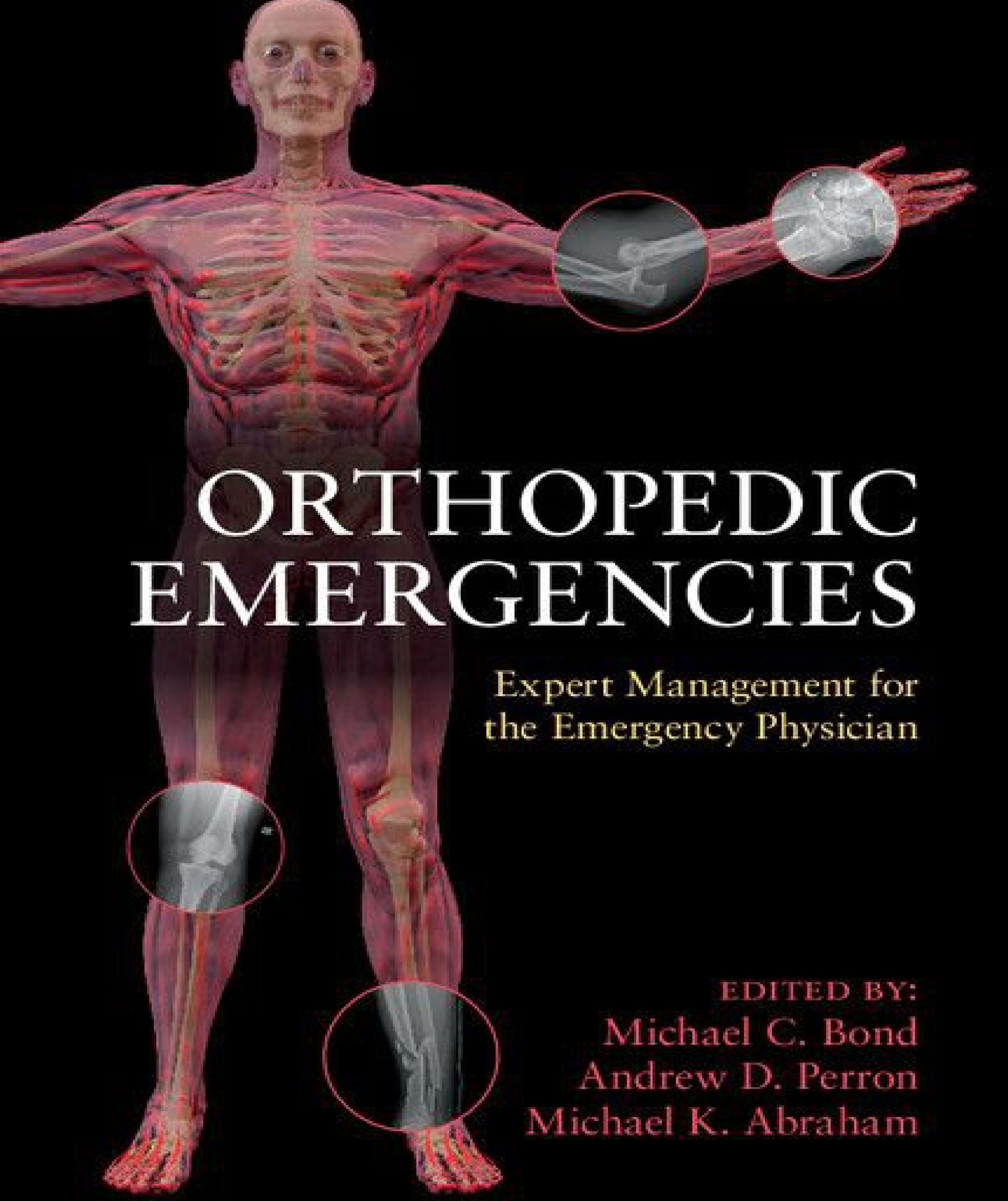

ORTHOPEDIC EMERGENCIES

Expert Management for the Emergency Physician

EDITED BY:
Michael C. Bond
Andrew D. Perron
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CAMBRIDGE | Medicine

