thumb (Fig. 6.4).

1. *Indications*: Fractures or suspected fractures of the scaphoid, fractures of first metacarpal or the phalanges of the thumb.
2. *How to*: Wrap from the distal palm to the proximal forearm with cast padding. Additional cast padding should be wrapped around the thumb, making sure adequate padding is present over all sites. A slab of plaster or fiberglass should then be placed over the radial wrist, extending as far as needed onto the thumb, and gently wrapped around the radial and ulnar aspect of the thumb to immobilize it.

Intrinsic Plus Splint

A splint that has volar and dorsal components. Intrinsic plus describes a position of 20–30° of wrist extension, 70–80° MCP flexion, and full PIP/DIP extension (Fig. 6.5).

FIGURE 6.5 Intrinsic plus splint

1. *Indications*: Fractures of metacarpals.
2. *How to*: Wrap the hand, wrist, and distal forearm with cast padding. This splint should always use plaster, as it molds more tightly to the shape of the hand and maintains the required position. Every effort should be made to hold the patient in a position similar to the desired final result throughout the process to prevent bulging or tearing of the cast padding. Place one slab of 6–8 sheets of plaster on the dorsal aspect and one slab of 5–6 sheets on the volar aspect of the hand and wrist, extending to the distal forearm. The desired position must be maintained until the plaster reaches a rigid state.

Coaptation Splint

A splint that includes both a long-arm posterior slab and a slab which runs from the axilla medially around the elbow and up to the AC joint laterally.

1. *Indications*: Humeral shaft fractures.
2. *How to*: This splint requires at least one well-trained assistant to apply properly. Begin by positioning the patient upright, sitting at the edge of the bed with the affected extremity hanging off the side of the bed. Wrap the arm from hand to shoulder, taking care to adequately cover the shoulder up to the base of the neck and pad the bony prominences of the elbow as well as the axilla. The first slab is placed beginning just distal to the axilla, wrapping down the medial arm, around the elbow, and up the shoulder to the base of the neck. This piece is held in place, while a second slab is placed from the posterior proximal arm, across the posterior elbow and to the distal forearm, with the elbow flexed at 90°. Elastic bandages are then applied, and typically a valgus mold at the fracture site is required to counteract the abducting force of the deltoid.

Short-Arm Cast

This is the workhorse of upper extremity casting. It provides control via circumferential wrapping of fiberglass cast tape (Fig. 6.6).

1. *Indications*: Distal radius fractures.
2. *How to*: Begin by placing pieces of stockinette at the proximal forearm, over the thumb, and over the palm and fingers. Follow by wrapping cast padding from distal to proximal in an overlapping manner. Typically, two passes of 50/50 overlapping padding and three wraps at the distal and proximal end are adequate, with the padding partially covering the stockinette at each end. Fold the excess stockinette over the padding to help prevent breakdown of the

Figure 6.6 Short-arm cast with application of stockinette, padding, and fiberglass

padding. Fiberglass cast tape is then wrapped from distal to proximal in a similar manner, again with three layers at each end and two passes of 50/50 overlapping between. A mold can be placed while the fiberglass cures. Care should be taken to allow unrestricted motion of the thumb, fingers, and elbow.

Long-Arm Cast

This is the workhorse of pediatric upper extremity casting. In addition to the benefits of short-arm casting, a longer cast prevents pronation/supination, immobilizes the elbow, and prevents the cast from slipping down (Fig. 6.7).

1. *Indications*: Forearm fractures and elbow dislocations in the pediatric patient.
2. *How to*: Similar to the short-arm cast, the long-arm cast begins with stockinette; however, the proximal segment should be placed at the axilla. Wrap circumferential cast padding from the hand to the upper arm, and provide additional padding for the bony prominences of the elbow. Avoid overstuffing the antecubital fossa. Wrap from distal to proximal with cast tape. We recommend keeping the arm flexed slightly more than 90° during both padding and cast tape wrapping, then extending the last bit to 90°. This helps to avoid creases in the antecubital fossa.

Lower Extremity Splinting Techniques

Posterior Short Leg Splint

A splint which runs along the posterior aspect of the lower leg. Typically, the ankle is kept at 90° (Fig. 6.8).

1. *Indications*: Fractures of the toes or foot, stable ankle fractures, which do not require varus/valgus/rotational control.

FIGURE 6.7 Long-arm cast application, including stockinette, padding, and fiberglass

FIGURE 6.8 Posterior short leg splint

2. *How to*: Wrap the foot with padding from toes to the proximal calf, with additional padding for the heel and malleoli. A slab of plaster or fiberglass is then placed from the toes to the proximal calf. Avoid doubling excess material over on the proximal calf as this can lead to thermal injury or to pressure points. Cover with an elastic wrap.

Posterior Short Leg with Side Gussets

A short leg posterior splint that includes a slab, which wraps around from the medial to lateral aspect of the lower leg (Fig. 6.9).

1. *Indications*: For ankle fractures which require varus/valgus/rotational control.
2. *How to*: Follow similar steps to the short leg splint. After placing the posterior slab, an additional slab is placed that

Figure 6.9 Posterior short leg with side gussets

wraps from the medial calf, down the side of the leg, under the heel, and up the lateral side. Avoid allowing the two limbs of the gusset to contact each other in front, as this creates an unintentional circumferential construct. Cover with an elastic wrap and apply mold as needed.

Posterior Long Leg Splint

A posterior splint which goes from the proximal thigh distally to the metatarsal heads. May add second slab if varus valgus control is needed.

1. *Indications*: Distal femur fractures and tibial shaft fractures.
2. *How to*: Simple posterior splints extended up the proximal thigh, typically with a gentle bend at the knee.

Knee Immobilizer

A premade device with adjustable straps.

1. *Indications*: Tibial plateau fractures, reduced patellar/knee dislocations, distal femur fractures, and ligamentous injuries of the knee.
2. *How to*: Follow device instructions. In obtunded or frail patients, additional padding is appropriate.

FIGURE 6.10 Short leg cast

Short Leg Cast

The standard means of immobilizing the foot and ankle (Fig. 6.10).

1. *Indications*: Ankle fractures, Achilles tendon injuries, and hindfoot and midfoot injuries.
2. *How to*: Short leg casts are best placed with an assistant holding the hip, knee, and ankle at 90°. Custom stands are available for when an assistant cannot be found. Place stockinette around the proximal calf and an additional piece hanging over the toes and covering the distal foot. Wrap with cast padding, taking care to pad the heel, malleoli, and Achilles tendon. Fold over the stockinette and wrap with cast tape. Take care to avoid overfilling the instep.

Long Leg Cast

An extended version of the short leg cast which provides control at the knee as well.

1. *Indications*: Pediatric ankle fractures and nonoperative tibial shaft fractures in all ages.

2. *How to*: Often the easiest way to place a long leg cast is to do it in parts. Long leg casts require an assistant. Begin by placing stockinette at the proximal thigh and at the toes. If you plan to place the cast in parts, cast padding should be wrapped from the foot to the knee. Carefully, pad the ankle and heel. Follow the padding with cast tape up to the proximal tibia, but leave the proximal aspect only 1–2 layers thick as you will overrun it in the second stage. After the distal portion has hardened, place the patient into the desired amount of knee flexion, and complete the padding as needed up to the proximal thigh. Fold down the stockinette and overwrap with cast tape, ensuring multiple layers crossing from the proximal to the already hardened distal portion in order to make sure the two portions adhere well to each other.

Chapter 7
Joint Aspiration and Injection

Jonathan D. Hodax

Keywords Joint injection • Traumatic arthrotomy • Saline load test

Overview

Access to joints for injection and aspiration is useful for both diagnostic and therapeutic purposes. Indications include:

1. Collecting synovial fluid to test for bacteria, elevated nucleated cells, or crystals
2. Irrigating a suspected septic joint in order to mitigate the damage to cartilage before a formal irrigation and debridement can be performed
3. Injecting sterile isotonic fluid in order to evaluate for a traumatic arthrotomy (open joint)
4. Injecting local anesthetic to provide pain control and allow for an easier exam

J.D. Hodax, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: JDHodax@gmail.com

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Equipment

Everything needed should be collected beforehand and carefully laid out so that no break in sterile technique occurs.

Always bring the following:

1. Sterile gloves
2. Sterile prep (chlorhexidine or iodine)
3. 18-gauge needle × 2
4. Sterile gauze
5. Ace wrap

For suspected septic joint, include:

1. Test tubes for culture
2. Test tubes for synovial analysis
3. 5- or 10 cc syringe for aspiration
4. 60 cc syringe for irrigating joint after aspiration × 2
5. Sterile basin
6. Sterile saline, typically >500 ml

For suspected traumatic arthrotomy, also include:

1. 60 cc syringe
2. Sterile basin
3. Sterile saline, typically 500 ml

For a planned injection of anesthetic, also include:

1. Anesthetic
2. 20- or 21-gauge needle

Technique

Patient consent should be obtained prior to an injection. If your institution requires a procedural time-out, it should also be completed. Thoughtfully position your patient in a way that will allow easy access to the joint for all of the remaining steps. The skin should be prepared with antiseptic, and then all equipment should be laid out with care to avoid contamination of your sterile field. In a pinch, the packaging of sterile gloves can be opened and used as a sterile field. Carefully mark the planned injection site before beginning. Always have dressing supplies at the ready before beginning.

1. *For a suspected septic joint*: Aspirate the joint and withdraw as much fluid as possible. Take care to avoid contamination as you place this fluid into the test tubes. After the maximal amount of fluid has been withdrawn, it is important that the joint then be irrigated to decrease the bacterial and inflammatory burden. Use sterile fluid and a large-volume syringe to maximally fill and empty the joint sequentially, discarding the fluid each time.
2. *For a suspected traumatic arthrotomy*: After gaining access to the joint, begin to inject sterile solution. Observe wounds carefully for any seepage of fluid. If no seepage occurs and the joint is maximally distended, confirmation of a closed joint can be obtained by separating the syringe from needle and observing for high-pressure return of fluid. The amount of fluid should be measured and be roughly equal to the amount injected. On average, a knee joint can hold up to 120–150 cc, an elbow or an ankle 20–30 cc, and a wrist 5–10 cc. Be mindful that habitus and other factors can cause these volumes to vary.

Chapter 8
Hematoma Block

Jonathan D. Hodax

Keywords Injection • Analgesia • Local Block

Overview

Hematoma blocks are useful to help control pain during fracture reduction. The principle is to inject the fracture hematoma itself with a local anesthetic, therefore directly anesthetizing the bony ends. Many fracture reductions are appropriate for a hematoma block, with the exceptions of open fractures, fractures greater than 2 days old, and fractures in the setting of possible infection. Superficial sites such as the distal radius, metacarpals, and ankle are the most commonly used because local landmarks are palpable and neurovascular anatomy is well defined. In general, local anesthetics without epinephrine should be used given the low volume needed and the risk of causing vascular injury in the digits and extremities.

J.D. Hodax, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: JDHodax@gmail.com

J.D. Hodax et al. (eds.), *The Orthopedic Consult Survival Guide*, DOI 10.1007/978-3-319-52347-7_8,

Equipment

1. Sterile gloves
2. Antiseptic
3. 20 gauge needle
4. 10 cc syringe
5. Local anesthetic, typically 1 or 2% lidocaine
6. Gauze
7. Any casting or splinting materials needed for reduction

Technique

Patient consent should be obtained prior to an injection. If your institution requires a written consent or a procedural time-out, it should also be completed. Thoughtfully position your patient in a way that will allow easy access to the extremity for both the injection and the reduction that will follow. The joint should be approached from a safe direction that minimizes the risk to surrounding structures. Injury to a surrounding nerve or vessel is always a risk, and care should always be taken to avoid direct injection of anesthetic into a vessel. There should be minimal resistance to injection if the syringe is within the synovial space or fracture hematoma.

Chapter 9
Basic Fracture Reduction Principles

Jonathan D. Hodax

Keywords Reduction • Fracture • Techniques

Overview

Although often perceived of as simply "straightening out the bone," fracture reduction is a complex task that should always include a thorough knowledge of the injury and the best means to realign the fragments before being undertaken. These general principles will assist with the reduction of fractures and dislocations, with specifics written throughout this text for each anatomic location.

Limit the Patient's Ability to Counteract Your Efforts

Muscle spasms due to pain and anxiety are a major obstacle to reduction. A three-pronged approach to limiting a patient's muscular forces during reduction should include chemical

J.D. Hodax, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: JDHodax@gmail.com

J.D. Hodax et al. (eds.), *The Orthopedic Consult Survival Guide*, DOI 10.1007/978-3-319-52347-7_9,

agents such as benzodiazepines or conscious sedation, positioning the patient in a manner that decreases the length of their most powerful muscles (such as flexing the knee during an ankle reduction to put the gastroc-soleus complex at a mechanical disadvantage), and fatiguing the patient with gentle axial traction for 3–5 min before attempting a reduction. While not all of these adjuncts are required before a reduction, each can assist in making the procedure easier and safer.

"Just Pulling on It" Is Not Always the Answer

Straight axial traction is often helpful, but is rarely the only technique needed for an anatomic reduction. Fractures are caused by deforming forces that include the trauma itself as well as the pull of muscles, tendons, and ligaments on each fracture fragment in a variety of directions. The forces involved should be considered and carefully reversed. In addition, using straight axial traction alone may cause iatrogenic injury. This is particularly true in digital injuries where the volar or plantar plate can be pulled into a dislocated joint, blocking reduction.

Fatigue, Recreate, and Reduce

For many injuries a pattern of "fatigue, recreate, and reduce" can be successful. This is most often taught in distal radius fractures and other forearm fractures, where the two fragments may have bony spicules interdigitating and preventing reduction. In such instances, it can be helpful to first fatigue the patient with traction and then separate the two fragments by recreating (or slightly exaggerating) the deformity. After the fragments are freed, the deformity can be reduced by realigning the fragments under traction, then releasing traction.

You Can't Win 'Em All

Not every fracture is amenable to anatomic reduction by closed means. If it were, the field of orthopedic surgery would have far less to do. It is important to understand what fractures *must* be brought into anatomic alignment and which simply cannot be. It is never worth causing iatrogenic injury to a patient simply to get an X-ray to look better if the injury will be treated in the operating room anyway.

Chapter 10
Traction Pin Placement

Jonathan D. Hodax

Keywords Stabilization • External Fixation • Traction

Overview

Traction pin placement is used to reduce unstable fractures and dislocations and temporize certain fractures pending definitive fixation. Although traction pin technique varies slightly depending on the area of the body being placed in traction, the following should serve as general guidelines.

Indications

1. Length unstable or angular fractures
2. Articular incongruity or unstable dislocations
3. Temporizing pelvic, acetabular, and long bone fractures pending definitive fixation

J.D. Hodax, MD
Brown University, Department of Orthopedics,
Providence, RI, USA
e-mail: JDHodax@gmail.com

J.D. Hodax et al. (eds.), *The Orthopedic Consult Survival Guide*, DOI 10.1007/978-3-319-52347-7_10,

What to Ask

1. NPO status (for sedation) or OR if needed
2. Availability of X-ray if needed
3. Consent obtained
4. Imaging of fracture AND area where traction to be placed

What to Request or Bring

1. X-rays of the knee, tibia, ankle, and foot (if concerned about associated injury)
2. Everything needed for proper consent and procedural timeout per institutional protocol

Equipment

Everything needed should be collected beforehand and carefully laid out so that no break in sterile technique occurs. Always bring the following:

1. Sterile gloves
2. Sterile prep (chlorhexidine or iodine)
3. 18-gauge needle × 2 with 20 cc syringe and local anesthesia
4. Marking pen
5. Scalpel
6. Kelly clamp
7. Dressings

Traction equipment:

1. Drill
2. Traction pins
3. Traction bow
4. Traction bed
5. Cord
6. Weight

When to Escalate

1. *Open fractures*: Should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR). Application of traction and/or external fixation should occur in OR following formal I&D.

Imaging

1. AP and lateral views of the traction pin site are required *prior* to insertion (rule out additional injury or anatomic abnormality).
2. AP and lateral ("down the pin") views are required following insertion to confirm adequate placement of the pin.
3. Radiographs of the injury should be obtained following placement "in-traction"; weight adjustments made as needed.

Effective Communication

1. Obtain consent.
2. Correct pin site for injury.
3. Gather all supplies prior to starting.

Key Procedure Pearls

1. Skin traction should be limited to <10 lbs, and extreme caution should be used to avoid skin breakdown.
2. Perform and document distal neurovascular exam prior to beginning. Repeat following pin placement.

3. Use skin marker to draw out all landmarks (and joint lines) in area of pin placement. Use these to remain in the correct plane while placing traction pin.
4. If using local anesthesia, ensure it reaches the periosteum.
5. Cover the sharp end of pin following insertion for protection to patient and other health-care workers.

Technique

Traction pin technique varies slightly depending on the area of the body being placed in traction. In general, skin is prepped, all landmarks are drawn out, and local anesthetic is placed both medially and laterally at planned site of pin insertion and exit. A small skin incision is made ONLY at the site of insertion; the Kelly clamp is used to pierce fascia and spread, reaching bone. The pin is affixed to the drill; posterior and anterior margins are felt by "walking" the pin tip along cortex to find the middle or optimal start point. Hands are aligned to be parallel with joint line. An assistant can be of use to verify your hands are correct in the orthogonal plane. The pin is drilled across, piercing the near cortex, far cortex, muscle, fascia, and Subcutaneous tissues on opposite side. When pin exit site can be appreciated by palpation, the scalpel is used to make another small incision to allow the pin to egress. The pin should be positioned so that a roughly equal amount is exposed medial and lateral. Following insertion, the sharp tip is covered/protected, traction bow applied, post-placement X-rays obtained, weight hung, and post-traction X-rays obtained of the injury. Splinting is then performed per local practice. Emergency department external fixation ("traveling traction" or "ED ex-fix") may be used for unstable pilon or ankle fracture dislocations by combining proximal tibial and calcaneal traction pins and using external fixation bars and clamps to complete the construct.

1. *Distal Femoral Traction*: Pin placed medial to lateral, just proximal to femoral epicondyle and adductor tubercle

2. *Proximal Tibial Traction*: Pin placed lateral to medial, about 2 cm distal and 2 cm posterior to tibial tubercle

3. *Calcaneal Traction:* Pin placed medial to lateral, away from the neurovascular bundle, about 2 cm posterior and 2 cm inferior to medial malleolus

Adequate Reduction Parameters

1. Restoration of length and alignment
2. Reduction of abnormal joint loading forces

Follow-Up

1. Post-traction X-rays (Fig. 10.1) should be assessed to ensure adequate weight has been applied to obtain the desired result and alignment.
2. Skin should be checked for evidence of pressure necrosis from pin or traction bow. Weight and cord should never be allowed to rest on the skin of leg or foot.
3. Plans should be made for definitive fixation.

FIGURE 10.1 AP and lateral radiographs of traction pin placement including distal femoral (*above*), calcaneal (*middle*), and proximal tibial (*below*)

Part III
Upper Extremity Injuries

Chapter 11
Soft Tissue Injuries of the Hand

Andrew D. Sobel

Keywords Soft tissue • Hand • Penetrating • Burn • Crush • Bite

Overview

Soft tissue injuries (Fig. 11.1) of the hand may result from a range of pathologies including penetrating injuries, burns, frostbite, crush injuries, and bites require thorough evaluation for neurovascular status, along with signs of tendon injury or infection. Neurovascular or infectious exam findings may escalate management.

What to Ask

1. What is the mechanism of injury? Sharp/penetrating injuries with lacerations may have wider zones of injury and also injury to deeper structures than what may be obvious based

A.D. Sobel, MD
Department of Orthopedics, Brown Univeristy,
Providence, RI, USA
e-mail: andrew.d.sobel@gmail.com

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FIGURE 11.1 A soft tissue injury of the hand

on skin injury. Chemical burns require immediate removal of clothing and significant cleansing of skin with saline/ water. Frostbite injuries require rapid warming. Crush injuries often compromise microvasculature to the skin and result in delayed tissue necrosis. Animal or human bites require specific antibiotic coverage and based on the location possible surgical intervention.

2. What is the neurovascular exam? Lacerations may result in arterial injury which may require emergent intervention. Injury to peripheral nerves typically result in focal deficits. Crush or burn injuries may have more global deficits. A major complication of frostbite injury is vascular thrombosis.
3. What is the exact location of the injury? Dorsal hand lacerations have a very different acuity and spectrum of injuries compared to palmar lacerations. The skin injury caused by "fight bites" may appear more proximal than when the fingers were flexed during impact, obscuring potential joint involvement.
4. How long ago was the injury? Especially with injuries involving the blood supply to the hand, temporality is important when considering revascularization, thrombolysis, rewarming, etc.

What to Request

1. Consistent direct pressure placed onto site of active bleeding.
2. A blood pressure cuff which can be placed proximally as a tourniquet during wound exploration for hemostasis.
3. Rapid rewarming of patient (warm IV saline, forced-air warming unit, increased room temperature) and extremity (in water with temperatures around 40–42 °C) if frostbite has occurred or if there is consideration for a vascular repair.
4. Tetanus prophylaxis.
5. Removal of all clothes if chemical burn.
6. Patient should be immobilized until you arrive.
7. Analgesia for comfort.
8. Local anesthetic (e.g., lidocaine) for local or peripheral nerve block.
9. Hold antibiotics until a culture can be obtained (for infections).

When to Escalate

1. Dysvascular limb (from laceration or thrombosis)
2. Critically ill/septic patient (from infection)
3. Flexor tenosynovitis

Imaging

1. AP, oblique, lateral x-rays of the affected portion of the extremity
2. AP and lateral x-rays of any amputated structure

Effective Communication

1. Location of injury
2. Mechanism of injury
3. Vascular/bleeding status
4. Peripheral/digital nerve exam

What to Bring

1. Splint material
2. Suture/surgical instrument tray
3. Non-absorbable suture (tendon injury) and/or rapidly absorbing suture (skin closure)

Key Exam Pearls

1. Vascular – Modified Allen test, Doppler signals
2. Nerve – Median, radial, and ulnar distributions. Digital nerves if necessary
3. Tendon:
    1. A tenodesis exam can elicit complete tendon injuries.
    2. Hold other fingers straight when testing flexion as the flexor digitorum profundi typically have a shared muscle belly.
    3. Juncturae tendonae, extensor indicis proprius, and extensor digiti minimi may confound your exam when evaluating for extensor tendon laceration.
4. Infection – Kanavel's cardinal signs
    1. Fusiform swelling
    2. Percussion tenderness along the flexor sheath
    3. Flexed resting posture
    4. Pain with passive extension

Interventions and Procedures

Infection

Depending on the location and severity of the infection, drainage in the ED may be possible. Paronychia may be incised along the nail fold, felons may be incised, septa may be broken up through an ulnar (except for thumb and small finger, when radial is preferred) mid-axial incision, and dorsal hand and forearm abscesses may be incised, evacuated, and packed though a generous longitudinal incision to prevent early closure. Cultures must be obtained prior to giving antibiotics. Acute cat-bite tracts do not have to be incised acutely until failure of antibiotics or abscess formation. Volar infections or flexor tenosynovitis should be addressed in the operating room given the higher risk of damaging neurovascular structures. All patients should be immobilized.

Tendon Injury

Dorsal tendon lacerations can be repaired acutely if the ends can be found easily. Local anesthesia may be all that is necessary, but a radial sensory nerve block can help with procedural pain. Braided nonabsorbable suture can be passed in a Kessler or locking-loop fashion to approximate and hold the tendon edges. Knot bulk should be kept to a minimum, and there should be at least 4 sutures crossing the tendon gap. A volar blocking splint helps prevent repair failure. Flexor tendon injuries should be fixed in the operating room given the higher risk of damaging neurovascular structures. The elbow, wrist, and fingers should be splinted in slight flexion to help keep the proximal tendon edge relatively close to the distal end prior to surgery.

Nerve Injury

Nerve injuries must be fixed in the operating room under loupe or microscopic magnification. Skin injuries should be loosely closed and the patient should be splinted.

Artery Injury

Tamponade for 10–15 min with direct compression (not a pressure dressing) may alleviate bleeding and allow a clot to form. If direct compression is ineffective, a blood pressure cuff may be placed proximally on the arm and inflated above the patient's systolic blood pressure to prevent uncontrolled bleeding. A tourniquet should not be left on for a long period of time as lack of blood flow to the arm can cause distal necrosis. Intervention in the operating room is often necessary for continued bleeding or for injuries requiring revascularization or arterial repair.

Burn/Frostbite

Clothing should be removed to prevent further damage in heat and chemical burns. An injury penumbra in frostbite injuries may be reduced by rapid rewarming of the extremity in lukewarm water and the patient as mentioned above (see *What to Request*). Thrombolysis may be indicated for severe frostbite injuries depending on the vascular status of the extremity and your institution's local practice. These injuries put the extremity at a considerable risk for swelling so elevation above the level of the heart is necessary.

Follow-Up

1. Many procedures (other than the aforementioned) require advanced care in an operating room.
2. Specialists will be closely involved in the care of these injuries.
3. Admission to the hospital is typically necessary for infections, arterial injuries, and severe burns. Urgent surgical planning may be done as an outpatient for tendon and nerve injuries, but waiting longer than 2 weeks for an intervention is ill-advised.

Chapter 12
Adult Digital and Metacarpal Injuries

Andrew D. Sobel

Keywords Metacarpal fractures • Interphalangeal dislocations • Amputations • Nailbed injuries

Overview

Adult digital and metacarpal injuries including metacarpal fractures (Fig. 12.1), interphalangeal dislocations (Fig. 12.2), amputations, and nailbed injuries are common and require prompt evaluation. It is important to assess the neurovascular status, need for antibiosis, mechanism of injury, and presence and extent of nail plate injuries.

A.D. Sobel, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: andrew.d.sobel@gmail.com

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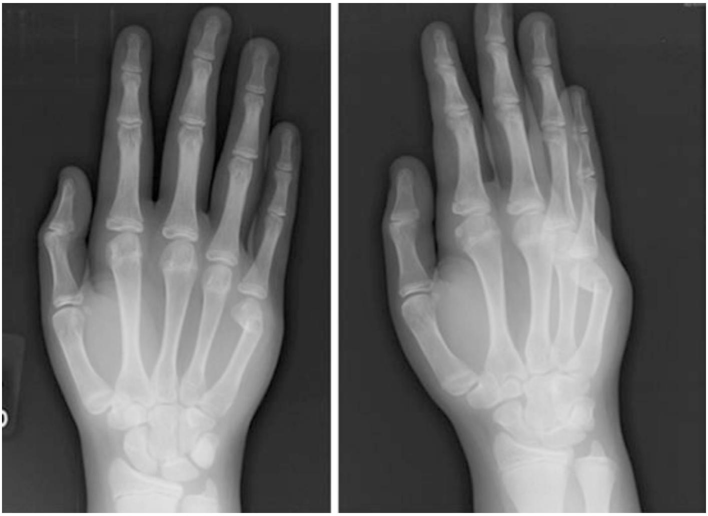

FIGURE 12.1 Radiographs of a fifth metacarpal fracture

FIGURE 12.2 A proximal interphalangeal joint dislocation

What to Ask

1. What is the neurovascular exam?
2. Has the patient been given any numbing agent, and where? Local/digital/peripheral block?
3. Is this an open injury? If so, immediate tetanus prophylaxis and antibiosis should be given.
4. What is the mechanism of injury?
    1. Crush and avulsion injuries portend worse outcomes if salvage is performed.
    2. High-pressure injection injuries have a wide zone of injury and necrosis.
    3. Metacarpal neck fractures caused by self-inflicted trauma (i.e., punching) may indicate poor compliance.
    4. "Ring avulsion" injuries may have proximal neurovascular traction injury.
5. Is there a subungual hematoma? Treatment for distal phalanx fractures and subungual lacerations varies based on the presence and extent of nail plate injuries with concomitant hematoma.
6. Does the patient smoke? Patent vascularity is important for tissue survival and treatment decision-making.
7. Has anyone attempted reduction of the interphalangeal dislocation? Repeated reductions may increase swelling or cause entrapment of tissue in the joint preventing closed reduction. Failure of appropriate closed reduction may also indicate tissue incarceration necessitating open treatment.

What to Request

1. Patient should be immobilized until you arrive.
2. Open soft tissue injuries should be dressed in wet gauze.
3. Analgesia for comfort.
4. Local anesthetic (e.g., lidocaine) for local or peripheral nerve block that you will perform.

5. Ensure that no one has locally or digitally blocked the digit prior to your arrival.
6. If an amputation has occurred, ask that the amputated tissue be wrapped in moist gauze and placed on ice.

When to Escalate

1. If an amputation has occurred by a sharp, clean laceration, replantation may be appropriate.
2. Severe soft tissue injury – ring avulsions, crush injuries, and high-pressure injection injuries.

Imaging

1. AP, oblique, lateral X-rays of the digit, hand, and wrist
2. X-ray of the amputated tissue
3. CT scan if concerned for carpometacarpal fracture/dislocation (often poorly visualized on X-rays)

Effective Communication

1. Mechanism
2. Soft tissue injury/loss
3. Fractures
4. Subungual hematoma
5. Previous reduction attempts
6. Nail plate injury

What to Bring

1. Splint material for individual finger or hand/wrist (aluminum foam splint, prefabricated splint, or plaster)
2. Antibiotic ointment, nonadhesive dressing to cover soft tissue injuries

3. Sterile tray with hand surgery instruments if revision amputation or tendon repair possibly required
4. Finger tourniquet or Penrose drain to provide hemostasis
5. Fluoroscopy for interphalangeal dislocations

Key Exam Pearls

1. Sensation (individual digital nerves).
2. Motor (FPL/EPL as well as EDC/FDP/FDS/IO for each digit).
3. Thorough inspection of lacerations/wounds to assess for small dermal violations.
4. Vascular exam – Allen's Test may assess radial/ulnar flow; a Doppler probe can assess patency of digital arteries.

Reduction/Procedures

Metacarpal Fractures

After assessing the soft tissues for significant injury or violations of the dermis, patients may be locally or peripherally blocked (ulnar nerve block at the wrist is extremely effective for fifth metacarpal fractures). The Jahss maneuver or a three-point mold may be employed for reduction of metacarpal neck fractures, if indicated. Splinting of the affected and bordering digits in the intrinsic plus position should be performed.

Interphalangeal Dislocations

Proper technique is crucial to successful closed reduction. Excessive traction or exaggeration of the deformity must *never* be used as this may incarcerate the volar plate or other tissues within the joint. Reduction may be performed after digital block and under fluoroscopic guidance to ensure concentric reduction through full joint arc of motion.

The technique involves slight exaggeration of the deformity and a gentle force in the direction you wish the distal segment to travel (e.g., slight hyperextension and palmar directed force for dorsal dislocations). Most simple dislocations are stable through range of motion after reduction. Splinting of the affected digit is appropriate until early follow-up. Typically dorsal dislocations are splinted in slight flexion, and volar dislocations in relative extension.

Amputations

Salvage or replantation of the affected digit may be considered if it is a thumb, one of multiple digits, the amputation has occurred at the palm level, or the patient is a child. Contraindications include severe vascular issues/extensive smoking history, crush or avulsion mechanism, or a time from injury >6 hours. Replantation requires extensive counseling by the provider performing the surgery, so hasty involvement of a hand specialist is necessary. If replantation is not possible or indicated, flap coverage may be indicated. This is typically performed in an operating room.

If the injury involves minimal soft tissue loss and there is no bone or tissue loss, the lacerations may be cleaned thoroughly and dressed with the goal to have the injury close by secondary intention. Revision amputation may be performed if the injury is not amenable to the above treatments. This is performed by removing small amounts of bone to allow for soft tissue coverage. Enough bone must remain to support nail growth, so if this is a concern, the nail must be removed and the germinal matrix must be completely ablated (difficult to do outside of the OR). To prevent hypersensitivity and/or neuroma formation, traction neurectomies must be performed on the remaining digit with care taken not to injure the digital arteries. Ring avulsion injuries should be addressed in the OR.

Nail Bed Injuries

Subungual lacerations can be managed with trephination, regardless of the size of hematoma or presence of fracture if the nail plate is intact. If the nail plate is damaged or avulsed, nail plate removal and repair of any laceration to the nail bed with small (i.e., 6-0) fast dissolving suture (i.e., chromic) or dermal adhesive is appropriate. The nail fold does not need to be splinted open to allow for regrowth of the nail. Antibiotic ointment, nonadhesive gauze, and a bulky dressing may be used to cover the repair site.

Follow-Up

1. All injured extremities should be elevated and iced to control swelling.
2. Patients with metacarpal fractures and interphalangeal dislocations may follow up routinely in the office.
3. Patients with revision amputations and nail bed injuries should follow up in a few days for dressing removal and further instruction on care to the finger.
4. Patients whose amputations have been replanted must be admitted for tissue monitoring and advanced care.

Chapter 13
Pediatric Digital and Metacarpal Injuries

Joseph A. Gil

Keywords Pediatric hand • Physeal • Fight bite

Overview

Pediatric digital and metacarpal injuries require timely assessment of open versus closed status, neurovascular compromise, intra-articular versus extra-articular involvement, postreduction stability, associated injuries, displacement, physeal involvement, and nail bed involvement. "Fight bite" injuries and open fractures require escalation of management.

What to Ask

1. Are there any open wounds (possible open fracture)?
2. Are there any associated injuries?
3. What is the patient's neurovascular status?
4. Can the patient's jewelry be removed, and is the IV access on contralateral arm?

J.A. Gil, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: josephgil773@gmail.com

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What to Request

1. X-rays of the hand and finger involved.
2. If the fracture is displaced and requires reduction or a subungual hematoma is found that requires evacuation, request conscious sedation.

When to Escalate

1. Open fractures: Should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR).
2. "Fight bite" injuries require broad-spectrum antibiotics and formal irrigation and debridement in OR.

Imaging

1. AP, oblique, and lateral views of the hand are necessary for evaluation.
2. Obtained dedicated finger films if a specific finger is injured.
3. Postreduction X-rays of the hand or finger (AP and lateral) after reduction.

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Intra-articular versus extra-articular
4. Stability after reduction
5. Associated injuries
6. Displaced/non-displaced

7. Physeal involvement
8. Nail bed involvement

What to Bring

1. Casting/splinting material (see Chapter 6)
2. Fluoroscopy if reduction required

Key Exam Pearls

1. Sensation of hand (median/radial/ulnar nerves) or specific fingers involved (ulnar and radial border).
2. If the patient cannot comply with sensory exam: sweat in a nerve distribution indicates intact sensation.
3. Motor (EDC and FDS/FDP or EPL and FPL).
4. Evaluate all wounds: dermal violation raises suspicion for open fracture.
5. Subungual hematoma >50% requires evacuation.

Reduction [1]

Reduction is often performed under conscious sedation in pediatric patients. The objective is to restore joint congruity and osseous alignment. Each reduction and splint will vary depending on the specific bone involved. For example, adequately reduced finger metacarpal fractures should be immobilized in an intrinsic plus splint, whereas an adequately reduced thumb metacarpal fracture should be immobilized in a thumb spica splint. In general pediatric patients should be overimmobilized, as they are less compliant and have decreased risks of stiffness after immobilization.

Adequate Reduction Parameters [1]

1. For metacarpal neck fractures Fig. 13.1 of the second and third fingers, 15° of deformity is acceptable; for the fourth and fifth fingers, 40°of deformity is acceptable. Rotation should be corrected to anatomic.
2. For metacarpal shaft fractures, 10° is acceptable for second and third fingers, while 20° is acceptable for fourth and fifth fingers. Rotation should be corrected to anatomic. If the fracture is open or if there is a rotational deformity, operative interventions is indicated.

Figure 13.1 A small-finger metacarpal fracture in a skeletally immature patient

Follow-Up

1. Remain non-weight bearing and continue to ice and elevate.
2. See an orthopedic surgeon within 1 week.

Reference

1. Egol KA, Joval KJ, Zuckerman JD. Handbook of fractures. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2010.

Chapter 14
Adult Carpal Injuries

Andrew D. Sobel

Keywords Wrist • Perilunate • Scaphoid • Triquetrum • Hamate

Overview

Wrist injuries require thorough evaluation of the mechanism of injury, associated injuries, and neurovascular status. It is important to note the presence or absence of a triquetral avulsion, hook of hamate fracture, scaphoid fracture, perilunate injury, or any DISI/VISI deformity. The capitolunate angle, scapholunate angle and Gilula's lines should be evaluated.

A.D. Sobel, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: andrew.d.sobel@gmail.com

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What to Ask

1. What is the neurovascular exam? Acute carpal tunnel syndrome should be ruled in or out immediately.
2. Are there any other injuries? Large distracting injuries may obscure other findings.
3. What is the mechanism of injury? Low- versus high-energy falls, assault, and crush injuries portend different needs.

What to Request

1. Patient should be immobilized until you arrive.
2. Jewelry be removed, IV access on contralateral arm.
3. Analgesia and/or anxiolytic for comfort.
4. Local anesthetic (e.g., lidocaine) for local or peripheral nerve block.

When to Escalate

1. Open injuries
2. Irreducible fractures/dislocations
3. Acute carpal tunnel syndrome

Imaging

1. AP, oblique, lateral X-rays of the wrist and hand, AP and lateral of the forearm
2. Carpal tunnel view X-ray if concerned about hook of hamate fracture
3. Postreduction X-rays and CT scan if reduction is necessary

Effective Communication

1. Presence or absence of a triquetral avulsion ("bony sprain")
2. Hook of hamate fracture
3. Scaphoid fractures (proximal pole, waist, or distal pole)
4. Greater, lesser, or interior arc perilunate injuries
5. Gilula's lines
6. Scapholunate angle
7. DISI/VISI deformity
8. Capitolunate angle

What to Bring

1. Splint material. Plaster will be necessary if molding or reduction is performed.
2. Finger traps (if a reduction is necessary).

Key Exam Pearls

1. Sensation (median/radial/ulnar nerves, individual digital nerves).
2. Motor by nerve distribution (AIN, PIN, ulnar) and individual digits (FPL/EPL/FDP/FDS/IO).
3. Compartment checks – determine fullness of all ten hand compartments, significant pain on passive stretch of fingers/wrist out of proportion, and capillary refill.
4. Vascular exam – use a Doppler probe if you cannot palpate pulses. An Allen's test is helpful if there is concern about perfusion of the hand.

Reduction

Scaphoid, Triquetrum, and Hamate Injuries (See Fig. 14.1)

No reduction maneuvers are necessary. Scaphoid fractures may be immobilized in short-arm, thumb spica splints. Triquetral avulsion fractures may be splinted temporarily for comfort. Hook of hamate fractures may be acutely casted if the injury was caused by a low-energy mechanism. Hamate body fractures may temporarily be splinted.

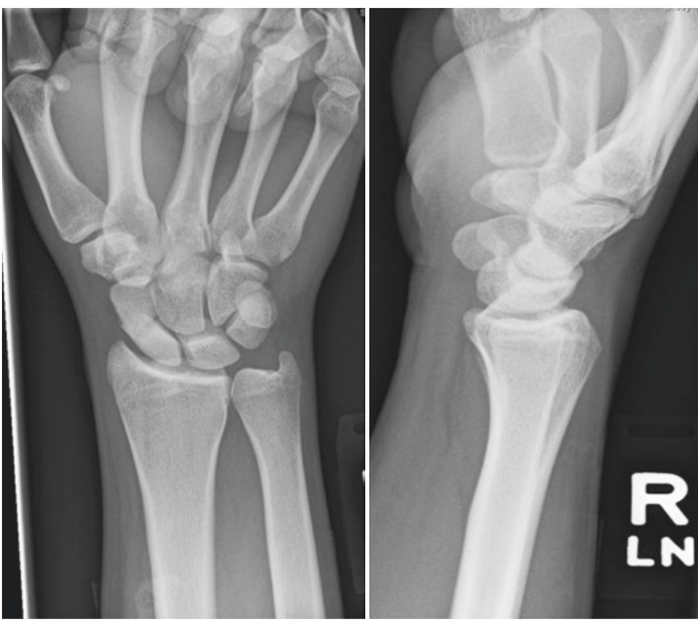

Figure 14.1 Carpal injuries. Note the radiopaque line through the scaphoid (AP and lateral images)

Perilunate Injuries (See Fig. 14.2)

Following the Mayfield classification, there is a spectrum of injuries to the carpus about the lunate. Subtle injuries with widening of the scapholunate interval do not require reduction, though higher-energy injuries in which the lunate dislocates volarly require appropriate and rapid setup and reduction to reduce the risk of acute carpal tunnel syndrome. Patients should be given an anxiolytic (e.g., 10 mg diazepam, if the patient can tolerate this dose) through an IV after a local block (e.g., 10 mL of 1% lidocaine) and hung in finger traps with roughly 10 pounds of weight placed around the distal arm with the elbow flexed at 90°. After at least 10 minutes of fatiguing of the extremity's musculature, reduction of the carpus is performed with wrist extension (exaggeration of the deformity), significant traction, and then flexion of the carpus (with force centered on the dorsal aspect of the capitate) over the dorsal lip of the lunate. A splint should be applied with the wrist in very slight flexion (excessive flexion of 20° or more will increase pressures within the carpal tunnel) and a mold of the dorsal carpus.

Follow-Up

1. Patients with perilunate injuries caused by high-energy mechanisms and/or Mayfield I–IV injuries should be admitted, and serial compartment/neurovascular checks should be performed. Operative intervention will be necessary.
2. Patients with scaphoid and hamate body fractures should follow up within 1 week of injury. Displaced fractures will require surgery.
3. Triquetral avulsion fractures are equivalent to wrist sprains, and patients will be mobilized early after routine office follow-up.

FIGURE 14.2 An acute lunate dislocation.
Note: THE DISRUPTION OF GILULA'S LINES

Chapter 15
Adult Distal Radius Fractures

Seth O'Donnell and Jonathan D. Hodax

Keywords Distal radius fracture • Acute carpal tunnel syndrome

Overview

A common injury, distal radius fractures (Fig. 15.1) require timely sensory and motor evaluation along with associated wounds for possible open fracture. Median nerve paresthesia or pain out of proportion suggests acute carpal tunnel syndrome.

What to Ask

1. Are open wounds present (possible open fracture, often from ulnar styloid)?
2. Are there any associated injuries?
3. Does the patient have paresthesia (concern for acute carpal tunnel syndrome)?

S. O'Donnell, MD (✉) • J.D. Hodax, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: odonnell.seth@gmail.com

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Figure 15.1 AP and lateral radiographs of a distal radius fracture in a skeletally mature patient

What to Request

1. Ensure arm is stabilized, elevated, and iced immediately.
2. X-rays of the wrist, forearm, and elbow.
3. Jewelry be removed, IV access on contralateral arm.
4. 2.5–10 mg of IV valium and local hematoma block lidocaine as adjuncts to reduction.

When to Escalate

1. Open fractures: Should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR)
2. Paresthesia: Acute carpal tunnel syndrome may require emergent fixation and release if it persists after reduction

Imaging

1. AP, oblique, and lateral views of the wrist are necessary for evaluation.
2. Advanced imaging (CT) is generally not required acutely, though it may be useful for operative planning in some complex fracture patterns.
3. Postreduction X-rays of the wrist (AP and lateral) after reduction.

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Intra-articular versus extra-articular
4. Stability after reduction
5. Associated injuries
6. Displaced/non-displaced

What to Bring

1. Casting/splinting material (short-arm cast/sugar-tong splint, Chapter 6).
2. Lidocaine for hematoma block (see hematoma block, Chapter 8).
3. Fluoroscopy if reduction required

Key Exam Pearls

1. Sensation (median/radial/ulnar nerves).
2. Motor (EPL/FDS/FDP to index/FDP to small/EDC/IO).
3. Evaluate all wounds: Dermal violation raises suspicion for open fracture.
4. Median nerve paresthesia or pain out of proportion suggests acute CTS.

Reduction

When ready to perform a reduction a hematoma block should be placed at the fracture site and valium administered. An assistant is recommended if available.

For a dorsally angulated fracture (also referred to as "apex volar" or a Colles' fracture, the most common pattern), begin with traction to fatigue the patient's spasm. Exaggerate deformity to hyperextension to release any impaction, and realign with slight pronation. The second member of the team provides countertraction during reduction and maintains the hand in ulnar deviation during casting. Ulnar deviation is key to maintaining alignment and preventing collapse by placing the fracture fragments on stretch through their ligamentous attachments.

Finger traps/weight can be helpful when no assistant is available. The thumb and index finger are set in the traps to ulnarly deviate, with weight over the biceps. Fluoroscopy is recommended to confirm reduction and appropriate mold.

The mold is typically completed with three points. The distal point should be a broad and smooth over the distal fracture fragment (beware, it is often placed too distally). The middle point is placed volar, proximal to the carpal tunnel, and the most proximal mold is placed over the volar forearm to complete a gentle "C" shape. The MCP joints must be left free to allow motion and limit stiffness. Aggressive flexion of the hand and wrist should be avoided. Care should be taken to avoid skin tears in elderly patients, and gloves should be avoided during reductions if safe.

Adequate Reduction Parameters

1. Palmar tilt (~11° is normal on average) corrected to neutral.
2. Radial height should be within 2 mm of the contralateral wrist.
3. No intra-articular step-offs.
4. Radial inclination should be restored to match the contralateral.

Follow-Up

1. Remain non-weight bearing, and continue to ice and elevate, but actively move fingers to prevent stiffness.
2. See an orthopedic surgeon within one week.
3. Patients should move fingers to avoid stiffness.

Chapter 16
Pediatric Wrist and Scaphoid Fractures

Joseph A. Gil

Keywords Pediatric wrist • Scaphoid • Fractures

Overview

Thorough evaluation of pediatric wrist and scaphoid fractures includes open versus closed status, neurovascular status, associated injuries, displacement, and physeal involvement.

What to Ask

1. Are there any open wounds (possible open fracture, often from ulnar styloid)?
2. Are there any associated injuries? Fractures and dislocations about the ipsilateral elbow are common, and make reduction and immobilization more challenging.
3. What is the patient's neurovascular status?
4. Can the patient's jewelry be removed, and is their IV access on contralateral arm?

J.A. Gil, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: josephgil773@gmail.com

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What to Request

1. Ensure arm is stabilized, elevated, and iced immediately.
2. X-rays of the wrist, forearm, and elbow. Scaphoid views are appropriate if suspicious for injury.
3. If the fracture is displaced and requires reduction, ask for conscious sedation.

When to Escalate

1. Open fractures should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR).
2. Paresthesia: Acute CTS may require emergent fixation and release if it persists after reduction.

Imaging

1. AP, oblique, and lateral views of the wrist are necessary for evaluation.
2. Radiographs of the contralateral wrist may be helpful.
3. Postreduction X-rays of the wrist (AP and lateral).

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Associated injuries
4. Displaced/non-displaced
5. Physeal involvement

What to Bring

1. Casting/splinting material (for distal radius fractures see long-arm cast, Chapter 6; for scaphoid fractures include a thumb spica extension, Chapter 6; for an isolated scaphoid fracture simply use a thumb spica splint)
2. Fluoroscopy if reduction required

Key Exam Pearls

1. Sensation of hand (median/radial/ulnar nerves).
2. Motor (EPL/FPL/EDC/FDS/FDP/IO).
3. Evaluate all wounds: Dermal violation raises suspicion for open fracture.
4. Snuffbox tenderness should be treated as an occult scaphoid fracture. See thumb spica splint, Chapter 6.

Reduction [1]

Minimally displaced "buckle" or "torus" fractures (see Fig. 16.1) often are within acceptable limits to leave unreduced and only require casting to help protect the healing bone. For reduction of distal radius physeal fractures (see Fig. 16.2), apply constant gentle longitudinal traction to the forearm with the aid of an assistant or finger traction. This often leads to spontaneous reduction of the fracture. If the fracture does not reduce, apply gentle force over the fracture site while maintaining traction. Once reduced, a long-arm cast with a three-point mold is applied. The distal point should be broad and smooth over the distal fracture fragment. The MCP joints must be left free. Aggressive flexion of the hand and wrist should be avoided.

Figure 16.1 An oblique radiograph of a "buckle" fracture of the distal radius in a skeletally immature patient

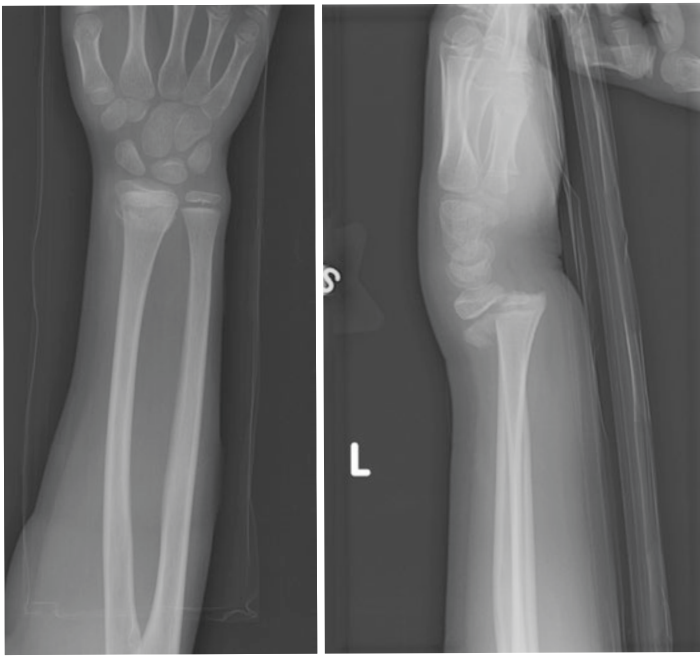

FIGURE 16.2 AP and lateral radiographs of a Salter-Harris II physeal fracture in a skeletally immature patient

Adequate Reduction Parameters [1]

1. In children less than 10 years old, less than 15° of angulation in the sagittal plane is acceptable; if the child is older than 10, less than 10° is acceptable if the physes of the radius are still open.