Orthopedic Emergencies: Expert Management for the Emergency Physician

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Preface

Providers working in Urgent Care centers, Emergency Departments, Casualty Rooms, and Accident and Emergency (A&E) Departments are unlikely to work a single shift without seeing a patient with an orthopedic injury. Providers in these settings evaluate more patients with acute injuries than our sub-specialty colleagues, so it is imperative that we have a good understanding of how to diagnose and treat these acute injuries. Many textbooks have been written on this subject. Most are large tomes that are extremely indepth and designed for the orthopedic surgeon or a sports medicine physician, while others are designed for the beginner. Neither, though, is designed to be a good bedside reference to use as you care for the patient.

This orthopedic emergencies book has been designed to be a quick reference for the seasoned provider who is looking to refresh their memory as well as the junior medical student who needs to understand some of the key aspects of care. The authors have worked hard to provide ***Pearls*** and ***Key facts*** that can be used for quick review, and specific and detailed recommendations on how to treat the various conditions. Finally, we have worked with the publisher to make the book spiral bound so that it can be opened and laid flat to be used as a bedside resource when doing procedures and placing splints.

Each chapter is laid out with the description of the injury or fracture, a discussion on how to make the diagnosis, treatment recommendations, and then common complications that the patients should be informed of. Whenever possible we have recommended a definitive treatment plan. For conditions where treatment is more controversial we have recommended that you discuss the case with your local consultant.

This textbook is divided into sections based on the area of injury, but also includes a chapter on orthopedic infections, pediatric injuries, common procedures, and finally a chapter on splints that includes step-by-step instructions with photographs. The organization of the book is designed to make it easy to just read up on orthopedic injuries and also to be able to find the necessary information quickly during a busy shift.

The authors and editors hope that you find this textbook to be an invaluable resource that is frequently left in the last room you saw a patient in. We welcome suggestions and recommendations for future editions.

Best of luck caring for your injured patients.

Chapter 1 Hand and wrist emergencies

Carl A. Germann

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Distal radius and ulnar injuries

PEARL: Fractures of the distal radius and ulna are the most common type of fractures in patients younger than 75 years.

PEARL: Distal radius and ulnar injuries are often associated with median and ulnar neuropathies.

Distal radius fracture

Key facts

- A ***Colles fracture*** (Figures 1.1 and 1.2): A transverse fracture of the distal radial metaphysis with dorsal displacement and angulation, often caused by a fall on an outstretched hand
- A ***reverse Colles*** or ***Smith fracture*** (Figure 1.3): A transverse fracture of the metaphysis of the distal radius, with associated volar displacement and volar angulation. The mechanism of injury is often a fall on to the dorsum of the hand with the wrist in flexion
- ***Barton fracture*** (Figure 1.4): A distal radius fracture with dislocation of the radiocarpal joint
    - A volar Barton fracture occurs when the wrist is volarly flexed, and affects the volar rim of the radius.
    - A dorsal Barton fracture occurs with dorsal flexion and affects the dorsal rim of the radius
- ***Hutchinson fracture*** (Figure 1.5): An intra-articular transverse fracture of the radial metaphysis with extension through the radial styloid, often caused by a direct blow or a fall on the radial side of the wrist
    - Also termed a Chauffer's fracture
- Clinical presentation: distal radius fracture patterns usually present with pain, swelling, and deformity of the wrist
- On physical examination, Colles fractures have a dinner-fork deformity caused by the dorsal displacement and angulation of the radius
- Smith fractures often have fullness on the volar aspect of the wrist
- Median nerve injury can occur with Colles and Smith fractures and a careful neurovascular examination both on initial presentation and following treatment is required

Figure 1.1 Colles fracture. Note the dorsal angulation of the distal radius as shown in Figure 1.2. (Image courtesy of Carl Germann, MD.)

Figure 1.2

Figure 1.3 Smith fracture. The hand and wrist is volarly displaced with respect to the forearm. (Image courtesy of Carl Germann, MD.)

Figure 1.4 Volar Barton fracture. A fracture of the volar margin of the carpal surface of the radius. (Image courtesy of Carl Germann, MD.)

Figure 1.5 Hutchinson fracture: An intra-articular fracture through the radial styloid process. (Image courtesy of Carl Germann, MD.)

Diagnostic testing

- For Colles and Smith fracture patterns, radiographs of the wrist will demonstrate the fracture through the radial metaphysis. The lateral radiograph is the best view to determine the degree of dorsal or volar displacement and angulation
- The lateral radiograph is the best view for revealing an intra-articular fracture of the radius and any associated carpal displacement in Barton fractures. A posteroanterior (PA) radiograph often shows a comminuted fracture of the distal radius
- PA radiographs of the wrist are best to see a Hutchinson fracture

Treatment

- Colles fractures should undergo closed reduction. This can be facilitated by the use of a hematoma block and finger traps. After successful reduction, patients should be immobilized in a **long-arm splint** in neutral position or pronation with orthopedic follow-up in 7 to 10 days. Emergent orthopedic consultation is necessary if initial attempts at closed reduction are unsuccessful, if there is neurovascular compromise, or if there is an open fracture
- Smith fracture should undergo closed reduction. Following reduction, patients should be placed in a **long-arm splint** in supination. Emergent orthopedic/hand-specialist consultation is

recommended for these fractures because they are more likely to be unstable and urgent surgical management is more often necessary
- Barton fractures require emergency orthopedic/hand-specialist consultation for early operative management
- Non-displaced Hutchinson fractures can be managed with a **short-arm splint** and routine orthopedic/hand-specialist follow-up. Displaced fractures require reduction and immobilization. Accurate anatomic alignment following reduction is essential because multiple ligaments of the wrist attach to the radial styloid process and inappropriate alignment can cause future complications

Prognosis

- Complications include:
  - Malunion
  - Radioulnar and radiocarpal instability
  - Arthritis
  - Chronic pain
  - Non-union
- However, good to excellent results are often achieved in most patients

Distal radioulnar joint disruption (DRUJ)

Key facts

- Disruption of the distal radioulnar joint (DRUJ) may be seen as an isolated injury, or more commonly, in association with distal radius fractures
  - Initially unrecognized in up to 50% of cases
- Dorsal dislocations are the most common and are typically the result of a fall on to an outstretched arm with a rotational pronation force to the impact
- Volar dislocations are typically the result of a fall on to an outstretched arm with a rotational supination force to the impact

Clinical presentation

- Often overshadowed by more apparent injuries
- On physical examination a dorsal dislocation reveals excessive prominence of the ulnar head and lack of forearm rotation secondary to pain when the wrist is supinated
- Volar dislocations will have a loss of the typical dorsal prominence of the ulnar head and lack of forearm rotation secondary to pain when the wrist is pronated

Diagnostic testing

- **PEARL: In DRUJ injuries, the lateral radiograph usually demonstrates volar or dorsal displacement of the ulna that normally overlap the radius.** Standard radiographs of a DRUJ

dislocation demonstrate overlap of the distal ulna with the distal radius on the PA view. On the lateral view the ulnar head will be displaced:
  - Dorsally for dorsal dislocations
  - Volarly with volar dislocations
- Radiographic signs of DRUJ instability are:
  - Ulnar styloid fracture involving the base with more than 2 mm displacement
  - Irreducible dislocation of the DRUJ
  - Fractures involving the sigmoid notch of the radius
  - Wide displacement of the DRUJ
  - Radial shortening

Treatment

- If DRUJ instability is suspected, based on clinical examination or radiographic studies, an emergent orthopedic or hand-specialist consultation should be obtained for reduction and immobilization

Prognosis

- DRUJ injuries have a high recurrence rate and may require reconstructive surgery

Carpal bone fractures and dislocations

Scaphoid fracture

PEARL: The scaphoid is the most commonly fractured carpal bone yet one of the most commonly missed wrist injuries. A thorough history and physical examination, coupled with a high index of suspicion, are necessary to make the diagnosis.