Follow-Up

1. Remain non-weight bearing and continue to ice and elevate.
2. See an orthopedic surgeon within 1 week.

Reference

1. Egol KA, Joval KJ, Zuckerman JD. Handbook of fractures. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2010.

Chapter 17
Adult Forearm Fractures

Andrew D. Sobel

Keywords Forearm • Monteggia • Ulnar shaft • Radial shaft

Overview

In adult forearm fractures (Fig. 17.1), it is critical to assess fracture comminution, open versus closed status, associated injuries, neurovascular compromise, and possible bone loss.

What to Ask

1. Is the fracture open? Subtle abrasions or very small lacerations may indicate open fractures.
2. What is the neurovascular exam? Ensure there are good pulses or signals by Doppler probe.
3. What is the exam of the forearm compartments? Late presentation or high-energy injuries are at greater risk for development of compartment syndrome.

A.D. Sobel, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: andrew.d.sobel@gmail.com

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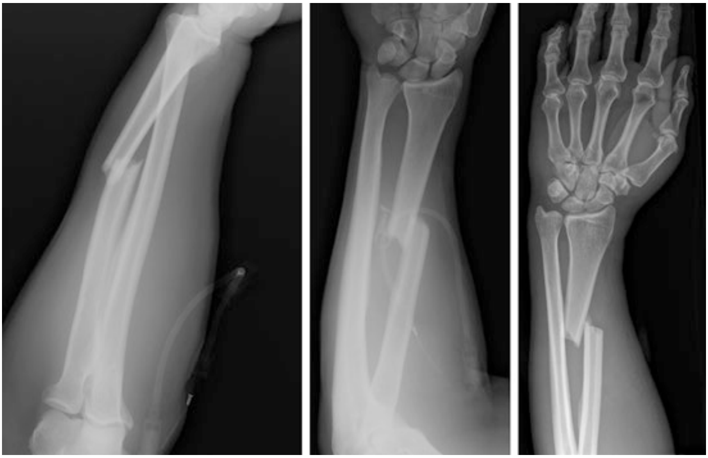

Figure 17.1 Radiographs of an isolated radial shaft fracture in a skeletally mature patient. In this fracture pattern, often called a “Galeazzi fracture,” the distal radioulnar joint is often disrupted

4. What was the mechanism of the fracture? High energy injuries may have associated injuries or develop compartment syndrome. Low-energy ulnar shaft fractures may be a result of injuries sustained during an altercation requiring appropriate privacy and protection of the patient within the emergency department.

What to Request

1. Patient should be immobilized until you arrive.
2. Analgesia with or without anxiolytic/antispasmodic for comfort.

When to Escalate

1. Open injuries
2. Concern for compartment syndrome
3. Associated dislocations of radiocapitellar joint

Imaging

1. AP and lateral X-rays of the forearm.
2. Imaging the joint "above and below" the fracture. Elbow imaging is especially important in isolated ulnar fractures to evaluate for dislocation of the radiocapitellar joint (Monteggia fracture pattern) and wrist imaging will evaluate dislocations of the distal radioulnar joint (Galeazzi fracture pattern).

Effective Communication

1. Fracture comminution
2. Open/closed
3. Associated injuries
4. NPO status (for operative planning)
5. Neurovascular status
6. Bone loss (especially if open)

What to Bring

1. Splint material – to immobilize for comfort

Key Exam Pearls

1. Sensation (median/radial/ulnar nerves).
2. Motor (EPL/FPL/EDC/FDS/FDP/IO).
3. Compartment checks – determine fullness, significant pain on passive stretch of fingers/wrist out of proportion, and capillary refill.

4. Vascular exam – use a Doppler probe if you cannot palpate pulses. An Allen's test is helpful if there is concern about perfusion of the hand.

Reduction

Although reductions of adult radius and ulnar fractures are possible, it is important to realize that these are provisional only. Radius-ulna fractures are considered an articular-equivalent because of the complex nature of pronation and supination in the forearm, and unstable injuries that require surgery for anatomic reduction to prevent loss of motion and deformity in the future. Provisional reduction can be achieved with the patient's elbow flexed to 90 degrees and traction applied while a well-padded sugar-tong splint is applied. Molding can aid in improving alignment and patient comfort temporarily. Monteggia fractures should not have aggressive reductions attempted given that the radial head will not reduce until ulnar length is restored in the operating room.

Follow-Up

1. Both bone forearm and Monteggia fractures in adults should be referred for surgery acutely.
2. Isolated ulnar shaft fractures may be seen within a week and transitioned to either a cast or fracture brace if they meet non-operative criteria (anatomic alignment and stable wrist and elbow joints).
3. Radial shaft fractures will require operative intervention if displaced, especially if the radial bow is compromised.

Chapter 18
Pediatric Forearm Fractures

Joseph A. Gil

Keywords Pediatric forearm • Compartment syndrome

Overview

Comprehensive pediatric forearm fracture (Fig. 18.1) evaluation includes determination of open versus closed status, neurovascular status, postreduction stability, associated injuries, and possible compartment syndrome.

What to Ask

1. What is the neurovascular status?
2. Are there any open wounds (possible open fracture)?
3. Does the patient have pain out of proportion (should raise concern for compartment syndrome)?
4. Does the patient have IV access on the contralateral arm?
5. If a reduction is required, has the patient been NPO for an adequate time?

J.A. Gil, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: josephgil773@gmail.com

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FIGURE 18.1 Radiographs of a closed radius and ulna shaft fracture in skeletally immature patient

What to Request

1. Radiographs of the wrist, forearm, and elbow must be obtained prior to reduction.
2. Conscious sedation should be performed by the emergency room to facilitate closed reduction and casting.

When to Escalate

1. Open fractures should be irrigated and receive antibiotics (formal irrigation and debridement in OR).
2. Concern for compartment syndrome.

Imaging

1. Radiographs of the wrist (AP, lateral, and oblique), forearm (AP, lateral), and elbow (AP, lateral, and oblique)
2. Postreduction X-rays of the forearm (AP and lateral) after reduction

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Stability after reduction
4. Associated injuries
5. Concern for compartment syndrome

What to Bring

1. Casting/splinting material (see long-arm cast, Chapter 6)
2. Fluoroscopy in the sedation room

Key Exam Pearls

1. Sensation of the hand (median/radial/ulnar nerves) or sweat in all distributions.
2. Motor (EPL/FPL/EDC/FDS/FDP/IO).
3. Evaluate all wounds: dermal violation raises suspicion for open fracture.

Reduction [1]

An assistant is preferred if available; if no assistant is available, finger traps and weight may be used. Generally, this involves the assistant suspending the arm while you perform traction and reduction maneuvers, and the assistant maintaining reduction while you cast.

Prior to beginning the closed reduction, make sure that the patient is positioned at the end of the stretcher so that the arm can readily be positioned over the fluoroscopic imager. Longitudinal traction should be applied to the forearm. The fracture pattern should be gently accentuated (e.g., dorsally angulated fracture should be further extended) and then corrected under traction. Be careful not to be too forceful to prevent causing an open fracture by piercing the skin with a fracture spike.

Theoretically, proximal third fractures should be more stable with the forearm in supination, middle third fractures should be more stable in neutral, and distal third should be more stable in pronation. This may, however, vary from case to case and should be confirmed with the fluoroscan.

Generally, we find that it is adequate to immobilize the forearm in the neutral position. Once the forearm is casted, a three-point mold should be applied to maintain alignment. In highly unstable fractures an interosseous mold may be used instead.

Adequate Reduction Parameters [1]

1. In children less than 10 years old, less than 15° of angulation in the sagittal plane is acceptable; if the child is older than 10, less than 10° is acceptable if the physes of the radius are still open. Rotational deformities are generally not acceptable. Young children can often be treated by closed reduction and casting if these parameters are met. Because teenagers have less remaining growth potential, they frequently require surgical fixation with anatomic reduction.

Follow-Up

1. Remain non-weight bearing and continue to ice and elevate.
2. See an orthopedic surgeon within 1 week.
3. Patients should move fingers to avoid stiffness.

Reference

1. Egol KA, Joval KJ, Zuckerman JD. Handbook of fractures. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2010.

Chapter 19
Elbow Dislocations

Andrew D. Sobel

Keywords Elbow dislocation • Simple • Complex

Overview

Elbow dislocations require assessment of direction of ulnar dislocation, neurovascular status, stability after reduction, and presence of fractures.

What to Ask

1. Can the patient safely be consciously sedated? Good sedation may be necessary to prevent damage to the joint during reduction.
2. What is the neurovascular exam? Ulnar nerve injuries are common with posterolateral dislocations. Median nerve injuries occur frequently as well.

A.D. Sobel, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: andrew.d.sobel@gmail.com

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What to Request

1. Patient should be sitting upright and be immobilized until your arrival.
2. Analgesia with or without anxiolytic/antispasmodic for comfort.
3. Conscious sedation and a provider authorized to deliver this care.

When to Escalate

1. Fracture/dislocations – a reduction attempt outside of the OR may still be helpful given potential delays to operating room or if the patient is not neurovascularly intact.
2. Irreducible dislocations.
3. Neurovascular injury.

Imaging

1. AP, oblique, and lateral views of the elbow are important (Fig. 19.1).
2. Imaging the bone/joint "above and below" the dislocation is important to look for other dislocations or fractures.
3. Postreduction CT scan of the elbow is only indicated if there is concern for fracture, if there are loose bodies within the joint preventing concentric reduction, or if the reduction is not anatomic.

Effective Communication

1. Direction of dislocation (based on direction of the ulna compared to the humerus)
2. Neurovascular status
3. Stability after reduction
4. Simple (no fracture) versus complex (fracture)

What to Bring

1. Fluoroscopy is extremely important (see Reduction, below).
2. Intra-articular injection – especially if isolated radial head dislocation.
3. Assistant for countertraction.
4. Splint material – to immobilize postreduction.

Key Exam Pearls

1. Sensation (median/radial/*ulnar* nerves).
2. Motor (EPL/FPL/EDC/FDS/FDP [especially to the small finger]/IO [especially the 1st dorsal interosseous muscle]).
3. Palpate bony landmarks – find the olecranon first.

Reduction

The most common elbow dislocation is a simple, posterolateral dislocation. Most simple posterior dislocations can safely be reduced in the emergency department, and conscious sedation is often employed for safety. The patient is kept sitting upright in a stretcher and an assistant stands parallel to the patient holding counter traction on the upper arm. One hand is placed on the forearm to pull traction and control pronation/supination, while the other is placed on the tip of the olecranon to guide it in the appropriate direction. In-line traction is pulled to correct any coronal plane deformity, while slight supination (or pronation in medial dislocations) to prevent the coronoid from contacting the posterior humerus is attempted. Once the coronoid passes the humerus, gentle elbow flexion is performed with pressure on the olecranon. An audible clunk is usually appreciated with reduction. Slow, controlled motions are preferred, as in most reductions. Quick, forceful pulling can result in fractures or shearing of cartilage surfaces.

After reduction, the elbow should be examined under fluoroscopy. A dynamic lateral X-ray through the entire range of motion in flexion-extension and pronation-supination should be performed. Points at which the ulnohumeral joint becomes unstable should be noted, and the patient should be splinted in a position maximal stability. If there is no concentric reduction at any point, consider an intra-articular chondral or osteochondral fragment as the culprit. Instability in extension is often due to lateral ulnar collateral or medial collateral ligamentous injury, whereas one should be concerned about coronoid fractures if instability in flexion is noted. Fractures may be present that prevent maintenance of reduction. "Terrible triad" injuries involving fractures of the olecranon and coronoid in the setting of dislocation (and often LUCL tears) will often require surgery for concentric elbow reduction. Immobilization in a pluster sugar tong splint with a long-arm posterior splint is appropriate.

Follow-Up

1. Elbow fractures are often very unstable and at risk for re-dislocating even in compliant patients while the splint is in place. Close follow-up is essential.
2. Have the patient remain non-weight bearing in a well-padded splint until follow-up within 1 week. Early range of motion is important as stiffness (especially blocking terminal extension) is the most common complication.
3. Fracture-dislocations and "terrible triad" injuries should follow up sooner for operative planning.
4. An MRI may only be obtained in the office subacutely to assess chondral injury if there is continued pain or ligamentous injury if there is continued instability.

FIGURE 19.1 Radiographs of acutely dislocated elbows. Note the variety of associated fracture patterns, each of which confers variable resistance to reduction and offers differing degrees of stability after reduction

Figure 19.1 (continued)

Chapter 20
Pediatric Elbow Fractures

Joseph A. Gil

Keywords Pediatric elbow • Compartment syndrome

Overview

The complete evaluation for pediatric elbow fractures includes determination of open versus closed, neurovascular status, intra-articular versus extra-articular, associated injuries, and stability after reduction.

What to Ask

1. Are there any open wounds (possible open fracture)?
2. Are there any associated injuries?
3. Can the patient's jewelry be removed and IV access be placed on contralateral arm?
4. Does the patient have pain out of proportion (should raise concern for possible compartment syndrome)?
5. What is the patient's neurovascular status?

J.A. Gil, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: josephgil773@gmail.com

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What to Request

1. Ensure the arm is stabilized, elevated, and iced immediately.
2. X-rays of the forearm, elbow, and humerus.
3. If the fracture is displaced and requires reduction, ask for conscious sedation.

When to Escalate

1. Open fractures should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR).
2. Concern for compartment syndrome.
3. When the affected extremity does not have a pulse.

Imaging

1. AP, oblique, and lateral view of the elbow and AP and lateral view of the forearm and humerus are necessary for evaluation.
2. Radiographs of the contralateral elbow, particularly for medial and lateral condyle fractures, may help.
3. Postreduction X-rays of the elbow (AP, oblique, and lateral).
4. Always look within the joint space for possible incarcerated fragments.
5. The pediatric elbow is complex, and injuries are often subtle. When in doubt you should always be ready to review images with a senior orthopedist and/or radiologist.

Effective Communication

1. Open versus closed
2. Neurovascular compromise

3. Intra-articular versus extra-articular
4. Stability after reduction
5. Associated injuries
6. Displaced/non-displaced
7. Physeal involvement

What to Bring

1. Casting/splinting material (for stable supracondylar fractures, adequately reduced lateral condyle, medial condyle, and radial neck fractures, nondisplaced olecranon fractures, see long-arm cast, Chapter 6. For unstable supracondylar fractures; inadequately reduced lateral condyle, medial condyle, and radial neck fractures; or displaced olecranon fractures, see long-arm splint, Chapter 6)
2. Fluoroscopy if reduction required

Key Exam Pearls

1. Sensation of the hand (median/radial/ulnar nerves).
2. Motor (EPL/FPL/EDC/FDS/FDP/IO).
3. Pulse and color of the hand (particularly for supracondylar fractures).
4. Evaluate all wounds: Dermal violation raises suspicion for open fracture.

Reduction [1]

1. *Supracondylar fractures* (see Fig. 20.1) are grouped as flexion or extension. The extension group is more common. There are three types of extension supracondylar fractures. Type 1 is non-displaced and only requires a long-arm cast. Type 2 is displaced or angulated at the anterior cortex, but the posterior cortex remains intact. Type 3 is complete displacement. There is controversy regarding the appropriate

Figure 20.1 Examples of supracondylar humerus fractures with varying degrees of displacement

management of Type 2 and 3 fractures. Therefore, escalate to your superior regarding emergency room reduction policies for these fractures. At the very least, the affected extremity will be immobilized in a long-arm splint.

2. *Lateral condyle fractures*: If the fracture is non-displaced, place in long-arm cast. If the fracture is displaced, attempt closed reduction by applying a varus force to the elbow with the forearm in supination and the arm in extension. If the fracture reduces, place the arm in a long-arm cast.
3. *Medial condyle fractures*: If the fracture is non-displaced, place in long-arm cast. If the fracture is displaced, attempt closed reduction by applying a direct force at the medial elbow with the forearm in pronation and the arm in exten-

sion. If the fracture reduces, place the arm in a long-arm cast.

4. *Radial head or neck fractures*: If the fracture is nondisplaced or angulated less than 30°, the arm is immobilized with sling, long-arm splint, or long-arm cast (depending on the compliance of the patient) followed by early range of motion. If the fracture is angulated more than 30°, once of several described methods can be utilized. The Israeli method involves placing the elbow in flexion and with direct force over the radial head; the forearm is rotated into a pronated position. If the reduction is successful, the arm is immobilized in a long-arm cast in 90° of flexion.

Adequate Reduction Parameters [1]

1. Supracondylar fractures: In an extension-type supracondylar fracture, the capitellum lies posterior to the anterior humeral line. Baumann's angle should be 70–75° or within 5° of the contralateral elbow.
2. Lateral condyle fractures: less than 2 mm of displacement.
3. Medial condyle fractures: less than 5 mm of displacement (controversial).
4. Radial head or neck fractures: less than 30° of angulation.

Follow-Up

1. Remain non-weight bearing and continue to ice and elevate.
2. See an orthopedic surgeon within 1 week.
3. Patients should move fingers to avoid stiffness.

Reference

1. Egol KA, Joval KJ, Zuckerman JD. Handbook of fractures. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2010.

Chapter 21
Humerus Fractures

Andrew D. Sobel

Keywords Humerus fractures • Proximal • Shaft • Distal

Overview

Humerus fracture (see Fig. 21.1) evaluation requires determination of open versus closed, neurovascular status, varus/valgus, head split, displacement, angulation, and intra-articular versus extra-articular. Timely and adequate reduction is essential.

What to Ask

1. Are there any open wounds (rare, but ensure the consultant has looked in the axilla)?
2. What is the neurovascular status (especially axillary and radial nerves)?
3. Can their jewelry on the ipsilateral arm/hand be removed, and can the IV access be placed on the contralateral arm?
4. What is the patient's hand dominance?

A.D. Sobel, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: andrew.d.sobel@gmail.com

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Figure. 21.1 Radiographic examples of humerus fractures including proximal, shaft, and distal fractures

5. What is the patient's ambulatory status and need for assistive devices?

What to Request

1. Patient should be sitting upright if possible and be placed in a sling until your arrival.
2. Analgesia and/or anxiolytic/antispasmodic for shaft fractures requiring reduction.

When to Escalate

1. Fracture/dislocations: see other chapters (Glenohumeral Dislocations, Chapter 22; and Elbow Dislocations, Chapter 19)
2. Open fracture
3. Neurologic injury or vascular compromise

Imaging

1. X-rays of the shoulder (true AP, one orthogonal view [scapular Y, axillary lateral, Velpeau view] at minimum), humerus (AP and transthoracic lateral), elbow (three views), and chest AP.
2. CT may be helpful for complicated proximal or distal humerus fractures.
3. Postreduction X-rays of the injury if reduction is performed.

Effective Communication

1. Open or closed
2. Neurovascular compromise
3. Varus/valgus, head split, displacement (proximal)
4. Angulation (shaft)
5. Intra- or extra-articular (distal)
6. Displaced/non-displaced

What to Bring

1. For proximal humerus fractures: sling
2. For shaft fractures: functional fracture brace (e.g., Sarmiento) or splint material (coaptation splint)
3. For distal fractures: splinting material (coaptation splint if unstable, posterior arm splint if stable)

Key Exam Pearls

1. Sensation (axillary/median/radial/ulnar nerves).
2. Motor (EPL/FPL/EDC/FDS/FDP/IO, wrist extensors, interossei, axillary).
3. Inspect axilla for missed open wounds.
4. Evaluate skin tenting (open fractures).

Reduction

Reductions of articular or periarticular proximal or distal humerus fractures (not dislocations) are not often recommended acutely. Initial splinting of the fracture "where it rests" is appropriate for distal humerus fractures in relatively anatomic alignment. A sling is appropriate for most proximal humerus fractures.

Depending on institutional preferences, acute reduction of displaced and angulated humeral shaft fractures may be appropriate. Immobilization in a coaptation splint will be necessary if a reduction is performed, but a well-fit functional fracture brace (also known as a "Sarmiento brace") without reduction is also acceptable in the appropriate, compliant patient. Braces may not work well if the patient has an obese arm, significant swelling, skin injuries, or a very displaced fracture. Ensure the brace or splint will extend proximal enough to the fracture to be effective in controlling the alignment.

If reduction and splinting is chosen, the patient should be placed fully upright in bed with his or her thorax lateral enough that the patient's scapula is almost fully off the bed. Having an assistant is helpful, but not vital to the placement of a coaptation splint. The axilla should be well padded and the skin should be protected with cotton wrapping. Splint material should start high in the axilla on the medial arm, wrap around the elbow, extend proximally past the lateral arm, and end proximal to the acromion. A posterior slab splint extending from the shoulder to, or past, the wrist can also be used for more stability. Wrist immobilization may be helpful if there is a radial nerve palsy.

Molding is typically completed with a medially directed force over the lateral aspect of the proximal fragment to counteract a varus deformity from the deltoid. Anteroposterior molding can be achieved if using the posterior slab as needed. Axial traction is not typically helpful as the correction achieved is only temporary.

PEARL The splint material will always drift distally past the acromion during molding so ensure that the splint ends very proximal (almost at the neck).

PEARL If you do not have an assistant, splint material can be placed inside large stockinette and tied around the contralateral aspect of the thorax and also around the contralateral aspect of the neck prior to molding. Stockinette ends can be trimmed after molding and wrapping is finished.

Adequate Reduction Parameters

1. $<20^{\circ}$ of anteroposterior angulation
2. $<30^{\circ}$ of varus/valgus angulation
3. Not significantly distracted or shortened

Follow-Up

1. Remain non-weight bearing.
2. Finger, wrist, and elbow range of motion should be performed (if not immobilized) to prevent stiffness.
3. Serial X-rays will be performed in the office to observe for continued reduction. Transition to a fracture brace, if not used initially, is common after swelling resolves.

Chapter 22
Glenohumeral Dislocation

Andrew D. Sobel

Keywords Shoulder dislocation • Glenohumeral • Hill-Sachs • Stimson's method

Overview

Patients presenting with a glenohumeral dislocation (Fig. 22.1) requires evaluation of the neurovascular status, the direction of the dislocation, and the presence of fracture, glenoid bone loss, and Hill-Sachs/reverse Hill-Sachs lesions.

What to Ask

1. Is the shoulder still dislocated? Many consultations about shoulder dislocations follow failed attempts by other providers. Speedy reduction limits neurologic and chondral injury, and delays can make reduction attempts more difficult because of spasm.

A.D. Sobel, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: andrew.d.sobel@gmail.com

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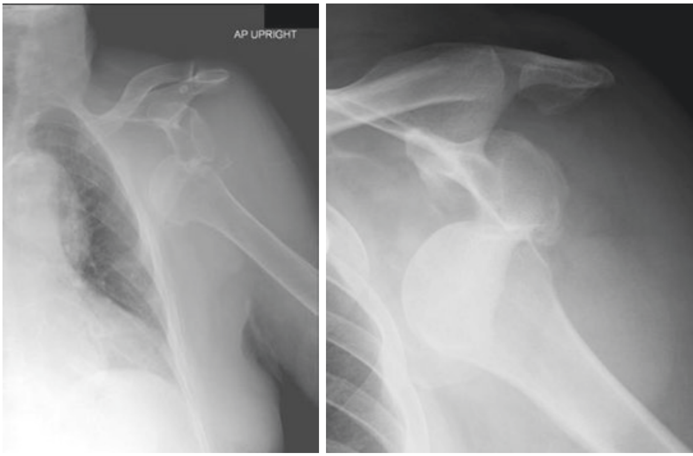

FIGURE 22.1 Radiographs of a glenohumeral dislocation. As discussed, it is essential to always examine X-rays for associated fractures, which can help in determining the risk for future instability events and the need for operative intervention

2. Is the dislocation acute or chronic? Attempting reduction of a chronically dislocated shoulder may cause serious injury to periarticular structures including the surrounding nerves, rotator cuff, bony structures, and even axillary artery/vein.
3. What types of reduction attempts have already been made and what adjuvants have been used? You will usually not repeat these if they have been correctly attempted already.
4. Can the patient safely be consciously sedated? If less involved methods have been tried and have failed, this is often the go-to for a swift and safe reduction.
5. What is the neurovascular exam? Axillary nerve palsies are common and should be identified early.
6. Has the patient dislocated their shoulder before? Repeat dislocaters often have structural problems in their shoulder that need to be fixed to prevent recurrence.
7. Does the patient dislocate voluntarily? There may be secondary reasons for the patient's current dislocation.

What to Request

1. Patient should be sitting upright and be placed in a sling until your arrival.
2. Analgesia with or without an anxiolytic/antispasmodic for comfort.
3. Reduction adjuvants as required by the chosen methodology (see "What to Bring" and "Reduction").

When to Escalate

1. Fracture dislocations: dislocations with associated fractures should be discussed with an orthopedic specialist before reduction.
2. Irreducible dislocations.
3. Neurologic/vascular injury.

Imaging

1. The shoulder must be radiographically evaluated in orthogonal planes. True AP (Grashey), scapular "Y," and axillary lateral (or equivalent Velpeau) views are preferred. Similar postreduction views are required. It is never appropriate to claim a joint is reduced based on a single image, so always have an orthogonal view!
2. The axillary lateral is considered by most orthopedists to be the best orthogonal view for evaluating reduction.
3. Postreduction CT scan is indicated if there is concern for fracture or if the shoulder is irreducible outside of the OR.

Effective Communication

1. Direction of dislocation (anterior, posterior, inferior)
2. Neurovascular status
3. Fracture description (if relevant)

4. Glenoid bone loss
5. Hill-Sachs/reverse Hill-Sachs

What to Bring

This depends on the methodology you will be attempting to reduce the shoulder and the direction of dislocation. We recommend a brief review of the following methods to prepare you before attempting reduction. You may often combine these methods or adjuvants:

1. Stimson's method (prone) – Webril/ACE wrap or wrist splint, stockinette, weights (IV bags are good alternatives)
2. Intra-articular injection – lidocaine, spinal or long needle, antiseptic
3. Traction/countertraction – bedsheet, assistant
4. Conscious sedation – a medical provider licensed in sedation

Key Exam Pearls

1. Sensation (*axillary*/median/radial/ulnar nerves)
2. Motor (EPL/FPL/EDC/FDS/FDP/IO, wrist extensors, biceps, triceps, axillary [patient should be able to fire without excursion])
3. Palpate humeral head (may serve as a lever point for reduction)

Reduction

Common reduction methods for anterior dislocations include non-traction techniques (Kocher, Milch), traction techniques (Stimson's, traction/countertraction, in-line), or scapular manipulation. Posterior dislocations can be reduced with similar methods, but often require conscious sedation because the mechanism of injury is often higher energy. Inferior dislocations can be converted to anterior dislocations by translating the head anteriorly and then reduced with any of the aforementioned techniques. Do not underestimate the utility of an intra-articular lidocaine injection for analgesia during reduction, even if sedation is used.

Follow-Up

1. Have the patient remain non-weight bearing in a simple sling (anterior dislocation) or sling in external rotation (posterior dislocation).
2. An MRI may be obtained in the office subacutely to investigate labral pathology (younger patients), rotator cuff tears (older patients), or chondral injury.

Chapter 23
Pediatric Shoulder Injuries

Joseph A. Gil

Keywords Pediatric shoulder • Proximal humerus fractures • Clavicle fractures

Overview

Comprehensive evaluation of pediatric proximal humerus and clavicle fractures includes determination of open versus closed, neurovascular status, intraarticular versus extra-articular, postreduction stability, associated injuries, displacement, and physeal involvement.

What to Ask

1. Are there any open wounds, particularly for clavicle fractures?
2. Are there any associated injuries?

J.A. Gil, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: josephgil773@gmail.com

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3. Has the patient's jewelry been removed, and is there IV access on the contralateral arm?
4. If a reduction is needed, is the patient ready for conscious sedation and NPO?

What to Request

1. Ensure arm is stabilized, elevated, and iced immediately.
2. For proximal humerus fractures, X-rays of the shoulder and humerus. For clavicle fractures, X-rays of the shoulder and clavicle.
3. If the fracture is displaced and requires reduction, ask for conscious sedation.

When to Escalate

1. Open fractures: should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR)

Imaging

1. AP, scapular Y, and axillary lateral of the shoulder; if clavicle is fractured, add AP and oblique views of the clavicle.
2. Clavicle fractures are often adequately visualized on AP radiographs. A cephalic tilt view and apical oblique view can help if visualization on AP is inadequate.
3. Postreduction X-rays of the shoulder if a reduction is attempted.

Effective Communication

1. Open versus closed
2. Neurovascular compromise

3. Intra-articular versus extra-articular
4. Stability after reduction
5. Associated injuries
6. Displaced/non-displaced
7. Physis involvement

What to Bring

1. Sling and swathe
2. Fluoroscopy if reduction is required

Key Exam Pearls

1. Sensation (axillary/median/radial/ulnar nerves).
2. Motor (EPL/FPL/EDC/FDS/FDP/IO/deltoid).
3. Evaluate all wounds: dermal violation raises suspicion for open fracture.

Reduction (Depends on Age) [1]

1. Proximal humerus fractures (Fig. 23.1): Given the high remodeling potential of the proximal humerus, a majority of proximal humerus fractures in children less than 5 years old are managed conservatively in a sling without an attempt at closed reduction. However, once the child is 5 years old or older, the degree of displacement that could be remodeled decreases. In these cases, closed reduction is performed by applying gentle traction with the shoulder in 90° of flexion. The shoulder is then gently abducted and externally rotated. For stable fractures, the shoulder is immobilized with a sling and swathe. Unstable fractures or those that fail closed reduction may need to be taken to the OR to be reduced and fixed.
2. Clavicle fractures (see Fig. 23.2): Generally, no reduction maneuver should be performed in the emergency depart-

Figure 23.1 Radiograph of a diaphyseal humerus fracture in a skeletally immature patient

Figure 23.2 Radiograph of a middle-third clavicle fracture in a skeletally immature patient

ment. The patient should be placed in a sling. If the skin is tented and does not improve in the sling or sling and swathe, admission and operative fixation are needed.

Adequate Reduction Parameters [1]

1. Proximal humerus fractures: in patients less than 5 years old, 70° of angulation, and any degree of displacement. In patients aged 5–12, 40° of angulation, and 50% displacement. For those older than 12 until the physes close, 15° of angulation, and less than 30% of displacement.
2. Clavicle fractures: generally, no reduction maneuver should be performed in the emergency department unless skin is tented over the fracture.

Follow-Up

1. Remain non-weight bearing and continue to ice the shoulder/clavicle.
2. See an orthopedic surgeon within 1 week.
3. Patients should move fingers/wrist/elbow to minimize swelling and stiffness.

Reference

1. Egol KA, Joval KJ, Zuckerman JD. Handbook of fractures. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2010.

Chapter 24
Clavicle Fractures and Dissociations

Jonathan D. Hodax

Keywords Clavicle fracture • Clavicle dislocation • Zanca view

Overview

Thorough evaluation of fractured (Fig. 24.1) or dislocated clavicle includes assessment of open versus closed, neurovascular status, location of fracture, status of overlying skin, associated injuries, and displacement.

What to Ask

1. Are there any open wounds or skin that is tented or threatened?
2. Are there any associated injuries?
3. Is the extremity neurovascularly intact?

J.D. Hodax, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: JDHodax@gmail.com

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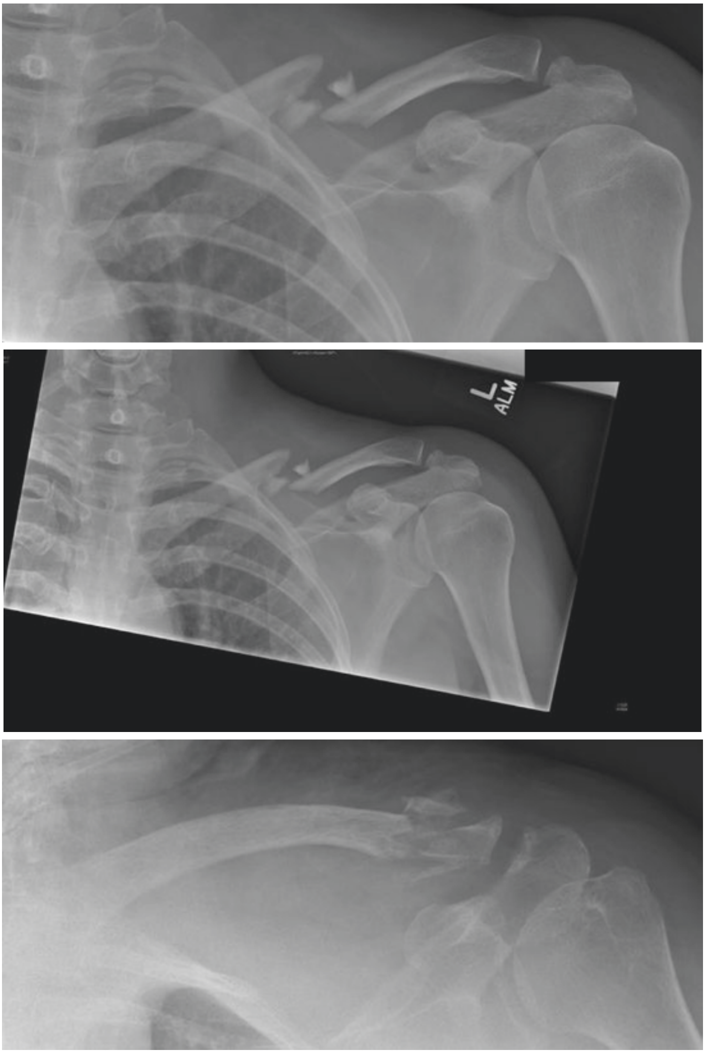

FIGURE 24.1 Radiographs of middle and lateral third clavicle fractures

What to Request

1. Ensure the arm is stabilized and placed into a sling.
2. Dedicated films of the clavicle should be obtained.

When to Escalate

1. Open fractures: should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR)
2. Any change in the neurovascular exam

Imaging

1. Dedicated films of the clavicle: 20° cephalad and 20° caudad films with the patient upright, out of sling (best demonstrates amount of displacement)
2. Zanca view: for lateral injuries and AC joint injuries; best demonstrates displacement at the AC joint

Effective Communication

1. Open versus closed
2. Neurovascular injury
3. Medial, mid-shaft, or lateral
4. Status of overlying skin
5. Associated injuries
6. Displaced/non-displaced (>/< one shaft width)

What to Bring

1. Sling

Key Exam Pearls

1. Sensation (axillary/median/radial/ulnar nerves).
2. Motor (EPL/FPL/EDC/FDS/FDP/IO/deltoid).
3. Evaluate all wounds: dermal violation raises suspicion for open fracture.

Reduction (Depends on Age)

1. No reduction is typically required.

Adequate Reduction Parameters

1. Displacement of >100% of the shaft width, particularly with an intervening fragment ("Z" deformity), is indicative of increased risk of nonunion without surgical intervention; however this does not indicate a reduction should be attempted.

Follow-Up

1. Remain non-weight bearing and continue use of sling.
2. See an orthopedic surgeon within 1 week.
3. Patients should move fingers/wrist/elbow to minimize swelling and stiffness.

Part IV
Axial Skeletal Injuries

Chapter 25
Cervical Spine Trauma

J. Mason DePasse

Keywords Cervical spine • Occipital condyle • Atlas fractures • Axis fractures • Cervical facet dislocations

Overview

Comprehensive workup of the cervical spine trauma patient includes thorough evaluation of the neurologic status, anatomic region (occiput, C1, C2, or subaxial spine), associated injuries, displacement/listhesis, any previous spine fusion, and fracture pattern (such as compression or burst fracture).

What to Ask

1. What is the patient's neurologic status or severity of deficits?
2. What is the patient's current immobilization?

J. M. DePasse, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: jmdepasse@gmail.com

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3. Are there any associated injuries?
4. Has the patient's exam changed while in the emergency department? A progressive loss of function requires urgent intervention to prevent further loss.

What to Request

1. CT scan if not already obtained (see Figs. 25.1 and 25.2).
2. Ensure collar in place immediately if any injury is suspected.
3. Ensure adequate resuscitation and maintinence of mean arterial pressure if concern for spinal cord injury.

When to Escalate

1. Any evidence of cervical spinal fusion, either from ankylosing spondylitis, diffuse idiopathic skeletal hyperostosis (DISH), or previous surgical arthrodesis
2. Jumped/perched facets, severely displaced odontoid or hangman's fractures, or any injury possibly necessitating emergent reduction
3. Neurologic deficits, especially if the exam is worsening

FIGURE 25.1 CT image demonstrating rotational instability of C1 on C2

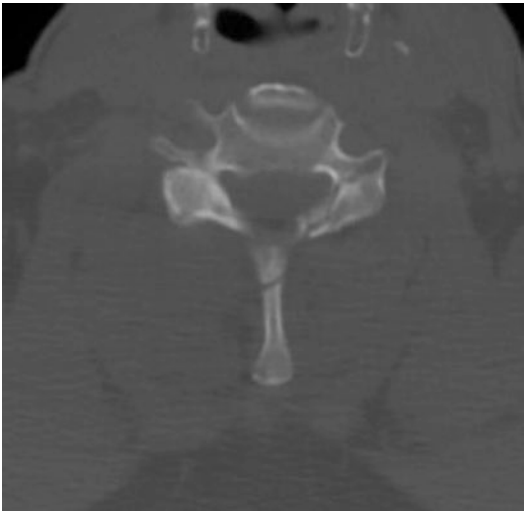

FIGURE 25.2 CT image demonstrating a spinous process fracture in the cervical spine

Imaging

1. May consider a plain radiograph series including AP, lateral, and open-mouth odontoid views.
2. Generally, all patients with cervical spine injuries will have CT scans of the cervical spine.
3. MRI should be performed if there are neurologic deficits, if the patient is obtunded, and prior to most closed reduction attempts.

Effective Communication

1. Neurologic status is crucial
2. Occiput, C1, C2, or subaxial spine
3. Associated injuries
4. Displacement/listhesis
5. Any previous spine fusion
6. Compression versus burst fracture

What to Bring

1. Game face and careful exam skills

Key Exam Pearls

1. Neck tenderness, locate C7 via vertebra prominens.
2. Complete neurologic exam, including reflexes and rectal tone.
3. Pathologic signs, including Hoffman's, Babinski, clonus.

Injuries

Occipital Condyle

Most injuries to the occipital condyle will be treated with a cervical orthosis, although significant comminution may require a halo vest and true alar ligament avulsions may require fusion. In contrast, all occipito-cervical dissociations will be treated with fusion, though most often these injuries are fatal in the field. There are several described measurements that suggest the diagnosis, though the occipital condyle-C1 interval is most sensitive. Any value greater than 1.5 mm is highly concerning.

C1 (Atlas) Fractures

Atlas injuries include arch fractures, lateral mass fractures, and the "Jefferson" burst fracture, which is defined as bilateral anterior and posterior arch fractures. Stability depends on an intact transverse atlantal ligament (TAL); displacement of the lateral masses greater than 6.9 mm indicates a disrupted ligament. Stable injuries can be treated with an orthosis; unstable injuries will be fused.

C2 (Axis) Fractures

Odontoid injuries are common in the young after high-energy trauma or the elderly after falls. Fractures through the tip (type 1) or extending into the body of C2 (type 3) are treated with a cervical orthosis, while fractures through the base of the dens (type 2) should be treated with fusion in the active elderly and either fusion or halo vest in the young.

Hangman's fractures occur from hyperextension and are treated depending on severity of displacement. If there is <3 mm of displacement, cervical orthosis is appropriate. More than 3 mm of displacement should be treated with halo traction or surgery, unless there is a horizontal fracture line suggesting a traction injury, in which case the patient should be treated in a halo with no traction.

Cervical Facet Dislocations

Facet dislocations can be missed if unilateral; monoradiculopathy is suggestive. Assess for the "hamburger sign" on axial CT, which is the superior facet now posterior to the inferior facet. These injuries may be reduced by hanging weight from Gardner-Wells tongs in the emergency department, but MRI may be considered before reduction. Fusion is then performed.

Subaxial spine fractures may be classified as compression fractures if the anterior column alone is involved or burst fractures if multiple columns are involved. Flexion teardrop fractures result from failure of the anterior column in compression and the posterior column in tension, whereas extension teardrop fractures are small avulsions of the ALL. Stable compression fractures and extension teardrops may be treated with an orthosis, whereas others will be treated with fusion and decompression as necessary, including possible corpectomy.

Follow-Up

1. Do not perform flexion/extension studies without discussing with the attending.
2. Follow the neurologic exam. Decisions regarding admission or discharge to follow-up are variable by institutional preference and dependent on injury severity and stability.

Chapter 26
Cervical Stenosis and Central Cord Syndrome

J. Mason DePasse

Keywords Cervical stenosis • Central cord syndrome

Overview

Suspected cervical stenosis or central cord syndrome requires systematic evaluation of the patient's neurologic status, etiology of stenosis, progression of deficits, specific location of stenosis, and duration of deficits.

What to Ask

1. What are the patient's specific neurologic deficits?
2. What is the duration of symptoms?
3. Has the patient had any previous surgeries, hardware, or injections?

J.M. DePasse, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: jmdepasse@gmail.com

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What to Request

1. MRI of the cervical spine

When to Escalate

1. Acute loss of ability to ambulate
2. Complete upper extremity paralysis
3. Significant progression of neurologic symptoms

Imaging

1. MRI of the cervical spine (Fig. 26.1)
2. CT of the cervical spine if concern for central cord syndrome after seemingly minor trauma

Figure 26.1 Mid-sagittal T2-weighted MRI image of a patient with severe cervical stenosis

Effective Communication

1. Neurologic status
2. Etiology of stenosis
3. Progression of deficits
4. Specific location of stenosis
5. Duration of deficits

Key Exam Pearls

1. Complete neurologic exam, including reflexes and rectal tone
2. Pathologic signs, including Hoffman's, Babinksi, and clonus
3. Bonus for inverted radial reflex (tapping the brachioradialis produces finger flexion) and finger escape sign (spontaneous abduction of the small finger)
4. Spurling's test – extension, rotation, and tilt to affected side and axial load reproduce radiculopathy
5. Relief of radiculopathy with shoulder abduction

Pathology

Cervical stenosis occurs when the central canal diameter is <13 mm (normal is 17 mm). Cervical stenosis can be caused by disk herniation, ossification of the posterior longitudinal ligament (OPLL), degenerative spondylosis, or repetitive microtrauma (spear tackler's spine). If there is pressure on the cord, such as with central disk herniation or OPLL, cervical myelopathy may result. If there is pressure on the root, such as with a lateral disk herniation, cervical radiculopathy is more likely.

Myelopathy is a syndrome characterized by upper extremity clumsiness and gait abnormalities, and it can be associated with weakness, paresthesia, hyperreflexia, and late urinary retention. Myelopathy often progresses in a stepwise pattern, and patients with poor access to medical care may present to the emergency room after progression prevents them from ambulating. Patients without functional impairment may be treated conservatively, but the disease is progressive, and often, by the time patients are presenting to the ER, decompression and fusion are required.

Lateral cervical disk herniation more commonly affects the exiting root than the traversing root. Thus, C6 is most commonly affected by a C5–C6 disk herniation. Regardless of etiology, cervical radiculopathy must be carefully distinguished from other conditions that present similarly, such as cubital and carpal tunnel syndrome or Parsonage-Turner syndrome. As with lumbar radiculopathy, the majority of patients can be treated conservatively with anti-inflammatories, though surgery should be considered for patients with significant neurologic deficits.

Cervical stenosis can also put the patient at high risk for central cord syndrome, which is commonly seen after minor trauma in which the patient's bony anatomy is preserved but the constricted canal results in a cord injury. Central cord syndrome is characterized by upper extremity symptoms that are more profound than lower extremity symptoms. Most patients recover lower extremity function, though full recovery of manual dexterity is unlikely. Central cord syndrome may be treated with a cervical orthosis or with decompression and fusion, depending on the degree of injury and the surgeon. Treatment is currently controversial.

Follow-Up

1. Varies widely based on injury, intervention, and local preferences

Chapter 27
Thoracolumbar Spine Trauma

J. Mason DePasse

Keywords Thoracolumbar spine • Compression • Burst • Flexion-distraction • Chance • TLICS

Overview

Thoracolumbar spine trauma—including compression, burst, and Chance fractures—necessitates a comprehensive neurologic exam, evaluation of the thoracolumbar junction, associated injuries, displacement/listhesis, and history of previous spinal fusions.

What to Ask

1. What is the patient's neurologic status?
2. Are there any associated injuries? Concomitant retroperitoneal and intra abdominal injuries are common.

J. M. DePasse, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: jmdepasse@gmail.com

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3. Has the patient had any previous surgeries, hardware, or injections?

What to Request

1. CT scan if not already obtained
2. Logroll precautions if potential instability presents
3. Ensure adequate resuscitation and mean arterial pressure if concern for spinal cord injury

When to Escalate

1. Any evidence of spinal fusion, either from ankylosing spondylitis, DISH, or previous surgical arthrodesis
2. Neurologic deficits, especially if the exam is worsening

Imaging

1. Plain films will be used primarily in follow-up and to assess alignment.
2. CT imaging of the thoracic or lumbar spine.
3. MRI should be performed if there are neurologic deficits or if the patient is obtunded.

Effective Communication

1. Neurologic status is crucial.
2. Thoracolumbar junction.
3. Associated injuries.
4. Displacement/listhesis.
5. Any previous spinal fusion.
6. Compression versus burst fracture.

Key Exam Pearls

1. Tenderness anywhere along the spinal axis
2. Complete neurologic exam, including reflexes and rectal tone
3. Pathologic signs, including Hoffman's, Babinksi, and clonus
4. May consider post-void residuals if concern for neurogenic bladder

Injuries

Compression fractures occur from failure of the anterior column alone in compression and are most common in elderly, osteoporotic spines (see Fig. 27.1). The vast majority of compression fractures are treated nonoperatively, though kyphoplasty can be considered with persistent pain. Additionally, tumor must always be considered, and MRI or further laboratory workup should be pursued if findings are atypical. Bracing, such as with a Jewett brace, may be utilized for kyphosis. Soft braces are also useful for pain control.

Burst fractures are usually caused by an axial load and involve failure of the anterior and middle columns. Retropulsion of bone into the canal may compress the cord, particularly in the narrower canal of the thoracic spine. Generally, burst fractures may be treated nonoperatively with or without a brace if the posterior ligamentous complex is preserved, but they require fusion if the complex is disrupted. Surgical decompression is generally required regardless of stability if there is neurologic compromise.

Flexion-distraction injuries (see Fig. 27.2), also called "Chance" injuries, are associated with lap belts and abdominal trauma and may be bony or purely ligamentous. They result from failure of the anterior and middle columns in compression with concomitant failure of the posterior column in

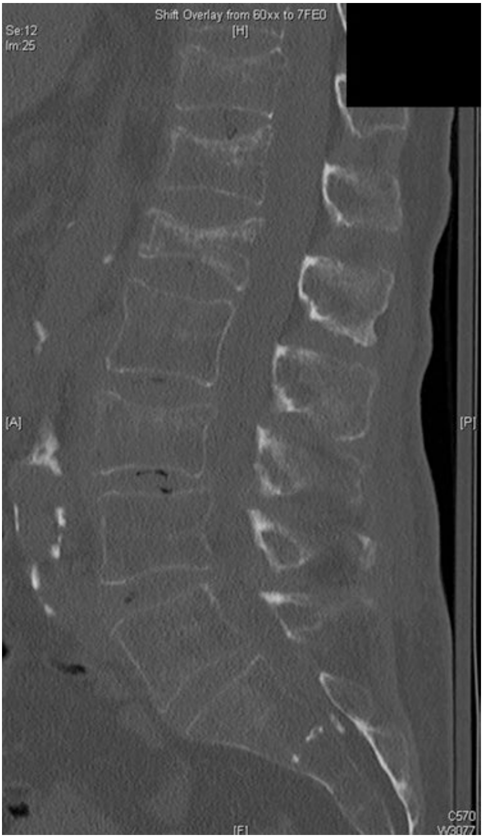

Figure 27.1 A compression fracture of the spine demonstrated on a CT scan. Note the low density of the bone on this image, suggestive of osteoporosis

tension. Purely ligamentous injuries may be easy to miss; high suspicion necessitates MRI. Bony injuries may be treated nonoperatively if the pattern is stable; for all other patterns, decompression and fusion are required.

Be aware of the thoracolumbar injury classification system (TLICS), which can be helpful to determine stability. The TLICS includes fracture pattern, posterior ligamentous

FIGURE 27.2 CT scan image and radiograph demonstrating a compression fracture of L1 with displacement of the anterior aspect of the superior end plate. This fracture pattern is suggestive of a flexion-compression mechanism

complex injury, and neurologic involvement to determine whether operative intervention is required; injuries with scores greater than four will almost always be treated operatively.

Follow-Up

1. Follow the neurologic exam.

Chapter 28
Lumbar Stenosis and Cauda Equina Syndrome

J. Mason DePasse

Keywords Lumbar stenosis • Cauda equina syndrome

Overview

The comprehensive workup of lumbar stenosis and cauda equina syndrome includes complete neurological exam, etiology of stenosis, progression of deficits, specific location of stenosis, and duration of deficits.

What to Ask

1. What are the specific neurologic deficits?
2. What is the duration of symptoms?
3. Has the patient had any previous surgeries or injections?

J. M. DePasse, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: jmdepasse@gmail.com

J.D. Hodax et al. (eds.), *The Orthopedic Consult Survival Guide*, DOI 10.1007/978-3-319-52347-7_28,

What to Request

1. MRI of the lumbar spine with low threshold for requesting MRI of the entire spine to rule out double crush
2. NPO if concern for cauda equina syndrome

When to Escalate

1. Acute loss of ability to ambulate
2. Acute incontinence of bowel and bladder or acute urinary retention
3. Significant progression of neurologic symptoms

Imaging

1. MRI of the lumbar spine (see Fig. 28.1).
2. CT myelogram is required if the patient cannot undergo MRI (e.g., pacemaker).

Effective Communication

1. Neurologic status is crucial.
2. Etiology of stenosis.
3. Progression of deficits.
4. Specific location of stenosis.
5. Duration of deficits.