Key facts

- Scaphoid fractures account for 60–70% of all diagnosed carpal injuries
- Radiographic findings (Figure 1.6) can be subtle or absent, rendering the diagnosis difficult to make
- Accurate early diagnosis of scaphoid fractures is critical, as a missed or delayed diagnosis can result in long-term pain, loss of mobility, and decreased function
- The scaphoid has a high rate of non-union
- Avascular necrosis of the scaphoid is because its blood supply arises distally from small branches of the radial artery and the palmar and superficial arteries. The proximal portion of the scaphoid is completely dependent on this distal blood supply, thus it is at risk of avascular necrosis following fracture
- In general, the more proximal, oblique, or displaced the fracture, the greater the risk of interrupting the blood supply

Figure 1.6 Scaphoid fracture: An acute non-displaced fracture is shown in anteroposterior view. (Image courtesy of Carl Germann, MD.)

Clinical presentation

- Snuff box tenderness is classically cited as the most common finding, although the sensitivity of this test is disputed
- Many authors feel a better test for scaphoid injury is axial compression of the thumb along its longitudinal axis
- The examining physician (EP) should remain vigilant for associated injuries that can be found on physical examination
    - Common associated injuries include fractures of the distal radius, lunate, or radial head at the elbow
    - Median nerve injury has also been described in association with scaphoid fractures

Diagnostic testing

PEARL: Even with appropriate films, fractures of the scaphoid can be subtle and difficult to visualize. Conservative estimates suggest that 10–20% of these fractures will not be visible on any view in the acute setting.

- A typical wrist series includes a PA and lateral radiograph of the wrist
- In cases where there is high clinical suspicion, a scaphoid view of the wrist can also be obtained
  - This reduces the foreshortening of the scaphoid that occurs on a normal PA view, and displays the entire length of the scaphoid
  - However, even with excellent radiographic technique, a fracture may not be visualized
- Magnetic resonance imaging (MRI) and computed tomography (CT) have much better sensitivity and specificity in detecting scaphoid fractures. However, these are not routinely done in the ED as it does not affect the initial treatment, which consists of immobilization and orthopedic follow-up for clinically suspected scaphoid injury

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- Confirmed or suspected scaphoid fractures with normal radiographs require a **thumb spica splint**

PEARL: Confirmed or suspected scaphoid fractures require that the patient be placed in a thumb spica splint.

Prognosis

- The most common complication of scaphoid fractures is non-union, which has an overall occurrence rate of 8%–10%
- The rate of non-union varies with the actual fracture site
  - Non-union complicates up to 20%–30% of proximal- third fractures, and 10% –20% of middle-third fractures
  - Non-union of distal-third fractures is relatively rare
- Besides non-union, patients are also at risk to develop avascular necrosis (AVN) of the scaphoid, which occurs in approximately 10% of proximal pole fractures, and 5% of middle-third fractures

Lunate fracture

Key facts

- Lunate fractures account for 3.9% of all carpal bone fractures
- Isolated lunate fractures are uncommon except in the case of Kienböck’s disease, also known as idiopathic avascular necrosis of the lunate
- Associated injuries of the radius, carpal bones, or metacarpals occur 50% of the time

Clinical presentation

- The typical mechanism of injury for a lunate fracture is a fall on to an outstretched hand
- Patients with lunate fractures will present with pain over the dorsum of the wrist that is exacerbated by palpation of the dorsal aspect of the lunate
- Axial loading of the third metacarpal can also accentuate the pain

Diagnostic testing

- Standard wrist radiographs often fail to demonstrate lunate fractures because visualization of the lunate is often obscured by superimposed bones
- CT has been found to be more sensitive than plain radiography at identifying fractures of the lunate