Key Exam Pearls

1. Complete neurologic exam, including reflexes and rectal tone
2. Perineal and medial thigh sensation if concern for cauda equina syndrome
3. Pathologic signs, including Hoffman's, Babinksi, clonus

FIGURE 28.1 A midsagittal MRI image demonstrating severe narrowing at L2–L3

4. Essential to check for signs of coexisting cervical myelopathy, especially in patients with degenerative spines
5. Tension signs such as straight leg raise (L4-S1) and hip extension (L2-L3)

Pathology

Lumbar stenosis can be in the central canal, the lateral recess, or the neuroforamen. Central stenosis is often caused by ligamentum flavum hypertrophy or degenerative spondylolisthesis, and it results in findings of neurogenic claudication.

Typically, central stenosis will not bring a patient to the emergency room unless they have sustained a massive herniated disk that is causing cauda equina syndrome, characterized by saddle anesthesia, bilateral leg weakness, urinary retention and subsequent overflow incontinence, and bowel incontinence. Patients with cauda equina syndrome require urgent surgical decompression.

Lateral recess and foraminal stenosis is typically caused by disk herniation, facet hypertrophy, facet cysts, or spondylolisthesis. In the case of disk herniation, tension signs will often be positive. It is important to remember that most commonly the disk herniation will be in the lateral recess, thus affecting the traversing root (L5 at L4–L5) as opposed to the exiting root (L4 at L4–L5). Unless the patient has neurologic deficits, disk herniation should be treated with anti-inflammatories and pain control in the emergency department.

Follow-Up

1. Follow the neurologic exam.

Chapter 29
Spinal Epidural Abscess

J. Mason DePasse

Keywords Spinal epidural abscess • Fever • Spinal pain • Neurological deficits

Overview

Complete workup for spinal epidural abscess includes a thorough medical history, progression of deficits, duration of deficits, complete neurologic exam, location(s) of abscess, and concomitant osteomyelitis.

What to Ask

1. What are the specific neurological deficits?
2. Does the patient have any history of IV drug abuse, diabetes, or renal disease?
3. Has the patient had any previous spine surgeries or injections?

J. M. DePasse, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: jmdepasse@gmail.com

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4. What are the current vital signs? Always be sure to assess for septicemia.

What to Request

1. MRI with gadolinium of the entire spinal axis, including cervical, thoracic, and lumbar spine.
2. Labs: ESR, CRP, WBC, blood cultures x2, and UA.
3. Hold antibiotics unless frankly septic, so that operative cultures can be obtained and antibiotics taylored appropriately.
4. Ensure that patient is NPO.

When to Escalate

1. Sepsis
2. Significant progression of neurologic symptoms

Imaging

1. MRI with contrast of the cervical, thoracic, and lumbar spine to evaluate for noncontiguous lesions

Effective Communication

1. Neurologic status
2. Medical history
3. Progression of deficits
4. Location(s) of abscess
5. Duration of deficits
6. Concomitant osteomyelitis

Key Exam Pearls

1. Complete neurologic exam, including reflexes and rectal tone
2. Pathologic signs, including Hoffman's, Babinksi, and clonus

Pathology

Spinal epidural abscess (SEA) is classically associated with fever, spinal pain, and neurological deficits, though the presence of all three parts of this “triad” is actually uncommon. SEA is associated with IV drug abuse, diabetes, and renal disease, and it is most common in older patients with multiple medical problems. *Staphylococcus aureus* is the most common organism, though *S. epidermidis* can be encountered after invasive spinal procedures, and *Pseudomonas* may also be seen with IV drug abuse. Most abscesses form as a result of hematogenous spread, though direct spread from adjacent vertebral osteomyelitis can also occur.

Patients will present with a wide variety of complaints, though most commonly axial back or neck pain is the chief complaint. A very thorough neurologic exam is essential, as deficits must be closely monitored regardless of treatment. A workup should include MRI with contrast of the entire spinal axis to rule out noncontiguous disease and lab evaluation, including blood cultures, which can sometimes yield an organism.

Treatment consists of obtaining an organism, most commonly through open surgical biopsy at the time of debridement, surgical decompression with or without fusion, and antibiotic therapy. However, if the diagnosis is unclear, if the patient has no neurological deficits and a trial of conservative treatment is planned, or if the patient is too sick to undergo surgery, CT-guided biopsy may be performed. CT-guided biopsy for bone cultures may also be performed if there is associated osteomyelitis. For the vast majority of patients, prompt surgical debridement followed by aggressive antibiotic therapy is the mainstay of treatment, but in select patients who present without any neurologic findings, conservative therapy with antibiotics may be considered.

Follow-Up

1. Follow the neurologic exam closely.

Chapter 30
Sacral Fractures

J. Mason DePasse

Keywords Sacral fractures • Denis classification

Overview

The evaluation of sacral fractures requires determination of open versus closed fractures, neurovascular status, concomitant injuries, and classification of fracture.

What to Ask

1. Are there any concomitant injuries?
2. What is the patient's neurovascular status?
3. What is the patient age?
4. What was the mechanism? (Typically elderly, low-energy falls; young, high-energy mechanisms)

J.M. DePasse, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: jmdepasse@gmail.com

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What to Request

1. CT scan with fine cuts through the sacrum and sagittal recons

When to Escalate

1. Open fractures: need immediate antibiotics and operative debridement
2. Neurovascular compromise: needs to be communicated to the orthopedic surgery attending on call

Imaging

1. AP of the pelvis
2. CT scan with fine cuts through the sacrum
3. MRI when neurologic compromise is present

Effective Communication

1. Open fractures and neurovascular status must be communicated.
2. Concomitant injuries are also an important part of managing sacral fractures.
3. Classification of fracture.
4. The Denis classification is the most commonly used method of description, though familiarity with the descriptive terms “U-Type,” “H-Type,” and “inverted U-Type” is important.

What to Bring

1. No equipment needed

Key Exam Pearls

1. Neurovascular status is the most important part of the exam, as neurologic deficits are the most important predictor of negative outcomes; sensation to dermatomes supplying the groin and perianal region is important to test.
2. Rectal exam for tone/squeeze.
3. Assessment for open wounds. In high-energy mechanisms or if air is present near the fracture on CT a careful rectal exam for open fracture to the GI system should be performed.

Follow-Up

1. High-energy fractures get admitted and remain on bed rest until CT evaluated by attending orthopedic surgeon responsible for the patient.
2. Low-energy, or insufficiency, fractures in the elderly may be discharged with an assistive device such as a walker if neurologically intact, though this should be discussed with the orthopedic surgeon on call.
3. If necessary, admission to orthopedics, general surgery, ICU service, or medicine as dictated by patient condition and hospital practice.

Chapter 31
Anterior-Posterior Pelvic Fractures

Joey P. Johnson

Keywords Pelvis fractures • AP mechanism • Pelvic binder

Overview

Anterior-posterior-type pelvic ring injuries are generally caused by an anterior compressive force to the pelvis (Fig. 31.1). The telltale radiographic sign for this injury is pubic symphysis diastasis (widening). Diastasis of greater than 2.5 cm is generally considered an operative indication. Additionally, SI joint diastasis should be evaluated.

What to Ask

1. What is the patient's hemodynamic status? (Intrapelvic hemorrhage in these injuries can be fatal.)

J.P. Johnson, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: joey.johnson12@gmail.com

J.D. Hodax et al. (eds.), *The Orthopedic Consult Survival Guide*, DOI 10.1007/978-3-319-52347-7_31,

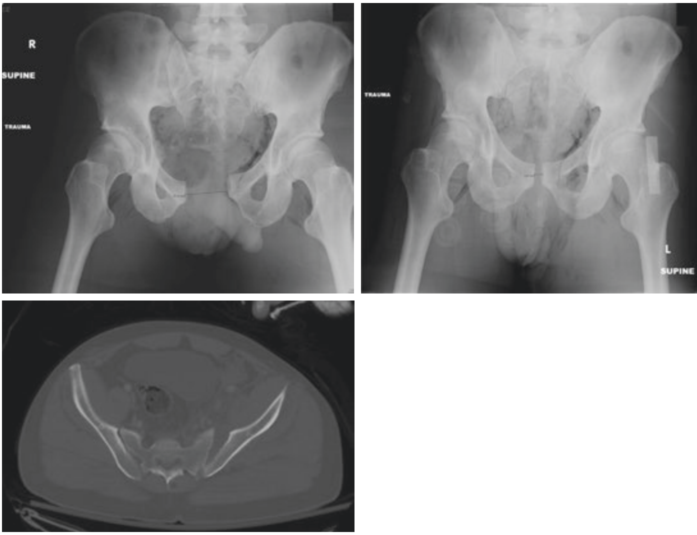

Figure 31.1 AP pelvis radiographs of a male patient with an anterior compression grade 3 injury before and after application of a pelvic binder and a representative CT image of the same patient

2. Are there any open injuries? A pelvic and rectal exam must be performed to rule out vaginal/rectal open fractures.
3. What are the associated injuries?

What to Request

1. CT scan of the pelvis through the level of the lesser trochanter with fine (2 mm) cuts to evaluate the pelvic fracture and identify any occult injuries, such as an associated femoral neck fracture without displacement.
2. Pelvic binder if available

When to Escalate

1. Open fracture – open wounds associated with a lateral compression pelvic injury carry a very high morbidity; they should be emergently identified and treated.

2. Hemodynamic compromise – these injuries carry a very high association with the head and intra-abdominal pathology that must be evaluated with any hemodynamic compromise.
3. If the patient is going to the OR with general surgery, the attending surgeon on call may elect to place an external fixator if possible.

Imaging

1. AP pelvis/Inlet/Outlet views
2. CT scan as mentioned above

Effective Communication

1. The Young and Burgess classification system is used to describe these injuries.
2. The presence of a genitourinary or rectal injury will often alter how these injuries are handled (external fixation versus symphyseal plating).
3. If a patient has to go to the OR for a general surgery purpose (e.g., exploratory laparotomy), this may encourage the operative orthopedic surgeon to provisionally (or definitively) stabilize this fracture with an external fixator.

What to Bring

1. Pelvic binder (or a bedsheet).

Key Exam Pearls

1. GU/rectal exams – open injuries can communicate with the GU and GI systems and be difficult to detect in the pelvis.
2. Thorough skin exam – open pelvic injuries carry a very high morbidity and should be identified and treated immediately.

3. A thorough neurovascular exam of the lower extremities is also important for this injury as neurovascular compromise can be an indication of an internal hemipelvectomy, which carries a much more grave prognosis (see Chapter 5).
4. When the patient arrives, *one* person should assess pelvic stability *one* time if instability is suspected but unproven. This involves an outward force on bilateral iliac wings with the examiners' hands placed on each ASIS. This is *not* something to be practiced on a patient with an unstable pelvis (the first clot is the best clot); once an APC unstable pelvis is determined, no further manual testing of pelvic stability should be performed to limit bleeding.

Reduction

In the hypotensive patient with pubic symphysis diastasis the application of a pelvic binder (or a firmly tied or clamped bedsheet) wrapped around the pelvis at the level of the greater trochanters and tightened can save the patient's life. If a pelvic binder or sheet is already on when you are examining a patient, make sure it is in the right position: at the level of the greater trochanters, not over the iliac crests. These are often placed incorrectly or migrate into an inappropriate location.

Adequate Reduction Parameters

1. Closure of symphyseal diastasis to <2 cm is ideal; however, if a patient's hemodynamic status improves, you have performed the goal of reduction.

Follow-Up

1. Admission to orthopedics, general surgery, or ICU service as dictated by patient condition and hospital practice.
2. Remain in pelvic binder, bed rest, until dictated otherwise by the attending orthopedic surgeon responsible for treating the patient.

Chapter 32
Lateral Compression Pelvic Fractures

Joey P. Johnson

Keywords Pelvic fracture • Lateral compression • Young and Burgess system

Overview

Lateral compression pelvic fractures are described by the Young and Burgess system. If the patient is going to the operating room with general surgery for other injuries or possible diversion for an open rectal injury, this should be communicated to the attending orthopedic surgeon as preperitoneal packing or external fixation may be necessary.

J.P. Johnson, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: joey.johnson12@gmail.com

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What to Ask

1. What is the patient's hemodynamic status? (Intrapelvic hemorrhage in these injuries can be fatal.)
2. Are there any open injuries? A pelvic and rectal exam must be performed to rule out vaginal/rectal open fractures.
3. What are the associated injuries?

What to Request

1. CT scan through the pelvis with fine cuts

When to Escalate

1. Open fractures – open wounds associated with a lateral compression pelvic injury carry a very high morbidity; they should be emergently identified and treated.
2. Hemodynamic compromise – these injuries carry a very high association with the head and intra-abdominal pathology that must be evaluated with any hemodynamic compromise.
3. If the patient is going to the OR with general surgery, the attending surgeon on call may elect to place an external fixator if possible.

Imaging

1. AP of the pelvis/Inlet/Outlet views
2. CT scan of the pelvis with fine cuts

Effective Communication

1. The Young and Burgess system is used to describe these fractures.

2. If the patient is going to the operating room with general surgery for other injuries or possible diversion for an open rectal injury, this should be communicated to the attending orthopedic surgeon as preperitoneal packing or external fixation may be necessary.

Key Exam Pearls

1. Examine for open wounds – all skin should be examined, including the groin and gluteal creases.
2. A thorough neurovascular exam – as neurovascular compromise can be an indication of a more severe injury.
3. Urologic examination.
4. Rectal and GU exam – tears in the rectal or vaginal vaults can be difficult to detect in open injuries that require emergent intervention; these injuries carry a very high morbidity and mortality.

Reduction

No reduction outside of the operating room is required for these fractures. Often, by the time you evaluate them, someone else will have placed them in a pelvic binder. If this has happened, remove the binder and perform a thorough skin exam as well as the GU and rectal exams. Pelvic binders can actually serve to further displace these fractures, in contrast to APC pelvic injuries.

Follow-Up

1. Most of these patients will require admission, either for surgical intervention or hemodynamic monitoring.
2. Admission to orthopedics, general surgery, or ICU service as dictated by patient condition and hospital practice.
3. Remain non-weight bearing and bed rest until dictated otherwise by orthopedic surgeon who will be managing the patient.

Chapter 33
Vertical Shear Pelvic Injuries

Joey P. Johnson

Keywords Pelvic injury • Vertical shear • Traction

Overview

Complete evaluation of vertical shear pelvic injuries (see Fig. 33.1) includes hemodynamic stability, neurovascular status, initial vertical displacement on imaging, the presence of open wounds, and whether the patient is going to the OR with general or vascular surgery emergently.

What to Ask

1. What is the patient's hemodynamic status? (Intrapelvic hemorrhage in these injuries can be fatal.)
2. Are there any open injuries? A pelvic and rectal exam must be performed to rule out vaginal/rectal open fractures.
3. What are the associated injuries?

J.P. Johnson, MD
Brown University, Department of Orthopedics,
Providence, RI, USA
e-mail: joey.johnson12@gmail.com

J.D. Hodax et al. (eds.), *The Orthopedic Consult Survival Guide*, DOI 10.1007/978-3-319-52347-7_33,

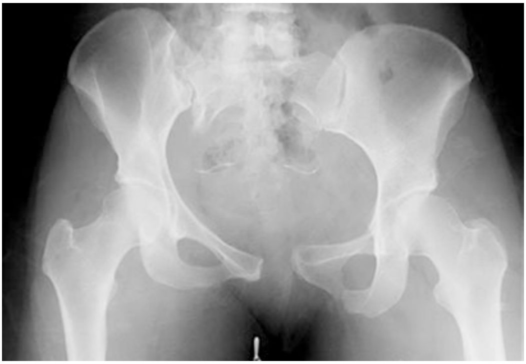

FIGURE 33.1 Representative AP radiograph of a vertical sheer-type pelvis fracture. Note the asymmetry of the pubic symphysis anteriorly and of the SI joints posteriorly

What to Request

1. CT scan with fine cuts through the pelvis
2. CT scan of the spine

When to Escalate

1. Open fractures – open fractures carry a very high morbidity and should receive immediate antibiotics, urgent operative debridement, and possible diversion by a general surgeon if the wound communicates with bowel.
2. Neurovascular compromise – this needs to be communicated to the operative surgeon on call and, in the setting of vascular injury, the vascular surgery team as well.
3. Hemodynamic compromise – again, these injuries are frequently seen with intra-abdominal injuries and closed head injuries that need urgent attention when causing hemodynamic compromise.

Imaging

1. AP/Inlet/Outlet views of the pelvis
2. CT scan of the pelvis with fine cuts

Effective Communication

1. Neurovascular and hemodynamic status
2. Whether the patient is going to the OR with general or vascular surgery emergently
3. Amount of vertical displacement present on initial imaging
4. The presence of open wounds

What to Bring

1. Traction supplies

Key Exam Pearls

1. Open wounds.
2. Neurovascular status – these injuries carry a very high correlation with lumbosacral plexus injuries.
3. Urologic examination.
4. Vaginal examination.
5. Rectal examination.

Reduction

These injuries can often be unstable in the cranial-caudal direction and necessitate traction if displacement is >1 cm.

If displacement necessitating traction is present, distal femoral traction should be placed (see Chapter 10). Traction weight should be added *slowly*. These are very unstable fractures, and excessive weight may result in "over-reduction". After every 10 pounds is placed, a repeat AP pelvis should be performed until reduction is confirmed.

Adequate Reduction Parameters

1. Cranial-caudal displacement <1 cm

Follow-Up

1. These patients are getting admitted, usually for operative intervention once hemodynamically stable, and adequately resuscitated.
2. Admission to orthopedics, general surgery, or ICU service as dictated by patient condition and hospital practice.

Chapter 34
Pubic Rami Fractures

Joey P. Johnson

Keywords Pubic rami fracture • Mental status

Overview

Standard descriptors of the fractures, as well as the patient's mental status, and other concomitant injuries are crucial for pubic rami fracture patients. The vast majority of these patients can weight bear as tolerated with an assistive device and follow-up in 4–6 weeks.

What to Ask

1. What is the patient's mental status? This can often be the main determinant of disposition.
2. Are the fractures acute?
3. Are there any concomitant injuries?
4. Are there any open wounds?

J.P. Johnson, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: joey.johnson12@gmail.com

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5. What was the injury mechanism? (Usually a ground level fall in the elderly)

What to Request

1. AP of the pelvis, inlet and outlet views of the pelvis
2. CT scan with fine (2 mm) cuts if there is any question that this may represent a lateral compression pelvic injury

When to Escalate

1. Open fractures (rare) need immediate antibiotics and urgent operative debridement.
2. Neuro-compromise (rare) is usually an indication of a missed sacral injury.

Figure 34.1 An AP radiograph of the pelvis demonstrating fractures of the right superior and inferior pubic rami

Imaging

1. AP/inlet/outlet views of the pelvis (see Fig. 34.1) are sufficient unless there is a concern for a lateral compression injury.
2. Even if a CT has been taken, X-rays are important because this is how the injury will be followed in the office.

Effective Communication

1. Standard descriptors of the fractures, as well as the patient's mental status and other concomitant injuries

Key Exam Pearls

1. If fractures are widely displaced, a manual vaginal examination and rectal examination are needed.
2. A standard neurovascular examination is also required.

Follow-Up

1. The vast majority of these injuries can weight bear as tolerated with an assistive device and follow-up in 4–6 weeks.

Chapter 35
Acetabular Fractures

Joey P. Johnson

Keywords Acetabular fracture • Judet and Letournel

Overview

Acetabular fractures (see Fig. 35.1) are described by the Judet and Letournel classification. Concomitant injuries, neurologic deficits, fracture dislocations, incarcerated bone fragments, and acute protrusio should be communicated.

What to Ask

1. Are there any concomitant injuries? Hip dislocations require emergent intervention.
2. Does the patient have any neurologic deficits?
3. What is the mechanism of injury?

J.P. Johnson, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: joey.johnson12@gmail.com

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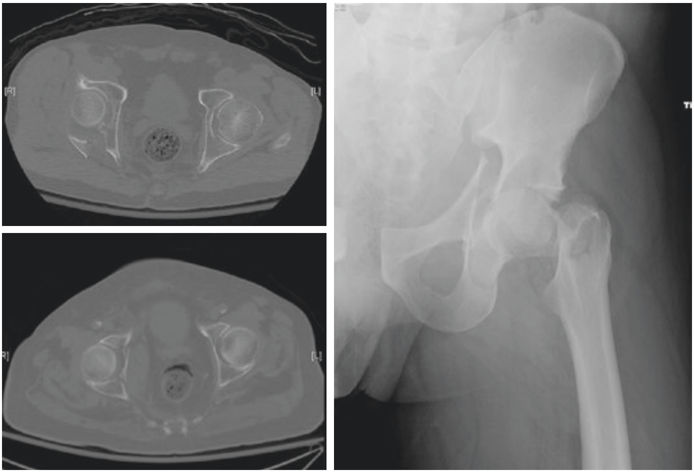

FIGURE 35.1 Representative CT and radiographic images of acetabular fractures

What to Request

1. CT scan with fine cuts and sagittal recons
2. Traction pin and supplies (when necessary)

When to Escalate

1. Any open fracture (rare) requires immediate antibiotics and operative debridement.
2. Neurologic injuries should be communicated to the attending orthopedic surgeon attending on call.
3. At some institutions, incarcerated bone fragments in the hip joint are considered operative emergencies.
4. Fracture dislocations require urgent reduction.

Imaging

1. AP of the pelvis
2. Judet views
3. CT scan of the pelvis with fine cuts and sagittal recons

Effective Communication

1. Concomitant injuries and any neurologic deficit must be communicated.
2. The Judet and Letournel classification is used to describe these fractures and should be referenced when discussing them.
3. Fracture dislocations, incarcerated bone fragments, and acute protrusion of the femoral head through the pelvis should be communicated as well.

What to Bring

1. Traction supplies when needed

Key Exam Pearls

1. Neurovascular exam – most frequently, the peroneal division of the sciatic nerve is involved in posterior fracture dislocations, evaluate for foot drop and sensation in the SP/DP distributions is essential.

Reduction

When present, fracture-dislocations require urgent reduction. The most important part of this is adequate sedation. To reduce these fractures, you must counteract some of the strongest muscles in the body; doing so without sedation is impossible and potentially dangerous for the practitioner and patient. For posterior fracture dislocations, three people are needed. The first person holds the patient's pelvis to the bed providing countertraction. The reductionist gets on the table, moves the affected extremity into 90 degrees of hip flexion and 90 degrees of knee flexion, and then pulls up behind the knee. Hip adduction is often useful. With fracture dislocations, reduction is not always felt, so radiographic evaluation and assessment of leg length and rotation is key. While the hip is being reduced, a third person should act as a spotter so the reductionist does not fall off the bed.

Anterior hip reductions generally require in-line traction alone for reduction, with countertraction applied by an assistant.

Protrusio usually requires in-line traction and constant fatigue provided by traction weights. After all reductions, the hip should be ranged through physiologic motion to assess stability. If the hip is unstable, if there are incarcerated fragments, or in the setting of protrusio, distal femoral traction should be applied (Chapter 10).

Adequate Reduction Parameters

1. Concentric reduction of the hip joint as assessed by CT scan of the pelvis

Follow-Up

1. If a dislocation is reduced, postreduction CT scan of the pelvis with fine cuts must be obtained. If this shows incarcerated fragments, distal femoral traction should be applied, and the attending orthopedic surgeon should be notified.
2. A postreduction AP of the pelvis should also be obtained.
3. Admission to orthopedics, general surgery, or ICU service as dictated by patient condition and hospital practice.

Part V
Lower Extremity Injuries

Chapter 36
Hip Dislocation

Joey P. Johnson

Keywords Hip dislocation • Sedation

Overview

Hip dislocation (Fig. 36.1) workup necessitates an evaluation of concomitant injuries, neurologic deficits, if the dislocation is primary or recurrent, the direction of dislocation, fracture dislocations/incarcerated fragments, and stability after reduction.

What to Ask

1. How long has the hip been dislocated?
2. Is the ER ready to perform a sedation to reduce the hip?
3. Are there any concomitant injuries? Posterior wall acetabular fractures are common and can predict stability after reduction.
4. What is the patient's neurologic exam? (Specifically peroneal nerve palsy for posterior foot drop/numbness)
5. What is the mechanism of injury? (High or low energy)

J.P. Johnson, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: joey.johnson12@gmail.com

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FIGURE 36.1 Representative CT and radiographic images of hip dislocation

What to Request

1. True AP and lateral of the hip to determine the direction of dislocation
2. Traction pin and supplies (needed if unstable, wise to have available)
3. Urgent sedation (never attempt reduction of a native hip without sedation)

When to Escalate

1. Neurologic injuries (always reevaluate postreduction and notify the attending surgeon if improved or persistent).
2. At some institutions, incarcerated bone fragments in the hip joint are considered operative emergencies.
3. All dislocations require urgent reduction.

Imaging

1. AP of the pelvis, lateral of the hip
2. CT scan of the pelvis with fine cuts and sagittal recons postreduction to evaluate for free fragments

Effective Communication

1. Concomitant injuries
2. Neurologic deficit
3. Primary or recurrent
4. Direction of dislocation
5. Fracture dislocations/incarcerated fragments
6. Stability after reduction

What to Bring

1. An assistant
2. Have traction supplies available

Key Exam Pearls

1. Neurovascular exam – most frequently, the peroneal division of the sciatic nerve is affected in posterior dislocations; occasionally, the femoral nerve can be involved in anterior dislocations.

2. After reduction, the hip should be ranged and assessed for stability. When taken through a physiologic range, if the hip dislocates, this is considered unstable; repeat reduction should be performed and a traction pin placed.

Reduction

The most important part of hip reduction is adequate sedation. To reduce these dislocations, you must counteract some of the strongest muscles in the body; doing so without sedation is impossible and potentially dangerous for the practitioner and patient.

For posterior fracture dislocations, three people are needed. The first person holds the patient's pelvis to the bed providing countertraction. The reductionist should stand on the bed, move the affected extremity into 90° of hip flexion and 90° of knee flexion, and then pull up behind the knee. Hip adduction assists reduction. With fracture dislocations, reduction is not always felt, so radiographic evaluation and assessment of leg length and rotation is key. Reduction of simple (non-fractured) dislocations is often palpable, visible, and audible. While the hip is being reduced, a third person should act as a spotter so that the reductionist does not fall off the bed.

Anterior hip reductions generally require longitudinal traction alone for reduction, with countertraction applied by an assistant.

Obturator dislocations require in-line traction, with countertraction applied by the assistant, and gentle adduction while maintaining adequate traction.

After all reductions, the hip should be ranged through physiologic motion to assess stability. If the hip is unstable or if there are incarcerated fragments, distal femoral traction should be applied (Chapter 10).

Adequate Reduction Parameters

1. Concentric reduction on X-ray or CT scan of the pelvis

Follow-Up

1. A postreduction AP of the pelvis should first be obtained to confirm reduction.
2. If a dislocation is reduced, postreduction CT scan of the pelvis with fine cuts must be obtained. If this shows incarcerated fragments, the patient should either be taken emergently to the OR for removal of fragments or distal femoral traction should be applied, and the attending orthopedic surgeon should be notified, depending on institutional preference.
3. Generally, with a stable, congruent hip after reduction and no associated fracture, the patient can be made toe-touch weight bearing and follow-up in 1–2 weeks.
4. Posterior hip dislocations are usually placed in a knee immobilizer, given posterior precautions. Anterior hip dislocations are given anterior precautions.

Chapter 37
Femoral Head and Neck Fractures in the Young Patient (<65)

Joey P. Johnson

Keywords Femoral head fracture • Femoral neck fracture • Young patients • Pauwels classification

Overview

Described by the Pauwels classification, femoral neck fracture workup must include evaluation of concomitant injuries and presence of dislocation.

What to Ask

1. Are there any concomitant injuries? These are often seen with femoral shaft fractures.
2. What is the mechanism of injury?

J.P. Johnson, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: joey.johnson12@gmail.com

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What to Request

1. AP pelvis, AP, and lateral of the hip.
2. Sedation (if associated with a dislocation) – never attempt reduction of a femoral neck fracture-dislocation without discussing it with the orthopedic surgeon on call!

When to Escalate

1. Immediately – when you see this injury, call the orthopedic attending on call.
2. Because of the high risk of avascular necrosis of the femoral head these fractures are arguably surgical emergencies.
3. All dislocations require urgent reduction, but for this particular fracture, this may be done in the OR at the surgeon's discretion.

Imaging

1. AP of the pelvis, lateral of the hip
2. CT scan of the pelvis with fine cuts and sagittal recons (postreduction)

Effective Communication

1. Concomitant injuries must be communicated.
2. If a dislocation is present, this must be communicated.
3. Pauwels classification is often used for femoral neck fractures, but what must be known is the verticality of the fracture, and whether or not it is displaced.

Key Exam Pearls

1. Neurovascular exam.
2. For associated dislocations: After reduction, the hip should be ranged and assessed for stability. When taken through a physiologic range, if the hip dislocates, this is considered unstable, repeat reduction should be performed, and a traction pin placed.

Reduction

1. If dislocated, discuss with the orthopedic surgeon on call before attempting a reduction.

Follow-Up

1. This is a surgical urgency or emergency depending on your particular institution; always discuss this injury with the orthopedic surgeon on call prior to deciding on a treatment plan.

Chapter 38
Intertrochanteric, Basicervical, and Femoral Neck Fracture in the Geriatric Patient

Joey P. Johnson

Keywords Intertrochanteric fracture • Basicervical fracture • Femoral neck fracture • Geriatric

Overview

Comprehensive evaluation of intertrochanteric (Fig. 38.1), basicervical, and femoral neck (Fig. 38.2) fractures in the geriatric patient includes patient's baseline ambulatory status, medical comorbidities, preoperative optimization, displaced or valgus impacted fracture pattern, and concomitant injuries.

What to Ask

1. What is the mechanism of injury?
2. Are there any associated injuries? Rib fractures may occur and change the patient's disposition.

J.P. Johnson, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: joey.johnson12@gmail.com

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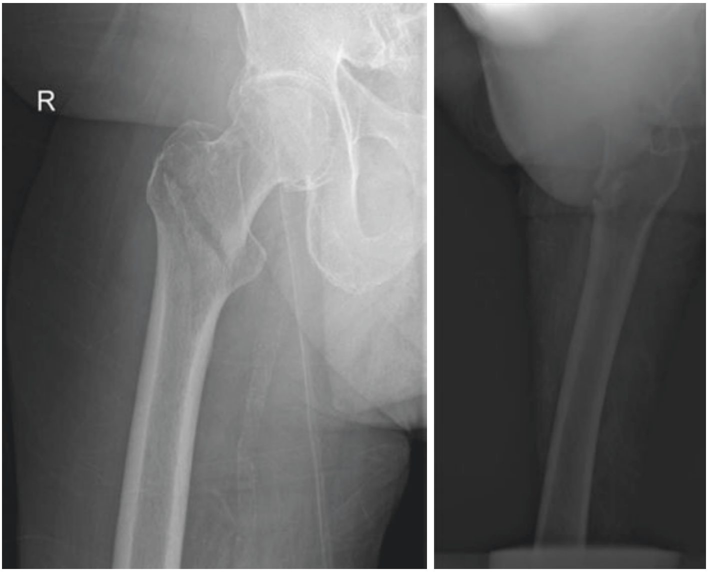

FIGURE 38.1 Representative radiographic images of intertrochanteric fractures

3. What are the patient's medical comorbidities?
4. Was the fall a syncopal fall, and have medical causes for the fall been evaluated?

What to Request

1. Preoperative workup (labs, EKG, CXR)
2. X-rays of the pelvis, hip, and entire length of the femur

When to Escalate

1. Associated polytrauma

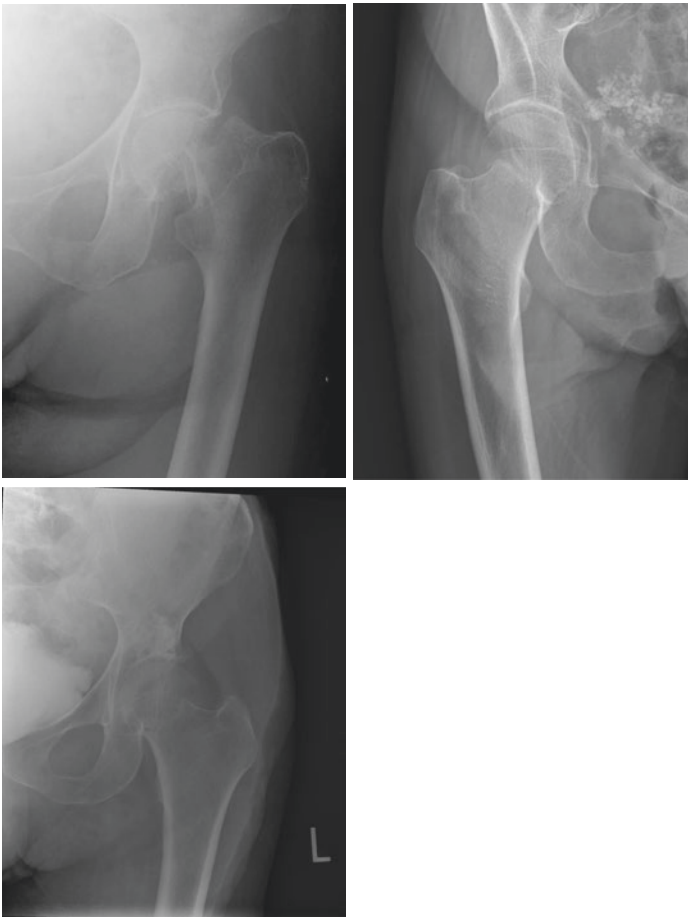

FIGURE 38.2 Representative radiographic images of femoral neck fractures

Imaging

1. AP pelvis, AP, and lateral views of the hip are necessary to determine whether the fracture is displaced or valgus impacted. (Femoral neck)

2. Oblique views may provide additional information.
3. Advanced imaging (CT) is generally not required.
4. Differentiating these fractures is needed for operative planning; however, the ER course is typically the same for all three.

Effective Communication

1. Neck versus intertrochanteric fracture (may require a traction-internal rotation view to be sure)
2. Displaced or valgus impacted
3. Concomitant injuries
4. Medical comorbidities
5. Medical clearance status
6. Patient's baseline ambulatory status

What to Bring

1. These fractures typically require no ER intervention.

Key Exam Pearls

1. A standard neurovascular exam is appropriate.

Adequate Reduction Parameters

1. Reduction is not required in the emergency department.

Follow-Up

1. Remain non-weight bearing; a Foley catheter is required if the patient is unable to use a bedpan/urinal.

2. Admission is required, usually for operative intervention to whatever service is appropriate at your hospital.
3. Medical optimization and risk stratification should be obtained as soon as it is feasible to allow for rapid operative intervention.

Chapter 39
Subtrochanteric Femur Fractures (Proximal 5 cm of Femoral Shaft)

Jonathan D. Hodax

Keywords Subtrochanteric femur fracture

Overview

Complete evaluation of subtrochanteric femur fractures (Fig. 39.1) includes neurovascular compromise, open versus closed, degree of shortening, associated injuries, displaced/non-displaced, results of CT of femoral neck, and existing hardware.

What to Ask

1. Are there any open wounds? These injuries are often high-energy trauma.
2. Are there any associated injuries?
3. Is there a current concern for compartment syndrome?

J.D. Hodax, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: jdhodax@gmail.com

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FIGURE 39.1 Radiographic image of subtrochanteric femur fracture

What to Request

1. Ensure leg is stabilized and iced immediately.
2. X-rays of the knee, femur, and hip to evaluate femur.
3. Trauma series (X-ray chest and pelvis) appropriate if high energy.
4. CT hip (see Imaging, below).
5. Be prepared for conscious sedation if traction needed (see Reduction).

When to Escalate

1. Open fractures: should be irrigated and stabilized in ED and receive antibiotics (will require formal irrigation and debridement in OR).
2. Pain out of proportion/paresthesia: compartment syndrome requires emergent fasciotomy in OR.
3. Vascular compromise: altered pulse exam or ABI<0.8 (or 0.2 less than contralateral) is suggestive of vascular injury.
4. Prior to placing skeletal traction (depending on institutional policy).

Imaging

1. AP and lateral of the femur, knee, and hip are necessary for evaluation.
2. CT imaging of the femoral neck is appropriate to rule out an occult fracture (may vary depending on institutional policies).
3. Advanced imaging (CT) is appropriate if highly comminuted or concern for intra-articular extension.
4. Postreduction X-rays of the fracture and pin if skeletal traction required.

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Degree of shortening
4. Associated injuries
5. Displaced/non-displaced
6. Results of CT of femoral neck
7. Associated hardware (knee or hip replacement, plate/nail in femur)

What to Bring

1. Traction supplies if closed and shortened or if not able to urgently take to OR

Key Exam Pearls

1. As with shaft fractures, radiographic evaluation of the femoral neck for fracture is essential.
2. Sensation (saphenous/sural/deep and superficial peroneal/tibial n.).
3. Motor (extensor hallucis longus/flexor halluces longus/gastrocnemius/tibialis anterior).
4. Vascular exam (perform ABIs if concerned for vascular injury).
5. Evaluate all wounds: dermal violation raises suspicion for open fracture.

Reduction

Subtroch femur fractures (fractures within 5 cm of the lesser trochanter) are often high-energy injuries and associated with multisystem trauma. Open fractures and concern for compartment syndrome are indications for emergent operative care in the hemodynamically stable patient. Multisystem injuries should be discussed and the patient treated in conjunction with trauma surgery services.

For patients who are not emergently going to undergo operative fixation, proximal tibial skeletal traction is often placed in the emergency department (see Chapter 10 for details).

Adequate Reduction Parameters

1. Skeletal traction is often required for temporary reduction if urgent operative intervention is not available.

Follow-Up

1. These fractures are appropriate for admission and operative treatment.

Chapter 40
Adult Femoral Shaft Fractures

Jonathan D. Hodax

Keywords Femoral shaft fracture • Adult

Overview

Complete evaluation of adult femoral shaft fractures (Fig. 40.1) includes neurovascular compromise, open versus closed fracture, degree of shortening, associated injuries, displaced versus non-displaced, results of CT femoral neck, and existing hardware.

What to Ask

1. Are there any open wounds (often high-energy trauma)?
2. Are there any associated injuries?
3. Is there a concern for compartment syndrome?

J.D. Hodax, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: jdhodax@gmail.com

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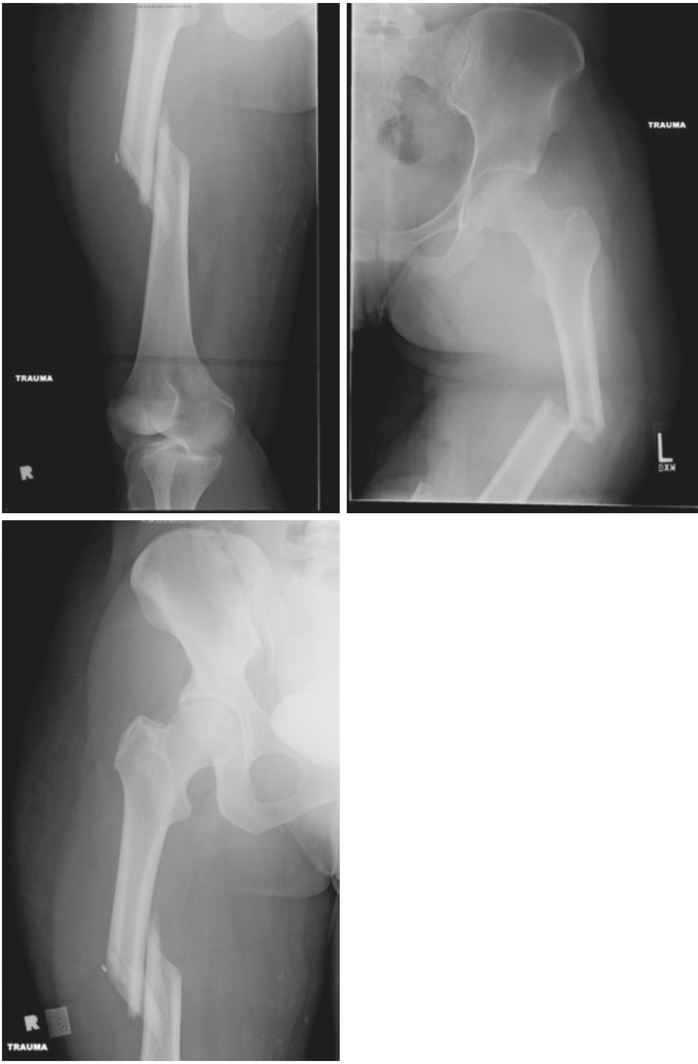

Figure 40.1 Representative radiographic images of femoral shaft fractures in skeletally mature patients

What to Request

1. Ensure the leg is stabilized and iced immediately.
2. X-rays of the knee, femur, and hip to evaluate femur.
3. Trauma series (X-ray chest and pelvis) appropriate if high energy.
4. CT hip (see Imaging, below).
5. Be prepared for conscious sedation if traction needed (see Reduction).

When to Escalate

1. Open fractures: should be irrigated and stabilized in ED and receive antibiotics (will require formal irrigation and debridement in OR).
2. Pain out of proportion/paresthesia: compartment syndrome requires emergent fasciotomy in OR.
3. Vascular compromise: altered pulse exam or ABI<0.8 (or 0.2 less than contralateral) is suggestive of vascular injury.
4. Prior to placing skeletal traction (depending on institutional policy).

Imaging

1. AP and lateral of the femur, knee, and hip are necessary for evaluation.
2. CT imaging of the femoral neck with 2 mm cuts is appropriate to rule out an occult fracture (may vary depending on institutional policies).
3. Advanced imaging (CT) is appropriate if highly comminuted or concern for intra-articular extension.
4. Postreduction X-rays of the fracture and pin if skeletal traction required.

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Degree of shortening
4. Associated injuries
5. Displaced/non-displaced
6. Results of CT of femoral neck
7. Associated hardware (knee or hip replacement, plate/nail in femur)

What to Bring

1. Traction supplies if closed and shortened or if not able to urgently take to OR

Key Exam Pearls

1. There is a high incidence of missed femoral neck fractures associated with shaft fractures. Fine cut CT and careful review of imaging is essential!
2. Sensation (saphenous/sural/deep and superficial peroneal/tibial n.).
3. Motor (extensor hallucis longus/flexor halluces longus/gastrocnemius/tibialis anterior).
4. Vascular exam (perform ABIs if concerned for vascular injury).
5. Evaluate all wounds: dermal violation raises suspicion for open fracture.

Reduction

Femoral shaft fractures are often high-energy injuries and associated with multisystem trauma. Open fractures, traumatic arthrotomies, and concern for compartment syndrome are all indications for emergent operative care in the hemodynamically stable patient. Multisystem injuries should be discussed and the patient treated in conjunction with trauma surgery services.

For patients who are not emergently going to undergo operative fixation, proximal tibial skeletal traction is often placed in the emergency department.

Adequate Reduction Parameters

1. Fracture should be grossly aligned; however, perfection is not required if operative intervention will be performed.

Follow-Up

1. These fractures are appropriate for admission and operative treatment.

Chapter 41
Pediatric Femur Fractures

Jonathan D. Hodax

Keywords Femur fractures • Pediatric

Overview

Pediatric femur fracture (Fig. 41.1) workup includes evaluation of open versus closed, neurovascular compromise, degree of shortening, associated injuries, displaced/non-displaced, and physeal involvement.

What to Ask

1. Are there any open wounds?
2. Are there any associated injuries?
3. Is there concern for compartment syndrome?
4. Is there any evidence of physeal involvement?
5. Is there any concern for non-accidental trauma (abuse)?

J.D. Hodax, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: jdhodax@gmail.com

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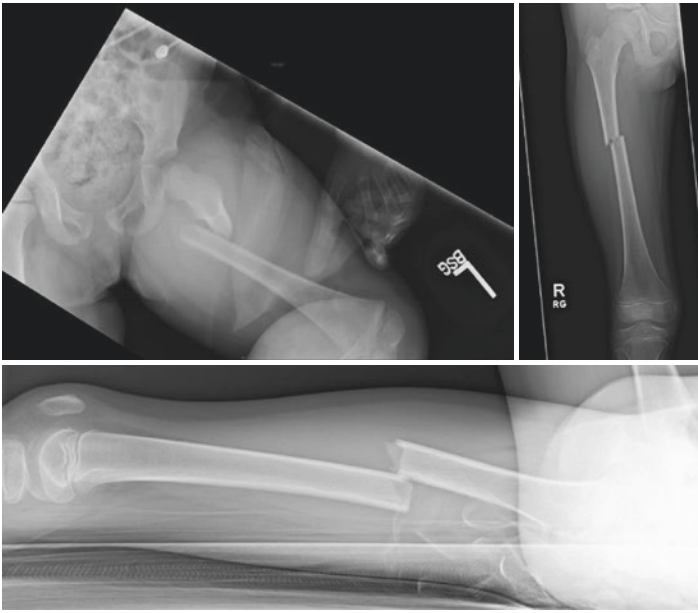

FIGURE 41.1 Representative radiographic images of femur fractures in skeletally immature patients

What to Request

1. Ensure the leg is stabilized and iced immediately.
2. X-rays of the knee, femur, and hip to evaluate femur.
3. Trauma series (X-ray chest and pelvis) appropriate if high energy.
4. Prepare patient/room for conscious sedation.

When to Escalate

1. Open fractures: should be irrigated and stabilized in ED and receive antibiotics (will require formal irrigation and debridement in OR).

2. Pain out of proportion/paresthesia: compartment syndrome requires emergent fasciotomy in OR.
3. Vascular compromise: altered pulse exam or ABI<0.8 (or 0.2 less than contralateral) is suggestive of vascular injury.

Imaging

1. AP and lateral of the femur, knee, and hip are necessary for evaluation.
2. In high-energy trauma, CT imaging of the femoral neck is appropriate to rule out an occult fracture.
3. Advanced imaging (CT) is appropriate if highly comminuted or concern for intra-articular extension.
4. Postreduction X-rays.

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Degree of shortening
4. Associated injuries
5. Displaced/non-displaced
6. Physeal involvement

What to Bring

1. Splinting or casting supplies (long leg splint/cast, Chapter 6)

Key Exam Pearls

1. There is a high incidence of missed femoral neck fractures associated with shaft fractures. Fine-cut CT and careful review of imaging are appropriate but should be considered carefully in pediatric population.

2. Sensation (saphenous/sural/deep and superficial peroneal/tibial n.).
3. Motor (extensor hallucis longus/flexor halluces longus/gastrocnemius/tibialis anterior).
4. Vascular exam (perform ABIs if concerned for vascular injury).
5. Evaluate all wounds: dermal violation raises suspicion for open fracture.

Reduction

Pediatric femoral shaft fractures range from non-displaced spiral fractures and mild physeal injuries all the way to displaced shaft fractures and complete physeal dissociations. Conscious sedation is typically appropriate in most hospitals before manipulating the extremity.

Open fractures and intra-articular fractures are typically operative and should be treated with splinting, ice, elevation, and admission for operative intervention. Length, alignment, and rotation should be grossly restored, and a careful neurovascular exam should be documented before and after splinting.

Closed fractures can often be treated by nonoperative means but may require long-leg casting with the addition of a pelvic band. Long oblique or otherwise unstable fractures may require admission and treatment in the operating room. Treatment varies by institution and should be decided after a careful evaluation of the available resources.

Adequate Reduction Parameters

1. Fracture should be grossly aligned; however, perfection is not required if operative intervention will be performed.

Follow-Up

1. Should be determined after discussion with an attending.

Chapter 42
Distal Femur Fractures

Jonathan D. Hodax

Keywords Distal femur fracture

Overview

Comprehensive workup for distal femur fractures (Fig. 42.1) includes evaluation of open versus closed fractures, neurovascular compromise, intra-articular versus extra-articular involvement, stability after reduction, associated injuries, displaced versus non-displaced, and existing hardware.

What to Ask

1. Open wounds (possible open fracture)
2. Associated injuries

J.D. Hodax, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: jdhodax@gmail.com

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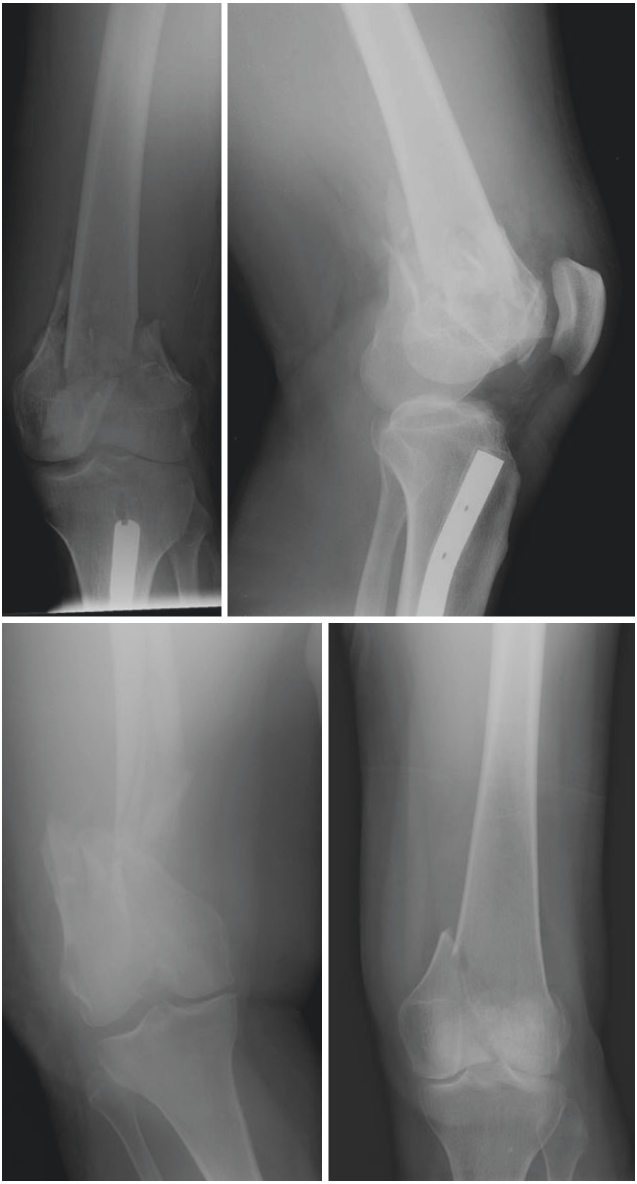

FIGURE 42.1 Representative AP and lateral radiographs of distal femur fractures

What to Request

1. Ensure the leg is stabilized, elevated, and iced in grossly normal alignment immediately.
2. X-rays of the knee, femur, and hip.
3. Trauma series (X-ray of the chest and pelvis) appropriate if high energy.
4. Be prepared for conscious sedation if traction is needed (see Reduction).