Treatment

- Early identification and management of these fractures is essential to prevent AVN, carpal instability, and non-union
- Patients with suspected or diagnosed lunate fractures should be immobilized in a thumb spica splint with the hand and thumb in neutral position
- Lunate fractures require a hand-specialist follow-up in 1 to 2 weeks

Prognosis

- Lunate fractures are at risk of avascular necrosis leading to:
  - Osteoarthritis
  - Chronic pain
  - Decreased grip strength

Triquetral fracture

Key facts

- Third most common carpal bone fracture following scaphoid and lunate fractures
- A fall can lead to impingement of the hamate or ulnar styloid process on to the triquetrum

Clinical presentation

- Patients often present following a direct blow to the wrist or a fall on to an outstretched hand
- Localized tenderness should be present over the dorsum of the wrist distal to the ulnar styloid

Diagnostic testing

- Lateral wrist radiographs may show a dorsal chip fracture of the triquetrum
- A pronated lateral view often projects the dorsal triquetrum away from other carpal bones
- Triquetral body fractures are best visualized on anteroposterior (Figure 1.7) and oblique radiographs

Figure 1.7 Triquetral fracture: Anteroposterior radiograph of a subtle triquetral fracture. (Image courtesy of Timothy Sweeney, MD.)

Treatment

- Immobilization of the wrist with a **short-arm splint** and prompt orthopedic follow-up is recommended
- Displaced fractures often require internal fixation

Prognosis

- The deep branch of the ulnar nerve lies in close proximity to the triquetrum and may cause motor impairment

- Non-union, malunion may occur

Pisiform fracture

Key facts

- The pisiform is rarely fractured and accounts for only 1.3% of all carpal bone fractures
- Pisiform fractures are most often caused by a direct blow or fall on to an outstretched hand
- Less commonly the pisiform can be avulsed by the flexor carpi ulnaris during forced wrist hyperflexion or from the strain of lifting a heavy object

Clinical presentation

- Patients with fractures of the pisiform complain of ulnar-sided wrist pain that is accentuated by resisted wrist flexion
- Physical examination demonstrates pain over the pisiform
- Occasionally, ulnar nerve palsy may result from compression by a fragment of the pisiform which serves as the ulnar wall of the Guyon's canal, which the ulnar nerve transverses

Diagnostic testing

- Diagnosis of a pisiform fracture is difficult on standard radiographs because adjacent and overlying bones prevent an unobstructed view of the pisiform
- If a pisiform fracture is suspected special views, such as a carpal tunnel view or a reverse oblique view with the wrist in 30° of supination, can be helpful in imaging the pisiform
- CT can be used if clinical suspicion of pisiform fracture persists despite normal or non-diagnostic plain radiographs

Treatment

- Immobilize in an ulnar gutter splint for 3 to 4 weeks
- If ulnar nerve palsy is present, hand-specialist consultation should be obtained for possible surgical decompression

Prognosis

- Most ulnar nerve palsies that are present at initial presentation will resolve in 8 to 12 weeks and require only close observation
- Pisiform fractures have an excellent prognosis

Carpal bone dislocations

Key facts

- Perilunate and lunate dislocations result from hyperextension
- Perilunate dislocations are more common, and lunate dislocations are more severe
- Perilunate and lunate dislocations generally are the result of high-energy trauma to the wrist, with the most common mechanism being a fall on to the outstretched hand, followed by motor vehicle and motorcycle crashes
- Carpal bone dislocations are a progressive pattern of carpal ligamentous injuries caused by wrist hyperextension and ulnar deviation
- Mayfield's study of the pathomechanics of these injuries led to the classification of carpal bone dislocations into four distinct stages with each stage representing a sequential intercarpal injury beginning with scapholunate joint disruption and proceeding around the lunate, creating progressive ligamentous injury and progressive carpal bone instability

PEARL: The intracarpal distance between the scaphoid and lunate should not be more than 2 mm.