When to Escalate

1. Open fractures: should be irrigated and stabilized in ED and receive antibiotics (will require formal irrigation and debridement in OR).
2. Pain out of proportion/paresthesia: compartment syndrome requires emergent fasciotomy in OR.
3. Vascular compromise: altered pulse exam or ABI<0.8 (or 0.2 less than contralateral) is suggestive of vascular injury.

Imaging

1. AP and lateral of the femur, knee, and hip are necessary for evaluation.
2. Evaluate carefully for concomitant femoral neck fracture.
3. Advanced imaging (CT) is generally needed for operative planning.
4. Postreduction X-rays of the knee if reduction required.

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Intra-articular versus extra-articular
4. Stability after reduction

5. Associated injuries
6. Displaced/non-displaced
7. Associated hardware (knee or hip replacement and plate/nail in femur)

What to Bring

1. Knee immobilizer
2. Traction supplies if shortening is present
3. Fluoroscopy if reduction or traction required

Key Exam Pearls

1. Sensation (saphenous/sural/deep and superficial peroneal/tibial n.).
2. Motor (extensor hallucis longus/flexor hallucis longus/gastrocnemius/tibialis anterior).
3. Vascular exam (perform ABIs if fracture displaced or if concerned for vascular injury).
4. Evaluate all wounds: dermal violation raises suspicion for open fracture.
5. Free air in knee joint on CT suggests open fracture.

Reduction

In the setting of low-energy trauma, these fractures are often minimally displaced and no reduction is required. Such fractures may be placed into a knee immobilizer, iced, and elevated until operative intervention.

Open fractures should be operated on acutely, and a knee immobilizer is appropriate after brief irrigation and stabilization with a knee immobilizer.

Displaced, closed fractures may be treated multiple ways. If an operating room is available and an attending surgeon favors urgent fixation, a knee immobilizer is often adequate.

Fractures that are shortened and cannot be operated on acutely often require placement of *skeletal traction*. The proximal tibia is the preferred site in the absence of ipsilateral tibia fracture. (See Chapter 10 for details of how to perform skeletal traction.)

Adequate Reduction Parameters

1. Shortening <5 mm
2. Grossly normal alignment until operative fixation

Follow-Up

1. These fractures are appropriate for admission and operative treatment.

Chapter 43
Patellar Dislocation

Jonathan D. Hodax

Keywords Patellar dislocation • Sunrise

Overview

Complete workup for patellar dislocation includes evaluation of first versus recurrent dislocation, open versus closed injury, associated injuries, and spontaneous versus manual reduction.

What to Ask

1. Are there any fractures or open wounds? Possible open fracture and/or traumatic arthrotomy?
2. Is the patella currently dislocated, or is it now reduced?
3. Have any attempts at reduction already been performed?
4. Is there an IV in place to provide appropriate analgesia and sedation if needed?

J.D. Hodax, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: jdhodax@gmail.com

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What to Request

1. Ensure the leg is stabilized, elevated, and iced immediately.
2. X-rays of the knee in AP and lateral.
3. IV access in place, initiate antibiotics if concern for open fracture.

When to Escalate

1. Open injuries: should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR)
2. Concern for a tibiofemoral dislocation (see Knee Ligament Injuries)

Imaging

1. AP and lateral X-rays are appropriate if the patella is still dislocated. After reduction these should be repeated along with a "sunrise" patella view of the knee.
2. Evaluate imaging carefully for intra-articular air.
3. *Don't miss*: a bony avulsion from medial femoral condyle (MPFL avulsion).

Effective Communication

1. Open versus closed
2. First versus recurrent dislocation
3. Associated injuries
4. Spontaneous versus manual reduction

What to Bring

1. Knee immobilizer
2. Arthrotomy injection kit if concerned for traumatic arthrotomy

Key Exam Pearls

1. Sensation (saphenous/sural/deep and superficial peroneal/tibial n.).
2. Motor (extensor hallucis longus/flexor hallucis longus/gastrocnemius/tibialis anterior).
3. Evaluate all wounds: dermal violation raises suspicion for open injury.

Reduction/Treatment

Patellar dislocations are often reduced before arrival to the ED. Often an osteochondral fragment of the lateral femoral condyle is broken off during a forceful reduction, so persistent dislocations should be pretreated with mild sedation. Reduction is performed by gently extending the knee, not by pushing on the patella.

A careful examination of the ligamentous structures of the knee (ACL, PCL, MCL, LCL, PLC) is appropriate if the patient is able to tolerate.

Follow-Up

1. Weight bearing as tolerated in a knee immobilizer is appropriate.
2. Follow-up with an orthopedic surgeon within 1 week.

Chapter 44
Ligament Injuries of the Knee

Jonathan D. Hodax

Keywords Ligament • Knee • ACL • MCL • LCL

Overview

Complete workup for ligament injuries of the knee (Fig. 44.1) includes evaluation of open versus closed injury, neurovascular status, associated injuries, and spontaneous versus manual reduction.

What to Ask

1. Are there any open wounds (possible traumatic arthrotomy)?
2. Are there associated injuries?
3. What is the vascular exam (HIGH index of suspicion for vascular injury in multi-ligament knee injuries)?
4. Was the knee ever dislocated? Is the knee currently dislocated?

J.D. Hodax, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: jdhodax@gmail.com

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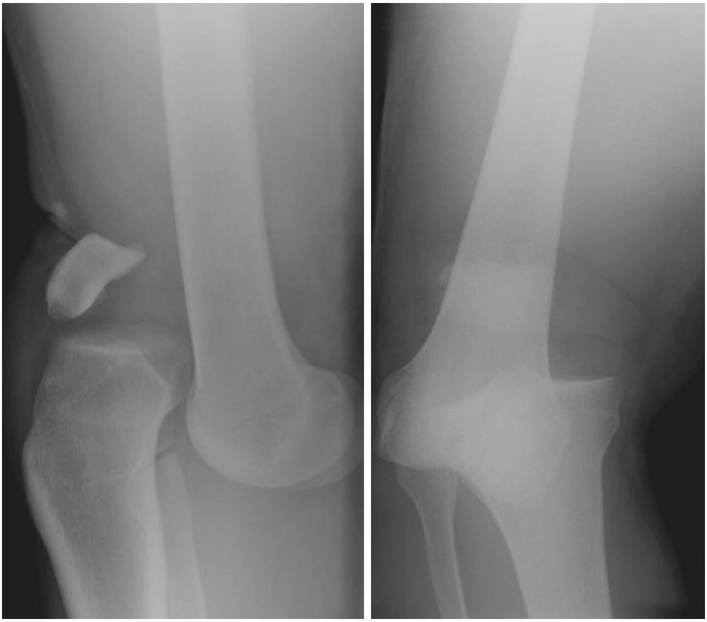

Figure 44.1 Representative radiographs of a patient with a multi-ligament injury of the knee (knee dislocations)

What to Request

1. Ensure the leg is stabilized, elevated, and iced immediately.
2. X-rays of the knee in AP and lateral.
3. IV access in place, initiate antibiotics if concern for open fracture.
4. Doppler for ABI/vascular exam.

When to Escalate

1. Open injuries: should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR)
2. Neurologic or vascular compromise
3. Dimpling of the skin after reduction or an irreducible dislocation should promptly be escalated to an attending.

Imaging

1. AP, lateral of the knee. Obliques may lend additional information but not required acutely.
2. Evaluate imaging carefully for intra-articular air.
3. *Don't miss*: dome-shaped fragment proximal to the fibular head (bony avulsion of LCL and associated tendons, known as an arcuate fracture).

Effective Communication

1. Open versus closed
2. Neurovascular status
3. Associated injuries
4. Spontaneous versus manual reduction

What to Bring

1. Knee immobilizer
2. Arthrotomy injection kit if concerned for traumatic arthrotomy

Key Exam Pearls

1. Sensation (saphenous/sural/superficial and deep peroneal, tibial).
2. Motor (extensor hallucis longus/flexor hallucis longus/gastrocnemius/tibialis anterior).
3. Evaluate all wounds: dermal violation raises suspicion for open injury.

Reduction/Treatment

Ligamentous injuries about the knee can typically be divided into single-ligament injuries (such as an ACL tear) or knee dislocation equivalents. While an ACL tear may have an

MCL sprain associated, significant injury to two or more ligaments is typically considered a knee dislocation (even if the patient presents with the joint in correct alignment!).

Knee injuries with a single ligament disrupted are often given a knee immobilizer or hinged knee brace and made weight bearing as tolerated. Providing a well-fit hinged knee brace and promoting motion can benefit the patient by helping them decrease swelling and effusion and begin early retraining of proprioception, often referred to as “prehab.”

Injuries in which there is evidence of multiple ligament injuries, either by MRI, plain film, or physical exam, should be considered high-priority consults. If the knee is actively dislocated it should be reduced as soon as possible. Typically pain control and axial traction are adequate but some light sedation may be required. ABIs should be tested after reduction or in the knee presenting reduced as there is a high incidence of popliteal artery injury. Careful neurologic exam is key, as the peroneal (common or its branches) may be injured. These patients should typically be placed into a knee immobilizer and triaged according to their vascular status and stability. External fixation may be required to maintain stability. Patients should be evaluated for compartment syndrome serially after presentation.

Follow-Up

1. Single-ligament injuries can typically be discharged to follow up within 1 week.
2. Multiply injured knees should be admitted for observation of compartment syndrome.

Chapter 45
Patellar Fractures and Extensor Mechanism Injuries

Jonathan D. Hodax

Keywords Patellar fracture

Overview

Comprehensive workup for extensor mechanism injuries – including patella fracture (Fig. 45.1), quadriceps tendon tear, and patellar tendon tear-includes evaluation of open versus closed injury, neurovascular status, associated injuries, and displacement. Patients with partial injuries, or those with some bony or soft-tissue attachment maintaining continuity, may still be able to perform a straight leg raise. Those with complete injuries typically cannot.

What to Ask

1. Are there any open wounds? Possible traumatic arthrotomy/open fracture?
2. Associated injuries?

J.D. Hodax, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: jdhodax@gmail.com

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FIGURE 45.1 Representative AP, lateral, and “sunrise” radiographs of patellar fractures

What to Request

1. Ensure the leg is stabilized, elevated, and iced immediately.
2. X-rays of the knee in AP and lateral.
3. IV access in place, initiate antibiotics if concern for open fracture.

When to Escalate

1. Open injuries: should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR)
2. Associated polytrauma

Imaging

1. AP, lateral of the knee. Obliques may lend additional information but not required acutely. Patella baja (a low-riding patella) is consistent with quadriceps tendon tear, while patella alta (a high-riding patella) is consistent with a patellar tendon rupture.
2. Evaluate imaging carefully for intra-articular air.
3. Beware: a bipartite patella is a normal variant where two ossification centers of the patella never fuse together. X-rays will demonstrate a smooth, evenly spaced line separating the superolateral patella from the remainder of the bone.

Effective Communication

1. Open versus closed
2. Neurovascular status
3. Associated injuries
4. Spontaneous versus manual reduction

What to Bring

1. Knee immobilizer
2. Arthrotomy injection kit if concerned for traumatic arthrotomy

Key Exam Pearls

1. Sensation (saphenous/sural/superficial and deep peroneal, tibial).
2. Motor (extensor hallucis longus/flexor hallucis longus/gastrocnemius/tibialis anterior).
3. Evaluate all wounds: dermal violation raises suspicion for open injury.

Reduction/Treatment

Nondisplaced patellar fractures, most specifically those with minimal gapping at the articular surface, can often be treated nonoperatively. A knee immobilizer is appropriate initially and can be followed by casting after initial swelling stabilizes. Displaced or comminuted fractures may be more appropriate for surgical intervention but do not require an acute reduction. Patellar tendon or quadriceps tendon tears that are complete (patient cannot perform a straight leg raise or cannot maintain <30° knee extension) typically require surgical treatment.

Follow-Up

1. Open fractures should be admitted for urgent operative management.
2. Displaced, comminuted, or otherwise complex fractures may be admitted or followed closely for surgical intervention.
3. Minimally displaced fractures and tendon injuries should follow up within 7–10 days to evaluate for late displacement. Crutches and toe-touch weight bearing are appropriate.

Chapter 46
Tibial Plateau Fractures

Jonathan D. Hodax

Keywords Tibial plateau • Schatzker classification

Overview

Comprehensive tibial plateau fracture (Fig. 46.1) workup includes evaluation of open versus closed injury, neurovascular status, associated injuries, spontaneous versus manual reduction, evaluation for compartment syndrome, and Schatzker classification.

What to Ask

1. Are there any open wounds (possible open fracture or traumatic arthrotomy)?
2. Are there any associated injuries?
3. What is the patient's vascular exam? Have a high index of suspicion for vascular injury if medial plateau involved!

J.D. Hodax, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: jdhodax@gmail.com

J.D. Hodax et al. (eds.), *The Orthopedic Consult Survival Guide*, DOI 10.1007/978-3-319-52347-7_46,

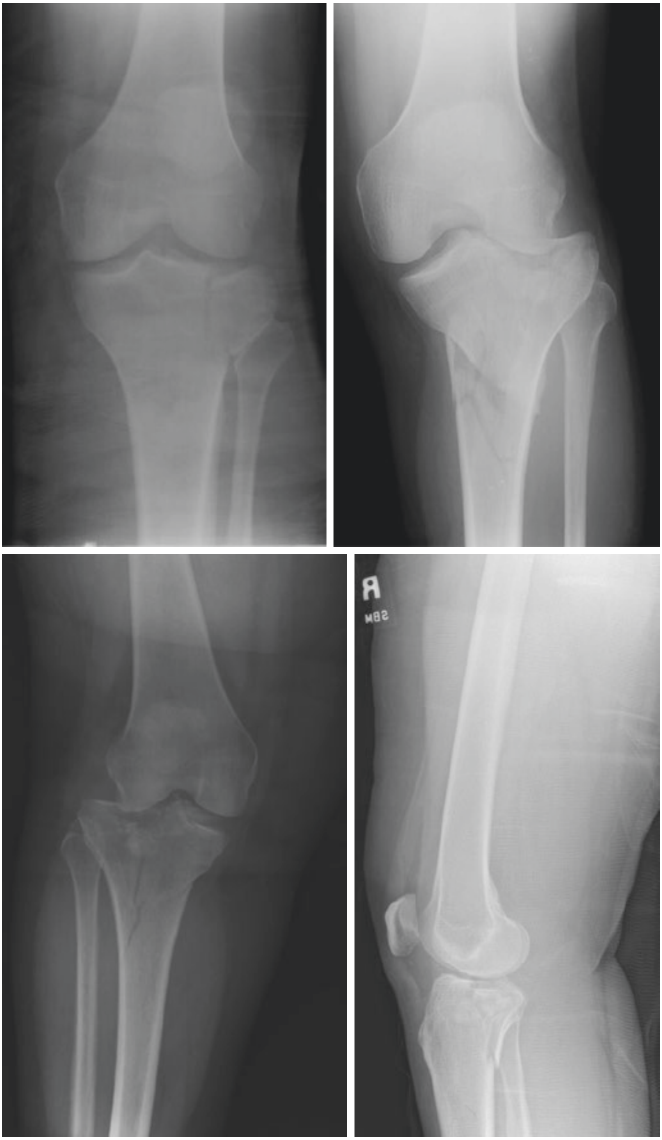

Figure 46.1 Representative AP and lateral radiographic images of tibial plateau fractures

What to Request

1. Ensure the leg is stabilized, elevated, and iced immediately. This can help to reduce the risk of compartment syndrome.
2. X-rays of the knee and tibia in AP and lateral.
3. IV access in place, initiate antibiotics if concern for open fracture.
4. Doppler for ABI/vascular exam.

When to Escalate

1. Open injuries: should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR)
2. Neurologic or vascular compromise, or concern for compartment syndrome

Imaging

1. Knee and tibia films.
2. Evaluate imaging carefully for intra-articular air.
3. *Don't miss*: associated axial load injuries. Spinal compression fractures, femoral neck fracture, or Pilon fracture.

Effective Communication

1. Open versus closed.
2. Neurovascular status.
3. Associated injuries.
4. Spontaneous versus manual reduction.
5. The Schatzker classification is often used to describe these injuries.

What to Bring

1. Knee immobilizer
2. Arthrotomy injection kit if concerned for traumatic arthrotomy

Key Exam Pearls

1. Sensation (saphenous/sural/superficial and deep peroneal, tibial).
2. Motor (extensor hallucis longus/flexor hallucis longus/gastrocnemius/tibialis anterior).
3. Evaluate all wounds: dermal violation raises suspicion for open injury.

Reduction/Treatment

These injuries rarely require ER reduction. The exception to this rule is a bicondylar plateau injury with significant shortening, which should be placed in skeletal traction (calcaneal).

Follow-Up

1. Minimally displaced injuries in patients able to tolerate non-weightbearing with crutches may be discharged to follow up acutely for surgical treatment.
2. Most patients will require admission for operative treatment.

Chapter 47
Adult Tibial Shaft Fractures

Jonathan D. Hodax

Keywords Tibial shaft • Adult

Overview

Adult tibial shaft fracture (Fig. 47.1) workup includes evaluation of open versus closed injury, neurovascular compromise, intra-articular versus extra-articular, stability after reduction, associated injuries, risk for compartment syndrome, and displaced versus non-displaced.

What to Ask

1. Are there any open wounds (open fractures range from <1 cm to near amputation) or any sites where skin is tenting/threatened?
2. Are there any associated injuries?
3. Is IV access in place? Immediately initiate antibiotics if there is any concern for open fracture.

J.D. Hodax, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: jdhodax@gmail.com

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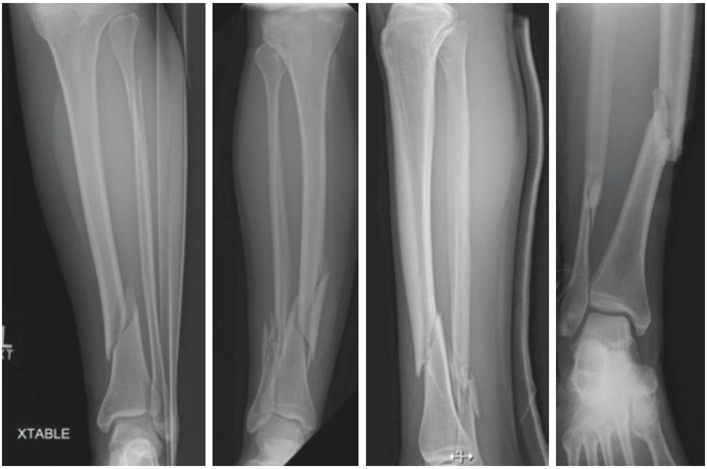

FIGURE 47.1 Representative radiographs of adult tibial shaft fractures

4. Does the patient have pain out of proportion or paresthesia? Should raise concern for compartment syndrome.

What to Request

1. Ensure the leg is stabilized, elevated, and iced immediately.
2. X-rays of the tibia, knee, and ankle.

When to Escalate

1. Open fractures: should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR)
2. Compartment syndrome: requires emergent fasciotomies

Imaging

1. AP and lateral views of the tibia are necessary for evaluation.
2. CT is appropriate if there is concern for intra-articular extension.
3. Postreduction X-rays of the tibia if reduction is performed.

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Intra-articular versus extra-articular
4. Stability after reduction
5. Associated injuries
6. Displaced/non-displaced

What to Bring

1. Casting/splinting material (see long leg splint or cast Chapter 6)
2. Fluoroscopy if reduction required

Key Exam Pearls

1. Sensation (saphenous/sural/superficial and deep peroneal, tibial).
2. Motor (extensor hallucis longus/flexor hallucis longus/gastrocnemius/tibialis anterior).
3. Evaluate all wounds: dermal violation raises suspicion for open fracture.
4. Deep peroneal n. paresthesia (first web space) or pain with passive motion of great toe suggests compartment syndrome.

Reduction/Treatment

Length stable (fractures that are transverse) fractures may be treated with a long leg cast with the knee at 30–45° of flexion. Cast treatment should be avoided if there is significant soft tissue injury, concern for development of compartment syndrome, an oblique fracture pattern, or in the setting of polytrauma.

Any patient may be temporized with a long splint. Typically, this begins just distal to the gluteal folds and extends to the toes, and side gussets should be used to control for rotation. Splinting allows for easier observation, takes less time, and can easily be loosened if compartment syndrome is a concern.

Adequate Reduction Parameters

1. Varus/valgus: within 5° of anatomic alignment.
2. Procurvatum/recurvatum (flexion/extension): within 10° of anatomic alignment.
3. Note that fractures with an intact fibula tend toward varus, and fractures of both bones tend toward valgus.
4. If the patient is being admitted for operative fixation, the reduction does not have to meet such strict standards; however, care should be taken to reduce any fragment that places pressure on the skin.

Follow-Up

1. In some rare situations, patients without risk for compartment syndrome may be casted and followed up with an orthopedic surgeon within 1 week.
2. Often admitted for operative intervention or observed for compartment syndrome.

Chapter 48
Pediatric Tibial Shaft Fractures

Jonathan D. Hodax

Keywords Tibial shaft • Pediatric

Overview

Complete pediatric tibial shaft fracture (Fig. 48.1) workup includes evaluation of open versus closed injury, neurovascular compromise, intra-articular versus extra-articular, stability after reduction, associated injuries, and displaced/non-displaced.

What to Ask

1. Open wounds (possible open fracture) or any sites where skin is tenting/threatened
2. Associated injuries
3. Pain out of proportion or paresthesia: concern for compartment syndrome
4. If a cast or reduction is needed, in the patient NPO and ready for sedation?

J.D. Hodax, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: jdhodax@gmail.com

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Figure 48.1 Representative radiographs of pediatric tibial shaft fractures

What to Request

1. Ensure the leg is stabilized, elevated, and iced immediately.
2. X-rays of the tibia, knee, and ankle.
3. IV access in place for conscious sedation and to initiate antibiotics if concern for open fracture.

When to Escalate

1. Open fractures: should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR)
2. Compartment syndrome: requires emergent fasciotomies

Imaging

1. AP and lateral views of the tibia are necessary for evaluation.
2. CT is appropriate if there is concern for intra-articular extension.
3. Postreduction X-rays of the tibia if reduction is performed.

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Intra-articular versus extra-articular
4. Stability after reduction
5. Associated injuries
6. Displaced/non-displaced

What to Bring

1. Casting/splinting material (see long leg splint or cast Chapter 6)
2. Fluoroscopy if reduction required

Key Exam Pearls

1. Sensation (saphenous/sural/superficial and deep peroneal, tibial).
2. Motor (extensor hallucis longus/flexor hallucis longus/gastrocnemius/tibialis anterior).
3. Evaluate all wounds: dermal violation raises suspicion for open fracture.
4. Deep peroneal n. paresthesia (first web space) or pain with passive motion of great toe suggests compartment syndrome.

Reduction/Treatment

In young pediatric patients (2–3-year-olds), non-displaced spiral tibial shaft fractures are common. These can typically be placed in a long leg cast with light sedation. Even patients who have minimal pain should be partially sedated, for example, with intranasal midazolam in order to allow for appropriate casting.

In more adult-type injuries, the reduction and treatment protocol are similar to that for adults.

Adequate Reduction Parameters

1. Varus/valgus: within 5° of anatomic alignment.
2. Procurvatum/recurvatum (flexion/extension): within 10° of anatomic alignment.
3. Note that fractures with an intact fibula tend toward varus, and fractures of both bones tend toward valgus.

Follow-Up

1. Low-energy injuries may be casted and discharged to follow up.
2. Displaced, open, or high-energy injuries should be admitted for observation and/or intervention.

Chapter 49
Pilon (Axial Load) Ankle Fractures

Seth O'Donnell and Joey P. Johnson

Keywords Pilon • Axial load • Ankle

Overview

Pilon fractures (Fig. 49.1) are high energy injuries. Workup includes evaluation of open versus closed injury, neurovascular compromise, compartment assessment, intra-articular versus extra-articular fracture lines, impaction at the joint surface, and associated injuries.

What to Ask

1. Are there any open wounds (possible open fracture) or threatened skin?
2. Is there evidence of neurovascular injury or compartment syndrome?
3. Are there any concomitant injuries?

S. O'Donnell, MD (✉) • J.P. Johnson, MD
Department of Orthopaedics, Brown University, Providence, RI, USA
e-mail: odonnell.seth@gmail.com

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FIGURE 49.1 Representative CT and radiographic images of Pilon fractures

What to Request

1. The affected extremity should be iced and elevated immediately.
2. X-rays of the foot, ankle, and tibia (see Imaging).
3. Additional imaging as needed to evaluate for associated injuries (femoral neck, tibial plateau, spine).

When to Escalate

1. Open fractures: should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR).
2. Fracture dislocations with skin tenting or significant blisters require emergent reduction and/or external fixation to decrease risk of conversion to open injury.
3. Concern for compartment syndrome.

Imaging

1. AP, lateral, oblique ankle views.
2. X-rays of the foot, tibia, and knee.

3. High-energy mechanisms should have trauma series (AP chest, pelvis) as well as evaluation of sites of axial load injury.
4. Postreduction advanced imaging (CT) useful in articular/periarticular injuries.

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Compartment assessment
4. Intra-articular versus extra-articular
5. Impaction at joint surface
6. Associated injuries

What to Bring

1. Splinting material (see Short Leg Splint, Chapter 6)
2. External fixator (per local practice)
3. Lidocaine, associated kit for external fixation (see Chapter 10)
4. Fluoroscopy if placing traction or external fixation

Key Exam Pearls

1. Carefully inspect skin for tears or evidence of open injury.
2. Assess soft-tissue swelling and presence/absence of skin wrinkles; make note of areas of blistering or necrosis. Because of the thin softtissue envelope around the ankle, pilon fractures are at high risk for fracture blister or other soft-tissue problems.
3. Palpate the foot and entire fibula to assess for additional injury.
4. Carefully evaluate for other axial load injuries or obtain imaging if exam is limited.

Reduction

Pilon fractures are caused by high-energy axial loads to the tibial plafond. By nature, closed reduction is often inadequate to restore length and joint alignment. External fixation is often employed to allow for soft-tissue rest prior to definitive fixation. "Traveling traction," or a uniplanar external fixator with bars connecting a calcaneal pin and a proximal tibial pin, may be utilized to temporize these patients until they can be placed into a multiplanar external fixator or reduced and fixed in the operating room. If a uniplanar fixator is to be placed, typically a fluoroscan and a team of three is required. After both pins have been placed and the bars and connectors attached, the reductionist places traction on the calcaneal pin to restore length and alignment. A second person provides counter-traction on the proximal tibial pin, and the third person tightens the connecting pieces of the fixator.

Adequate Reduction Parameters

1. Restoration of length and alignment of the tibiotalar joint
2. Relief of soft-tissue tension

Follow-Up

1. Patients are generally admitted to the hospital for application of external fixation in the OR, analgesia, and compartment check pending definitive fixation.
2. If external fixation is applied in the ED, be sure to check X-rays to assess reduction. Obtain CT scan for further evaluation of injury and pre-op planning.
3. Strict ice and elevation should be the rule. Patients should be non-weight bearing on the injured extremity.
4. Definitive fixation often occurs 10–14 days after presentation although the status of the soft tissue must be used as a guide.

Chapter 50
Rotational Ankle Fractures

Seth O'Donnell

Keywords Rotational ankle fracture • Quigley maneuver • Lauge-Hansen

Overview

Complete workup for rotational ankle fractures (Fig. 50.1) includes evaluation of open versus closed injury, neurovascular compromise, intra-articular versus extra-articular, stability after reduction, associated injuries, and displaced versus non-displaced.

What to Ask

1. Are there any open wounds (possible open fracture) or threatened skin?
2. Is there any evidence of neurovascular injury or compartment syndrome?

S. O'Donnell, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: sodonnell3@lifespan.org

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FIGURE 50.1 Representative AP and lateral radiographic images of rotational ankle fractures

What to Request

1. The affected extremity should be iced and elevated immediately.
2. X-rays of the foot, ankle, and tibia.
3. Adjuncts for reduction (lidocaine for hematoma block and antispasmodic such as IV valium).
4. An assistant is often required, particularly for large or poorly cooperative patients.

When to Escalate

1. Open fractures: should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR).
2. Fracture dislocations with skin tenting require emergent reduction to decrease risk of conversion to open injury.
3. Non-reducible ankle fracture-dislocations are a surgical urgency and may require open reduction and fixation.

Imaging

1. AP, lateral, and oblique ankle views.
2. X-rays of the foot, tibia, and knee (helpful to rule out Maisonneuve fracture).
3. Advanced imaging (CT) is often not required. The exception to this is supination-adduction injuries, which have significant injury to the distal tibial weight-bearing surface (the plafond).
4. Stress views: an external rotation force applied in a mortise view can help identify syndesmotic injury.
5. Careful review of imaging is important, particularly for "non-displaced lateral malleolus fractures" (Fig. 50.2).
6. The fracture lines on the lateral can look like part of the fibular fracture; however, on close inspection, there is disruption of the tibial joint surface.

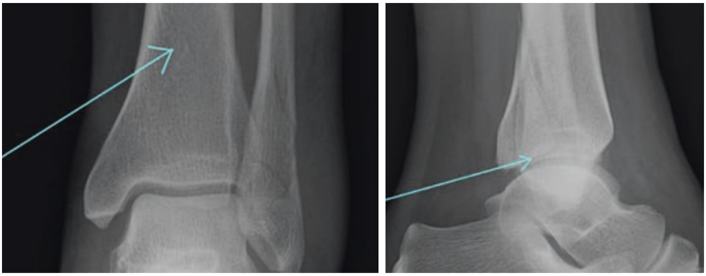

Figure 50.2 Although very subtle on the AP view, the arrow demonstrates the shadow of a posterior malleolar fracture in addition to the lateral malleolus fracture

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Intra-articular versus extra-articular
4. Stability after reduction
5. Associated injuries
6. Displaced/non-displaced

What to Bring

1. Splinting material (see Short Leg Splint, Chapter 6)
2. Lidocaine for hematoma block (see Hematoma Block, Chapter 8)
3. Fluoroscopy if used for reduction

Key Exam Pearls

1. Carefully inspect skin for tears or evidence of open injury.
2. Assess soft tissue swelling and the presence/absence of skin wrinkles; make note of areas of blistering.
3. Palpate the foot and entire fibula to assess for additional injury.

Reduction

Hematoma block should be placed and valium administered (ensure no allergies to these medications prior to their use). An assistant is recommended if available. Have splint materials (plaster only for subluxed/dislocated ankles, as fiberglass does not hold an adequate mold) prepared prior to starting.

If your assistant is not familiar with the technique, explain how they can help before starting. Positioning the patient supine (head down) with the hip and knee bent at 90° will decrease tension on the gastroc-soleus complex and allow for an easier and less traumatic reduction.

The Quigley maneuver is the classic ankle reduction technique for most ankle fracture dislocation patterns other than supination-adduction injuries. The goals are to reduce the talar dome under the tibial plafond and close the medial clear space. The key, for most ankle reductions, is "low-lateral." Your distal (low) hand should be on the lateral aspect of the ankle, cupping the heel/calcaneus while providing an anterior-medial force. The proximal hand/forearm is placed medially on the distal tibia providing a posterior-lateral force.

While reduction may occur as a sudden "pop," maintaining a mold until plaster has cured is key to success. Hold the mold until the splint is hard and then continue to hold for 2–3 min. Minimize fluoroscopy checks or anything that relaxes the mold during this time.

Supination-adduction injuries with a vertical shear fracture of the medial malleolus require only a gentle Quigley or often a "reverse Quigley." Pay particular attention while reviewing radiographs for medial impaction of the tibial plafond.

Adequate Reduction Parameters

1. AP view: tibiofibular overlap >10 mm, clear space <5 mm, symmetric joint space without talar tilt.
2. Mortise view: symmetric joint space about the entire joint, medial clear space <4 mm; talocrural angle 8–15° suggests restoration of fibular length.
3. Lateral view: reduction of the tibiotalar joint; ensure adequate film by seeing "perfect" lateral, based on the talar dome.
4. Generally speaking, the stability of an ankle after reduction will depend on the ligamentous attachments remaining and the size of the posterior malleolar fracture.
5. If a posterior mal is >30% of the articular surface, it may be a very difficult reduction.

Follow-Up

1. Truly isolated distal fibular fractures (SER-II) may weight bear as tolerated and be followed up.
2. Maisonneuve fractures should be reduced and splinted for the ankle injury; a knee immobilizer may be considered for the proximal 1/3 fibular fracture.
3. Operative ankle fractures with adequate reduction may often be discharged with orthopedic follow-up within 1 week for surgical planning.
4. The patient must remain non-weight bearing and continue ice and elevation of the operative extremity.
5. The splint, once applied following reduction, should not be removed by anyone other than the surgeon as re-displacement or dislocation will likely occur.

Chapter 51
Pediatric Ankle Fractures

Seth O'Donnell

Keywords Ankle fracture • Pediatric • Salter-Harris

Overview

Comprehensive workup of pediatric ankle fractures (Fig. 51.1) includes evaluation of open versus closed, neurovascular compromise, Salter-Harris classification, associated injuries, displaced versus non-displaced, status of physeal closure, and CT appearance after reduction.

What to Ask

1. Are there any open wounds (possible open fracture) or any sites where skin is tenting/threatened?
2. Are there any associated injuries?

S. O'Donnell, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: sodonnell3@lifespan.org

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FIGURE 51.1 Representative CT and radiographic images of pediatric ankle fractures

3. Does the patient have IV access in place? Initiate antibiotics if there is concern for open fracture.
4. Does the patient have pain out of proportion or paresthesia, or is there any other concern for compartment syndrome?
5. Has the patient been made NPO if sedation for reduction is needed?

What to Request

1. Ensure leg is stabilized, elevated, and iced immediately.
2. X-rays of the knee, tibia, ankle, and foot (if concerned about associated injury).

When to Escalate

1. Open fractures should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR).
2. Compartment syndrome requires immediate ice and elevation, as well as preparation for emergent fasciotomy.
3. Irreducible fractures may require operative intervention (periosteum, tendons, or other soft tissue structures may be interposed).

Imaging

1. AP, lateral, and oblique views of the ankle and distal tibia are necessary for evaluation.
2. AP and lateral views of the knee and full length tibia are required to rule out Maisonneuve-type fracture or associated injury.
3. Postreduction X-rays of the ankle following immobilization.
4. In complex fracture patterns and intraarticular fractures, a CT is required to evaluate the physis and joint surface. The CT should be obtained after reduction and casting/splinting.

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Salter-Harris classification
4. Associated injuries

5. Displaced/non-displaced
6. Status of physeal closure
7. CT appearance after reduction (articular fragments, residual displacement)

What to Bring

1. Local anesthetic if planning hematoma block
2. Casting/splinting material (see long versus short leg splintcast, Chapter 6 depending on local practice)
3. Fluoroscopy if used for reduction
4. Ice

Key Exam Pearls

1. Sensation (saphenous/sural/superficial and deep peroneal, tibial).
2. Motor (extensor hallucis longus/flexor hallucis longus/gastrocnemius/tibialis anterior).
3. Evaluate all wounds: dermal violation raises suspicion for open fracture.
4. Close evaluation of imaging for physeal injury (e.g., Salter-Harris type III or IV fracture). The distal tibial physis closes from central to medial, with anterolateral portion closing last.

Reduction/Treatment

Fractures displaced less than 2 mm may be treated with long leg cast and non-weightbearing. Displaced fractures should have analgesia and/or sedation to allow for closed reduction. The most common mechanism for a triplane or Tillaux fracture is external rotation; therefore, internal rotation force with correction of deformity often decreases displacement. Following reduction of closed injuries, a cast is applied with the ankle in neutral position. Long versus short leg cast should be applied based on local practice. Cast treatment should be avoided if there is significant soft tissue injury, concern for development of compartment syndrome, an oblique fracture pattern with displacement, or the setting of poly-trauma. In these situations, temporary immobilization with a splint may be sufficient. A mature patient may better tolerate short leg splint with side gussets.

Adequate Reduction Parameters

1. Less than 2 mm displacement in all planes
2. No interposed structures

Follow-Up

1. Follow-up with a (pediatric) orthopedic surgeon within 1 week.
2. Often admitted for operative intervention or observed for compartment syndrome.
3. Patients and families should be counseled regarding risk of post-traumatic arthritis and stiffness; counseling should also include physeal specific topics such as growth arrest, leg length discrepancy, or angular deformity depending on amount of growth remaining.
4. May be admitted for operative intervention, observation, or pain control if needed.

Chapter 52
Injuries of the Hindfoot

Seth O'Donnell

Keywords Hindfoot • Talus fractures • Subtalar dislocations • Calcaneus fractures • Achilles ruptures

Overview

Comprehensive workup of hindfoot injuries includes evaluation of open versus closed injury neurovascular compromise, fracture versus dislocation versus fracture-dislocation, intraarticular versus extra-articular, stability after reduction, energy of injury, associated injuries, soft tissue status, and displaced versus non-displaced.

What to Ask

1. Are there any open wounds indicating a possible open fracture?
2. Is there an obvious deformity?
3. Does the patient have skin threatening/tenting?

S. O'Donnell, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: sodonnell3@lifespan.org

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4. Is there any evidence of neurovascular injury or compartment syndrome?

What to Request

1. The affected extremity should be iced and elevated immediately.
2. X-rays of the foot and ankle (also tibia film in many institutions).
3. Adjuncts for reduction (lidocaine for hematoma/intraarticular block and antispasmodic such as IV valium).
4. A large, uncooperative, or agitated patient may require conscious sedation for adequate reduction.
5. Plaster and a lot of cast padding. (See Chapter 6).

What to Bring

1. Splinting material (short leg splint Chapter 6)
2. Lidocaine for hematoma block (hematoma block, Chapter 8)
3. Fluoroscopy if needed for reduction

When to Escalate

1. Open fractures should be irrigated in ED and receive antibiotics (will require formal irrigation and debridement in OR).
2. Concern for vascular injury or risk to limb.
3. Fracture-dislocations with skin tenting (e.g., tongue-type calcaneal fractures) or significant blisters.
4. Nonreducible hindfoot fracture-dislocations are a surgical urgency and may require external fixation.

Imaging

1. Three views of the foot and three views of the ankle required before and after reductions
2. In the event of a significant deformity about the foot/ankle, consider a single view of the foot/ankle prior to reduction to assist in planning reduction
3. Canale view: optional view for talar neck; difficult to obtain and maybe uncomfortable for patient
4. Harris view: optional axial view of calcaneus, useful for non-tongue-type fractures
5. Advanced imaging (CT): often useful in hindfoot injuries after reduction

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Fracture versus dislocation versus fracture-dislocation
4. Intra-articular versus extra-articular
5. Stability after reduction
6. Energy of injury/associated injuries
7. Displaced/non-displaced

Key Exam Pearls

1. Carefully inspect skin for tears or evidence of open injury.
2. Assess soft tissue swelling and presence/absence of skin wrinkles; make note of areas of blistering.
3. Palpate the foot and entire fibula to assess for additional injury.

Hindfoot Injuries in Detail

Talus Fractures

Isolated fractures of the talus are typically not reduced in the emergent setting, as the bone's blood supply is tenuous at best. Splinting for operative injuries or casting for non-displaced fractures is typically appropriate. Articular involvement should also be assessed when determining whether or not fractures are operative. Close examination of the talocalcaneal and tibiotalar articulations may reveal subluxation or frank dislocation of these joints (talar fracture-dislocation). Displaced fractures of the talus are rarely isolated, and associated dislocations and subluxations should be evaluated for. In the absence of an experienced orthopedist, talar fracture-dislocations should typically be reduced in the OR. An *os trigonum* is present in nearly half of normal feet and should not be confused for a fracture.

Subtalar Dislocations

In the setting of a dislocation of the talus on the calcaneus, the talonavicular joint is frequently also dislocated. Most are caused by inversion of the foot and result in medial subtalar dislocation. These fractures should be reduced urgently. Conscious sedation is standard, with an assistant to hyperflex the hip and bend the knee to at least 90°. Reduction is obtained by plantar flexing the foot, pulling longitudinal traction, exaggerating deforming force of injury, and then reversing the deformity.

Isolated subtalar dislocations are usually very stable post-reduction, and usually there is a satisfying "clunk" on reduction. They should be splinted in neutral or slight dorsiflexion, followed by a CT of the foot to ensure there are intra-articular fragments or subtle subluxation remaining. Irreducible fractures may require urgent operative interventions. A block to reduction may be caused by the posterior tibial tendon (lateral dislocation), extensor tendons (EDB), or retinaculum (medial dislocations)

Calcaneus Fractures

Calcaneus fractures (Fig. 52.1) with a "tongue-type" pattern (split in the axial plain with potential entrapment of soft tissues) should be considered an emergent concern. These require urgent reduction by placing the patient in full plantarflexion

FIGURE 52.1 Representative radiographs of calcaneus fractures

and may require urgent operative intervention to prevent an open fracture from developing. The remainder of calcaneal fractures should be splinted with an abundance of padding and carefully evaluated for other axial load injuries (spinal compression, femoral neck, tibial plateau, or Pilon fractures). CT imaging is often useful to delineate fracture lines and should be obtained per institutional protocols.

Achilles Rupture

These injuries often present with a painful "pop" during an eccentric load, such as landing from a jump. Rupture can be confirmed by palpating for a gap or via prone Thompson test. These injuries may be treated operatively or non-operatively, depending on patient factors and patient/physician preference. In the emergency setting, they should be splinted in their resting position and given early follow-up to allow intervention before ankle stiffness and tendon retraction develops.

Chapter 53
Injuries of the Midfoot

Seth O'Donnell

Keywords Midfoot • Lisfranc injuries • Navicular fractures • Navicular dislocation • Cuboid fractures • Crush injuries

Overview

Complete workup for midfoot injuries – Lisfranc injuries, navicular fractures, navicular dislocation, cuboid fractures, and crush injuries – includes evaluation of open versus closed injury, neurovascular compromise, compartment assessment, high versus low energy, intra-articular versus extra-articular, impaction at joint surface, and associated injuries.

What to Ask

1. What is the mechanism of injury? Always assess high- versus low-energy injuries.
2. Are there any open wounds?

S. O'Donnell, MD
Department of Orthopedics, Brown University, Providence, RI, USA
e-mail: sodonnell3@lifespan.org

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3. Is there any skin threatening/tenting?
4. Is there evidence of neurovascular injury or compartment syndrome?

What to Request

1. The affected extremity should be iced and elevated immediately.
2. X-rays of the foot and ankle.
3. CT scan can often add useful information. Additional imaging should be consistent with local practice and energy of mechanism to evaluate for associated injuries.

When to Escalate

1. Open fractures: administer IV antibiotics early and irrigated wounds ED; require formal irrigation and debridement in OR.
2. Fracture/dislocations with skin tenting or significant blisters require emergent reduction and/or external fixation to decrease risk of conversion to open injury.

Imaging

1. AP, lateral, and oblique foot views:

   Evaluate the medial column with the AP foot (looking at alignment of medial border of second metatarsal with medial border of middle cuneiform).

   Evaluate the lateral column with oblique foot (looking at alignment of medial fourth MT with medial cuboid.

   Evaluate alignment of MTs on lateral.
2. X-rays of the foot, tibia and fibula, and knee.
3. Additional plain films per mechanism and associated injuries.

4. Weight-bearing X-rays (when possible) are often more useful than not.
5. Advanced imaging (CT) is useful in most high-energy foot injuries.

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Compartment assessment
4. High versus low energy
5. Intra-articular versus extra-articular
6. Impaction at joint surface
7. Associated injuries

What to Bring

1. Splinting material (see short leg splint Chapter 6)
2. Cast shoe

Key Exam Pearls

1. Carefully inspect skin for tears or evidence of open injury.
2. Assess soft tissue swelling and presence/absence of skin wrinkles; make note of areas of blistering or necrosis.
3. Palpate the foot and entire leg to assess for additional injury.
4. Stress examinations may reveal instability or reproduce symptoms.
5. Plantar ecchymosis should raise suspicion of Lisfranc injury.
6. Serial examinations may be required.

Injuries

Lisfranc Injuries

Bony or ligamentous injuries to the midfoot may dissociate the proximal metatarsals from their articulation with the cuneiforms, commonly known as a Lisfranc injury. There is a high reported "miss" rate for these injuries (>20 %), often associated with additional injury (fracture of the cuboid, navicular, or cuneiforms). The second metatarsal is the most frequently reported associated fracture. It is important to assess radiographs and stress views for evidence of instability. Stable injuries can be managed conservatively with well-padded splint and non-weight bearing. Unstable injuries and those with >2 mm displacement of the TMT joint should be surgically addressed. Initial management should begin with reduction of any gross dislocation and immobilization. Most of these will require surgery – a well-padded posterior splint should be applied and close follow-up arranged.

Navicular Fractures

Do not confuse an accessory navicular (present in approximately 10 % of the population) with acute fracture. Ensure the talonavicular joint is not dislocated.

Navicular Dislocation

These injuries often require open reduction in the operating room. If an OR is not immediately available, an attempt at closed reduction under conscious sedation is appropriate.

Cuboid Fractures

It is important to assess the length and alignment of the lateral column of the foot ("nutcracker fracture"). Displacement or articular disruption >2 mm often requires surgery; severe shortening or joint disruption may require surgical treatment.

Crush Injuries

Crush injuries (Fig. 53.1) to the foot are a common cause of one or more fractures to the foot. In these cases, the soft tissues should also be carefully analyzed. Patients that appear

FIGURE 53.1 Representative radiographic image of crush injuries of midfoot. Note multiple fractures, as well as a prior 5^{th} MT injury

unable to adhere to strict bed rest, ice, and aggressive elevation should be considered for admission and observation.

In General

Most midfoot fractures will be initially treated nonoperatively in a cast shoe, CAM boot, or well-padded posterior splint. If there is a concern for compartment syndrome or neurovascular injury, patients should be kept NPO with adequate ice, elevation, and performance of serial examinations. Most non-displaced fractures can be treated with immobilization and non-weight bearing. Patients with intra-articular injury should be counseled on their increased risk of post-traumatic arthritis.

Follow-Up

1. Patients with closed, adequately reduced injuries can be placed into a short leg splint and follow up within 1–2 weeks.
2. Instructions for strict ice and elevation (above the level of the heart) should be emphasized.

Chapter 54
Injuries to the Forefoot

Seth O'Donnell

Keywords Forefoot • Metatarsal • Phalanx • Nailbed • Seymour

Overview

Complete workup of forefoot injuries (Fig. 54.1) includes evaluation of open versus closed injury neurovascular compromise, compartment assessment, high versus low energy, intraarticular versus extra-articular, impaction at joint surface, and associated injuries.

What to Ask

1. What is the mechanism of injury?
2. Are there any open wounds or nailbed involvement?
3. Is there any skin threatening or tenting to indicate soft tissue injury?

S. O'Donnell, MD
Department of Orthopedics, Brown University,
Providence, RI, USA
e-mail: sodonnell3@lifespan.org

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FIGURE 54.1 Representative radiographic image of a severe forefoot injury after k-wire fixation

4. Is the patient able to ambulate?
5. Is there any evidence of neurovascular injury or compartment syndrome?

What to Request

1. The affected extremity should be iced and elevated immediately.

2. X-rays of the foot and ankle.
3. CT scan can often add useful information in high energy situations. Additional imaging should be consistent with local practice and energy of mechanism to evaluate for associated injuries.

When to Escalate

1. Open fractures: administer IV antibiotics early and irrigated wounds ED, may require formal irrigation and debridement in OR.
2. Fracture dislocations with skin tenting or significant blisters require emergent reduction and/or external fixation to decrease risk of conversion to open injury.

Imaging

1. AP, lateral, and oblique foot views.
2. Additional plain films per mechanism and associated injuries.
3. X-rays of the foot and ankle.
4. Weight-bearing X-rays (if tolerated) better demonstrate injury.
5. Advanced imaging (CT) useful in most high-energy foot injuries.

Effective Communication

1. Open versus closed
2. Neurovascular compromise
3. Compartment assessment
4. High versus low energy
5. Intra-articular versus extra-articular
6. Impaction at joint surface
7. Associated injuries

What to Bring

1. Splinting material (see short leg splint Chapter 6)
2. Cast shoe

Key Exam Pearls

1. Carefully inspect skin for tears or evidence of open injury.
2. Assess soft tissue swelling and the presence/absence of skin wrinkles; make note of areas of blistering or necrosis.
3. Palpate the foot and entire leg to assess for additional injury.
4. Stress examinations may reveal instability or reproduce symptoms.
5. Plantar ecchymosis should raise suspicion of Lisfranc injury.
6. Serial examinations may be required.

Injuries

Unstable or widely displaced fractures of the first MT should be initially managed with immobilization and subsequently surgical fixation. Fractures of the second through fourth MT may be treated with a hard sole shoe and weight bearing as tolerated. Multiple fractures should raise suspicion of higher-energy mechanism and risk of additional injury.

Treatment of proximal fifth MT fractures is especially controversial. Some surgeons advocate for early weight bearing in select patients and others for early operative intervention. A good understanding of local practices is the best way to guide early treatment.

Nailbed injuries often can be managed using the principles of UE nail injuries and avulsions (remove the nail, repair the laceration, and give appropriate antibiotics, tetanus prophylaxis).

Seymour fractures (distal phalanx with nailbed injury) can occur in both adults and children; there must be a high suspicion for germinal matrix interposed in the fracture site. These often will require antibiotics and surgery.

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