- Stage I injury (scapholunate dissociation):
  - Results in a characteristic widening of the scapholunate joint on the PA view – Terry Thomas sign (Figure 1.8)
  - A gap of 2 mm or less between the scaphoid and lunate is considered normal on the PA view
  - Scapholunate dissociation can be associated with a rotatory subluxation of the scaphoid, where the scaphoid is seen on end with the cortex of the distal pole appearing as a ring shadow superimposed over the scaphoid; this is known as the "signet ring sign"
  - Standard radiographs are usually normal, so when a scapholunate ligament injury is suspected clinically, additional stress views can be obtained
  - Views taken in ulnar deviation with a clenched fist (the clenched fist AP view) will accentuate widening of the scapholunate joint
- Stage II injury (perilunate dislocation):
  - Seen best on the lateral view of the wrist (Figure 1.9)
  - Although the lunate remains in normal position in relation to the distal radius, the capitate is dislocated, usually in a dorsal direction
  - The PA view often will show overlap of the distal and proximal carpal rows and may also demonstrate an associated scaphoid fracture or subluxation (Figure 1.10)
- Stage III injury:
  - Appears similar to a stage II injury but with the addition of a dislocation of the triquetrum, best seen on the PA view, with overlap of the triquetrum on the lunate
  - The stage III injury is frequently associated with a volar fracture of the triquetral bone
- Stage IV injury (lunate dislocation):
  - Results in a characteristic triangular appearance of the lunate on the PA view, also known as the "piece of pie" sign (Figure 1.11)
  - This is caused by the rotation of the lunate in a volar direction
  - The triangular appearance of the lunate when dislocated is in stark contrast to its normal quadrangular appearance (Figure 1.12)

- This rotation is also visible on the lateral view of the wrist, where the lunate looks like a tea cup tipped in a volar direction that has spilled its contents ("spilled teacup sign") into the palm (Figure 1.13)
- On the lateral view, the capitate will lie posterior to the lunate and can even migrate proximally and make contact with the distal radius.

PEARL: In a lunate dislocation, the lunate will appear as a "spilled teacup" on the lateral wrist radiograph.

Figure 1.8 Scapholunate dislocation: Terry Thomas sign. (Image courtesy of Timothy Sweeney, MD.)

Figure 1.9 Perilunate dislocation: Dorsal displacement of the capitate is identified on the lateral view. (Image courtesy of Timothy Sweeney, MD.)

Figure 1.10 Perilunate dislocation: Posteroanterior radiograph showing overlap of the distal and proximal carpal rows. This is often referred to as a "jumbled carpus." (Image courtesy of Timothy Sweeney, MD.)

Figure 1.11 Lunate dislocation: Rotation of the lunate resulting in a triangular appearance on posteroanterior view. (Image courtesy of Carl Germann, MD.)

Figure 1.12 Lunate dislocation: Normal quadrangular appearance of the lunate. (Image courtesy of Carl Germann, MD.)

Figure 1.13 Lunate dislocation: Volar displacement of the lunate ("spilled teacup sign"). (Image courtesy of Carl Germann, MD.)

Clinical presentation

- Carpal bone dislocation injuries typically are the result of a high-energy mechanism such as fall from a height on to the outstretched hand, or a motor vehicle crash
- The mechanism of injury is ulnar deviation of the wrist coupled with dorsiflexion
- The patient will complain of pain and swelling over either the dorsum or volar aspect of the wrist and have limited range of motion
- On physical examination there will likely be palpable tenderness over the dorsum of the wrist,

particularly in the region of the scapholunate ligament, located just distal to Lister's tubercle

- With palpation alone it is often difficult to distinguish one source of wrist pain from other causes, including scapholunate strain, scaphoid fracture, triangular fibrocartilage complex tears, and other disorders

Diagnostic testing

- Plain radiographs of the wrist consisting of PA and lateral views are essential to diagnose wrist dislocations (as well as other carpal bone instabilities)
- The PA view should be obtained with the wrist in a neutral position
- A relatively constant 2 mm intercarpal joint space should be seen on a normal PA view. An increase in this distance suggests ligamentous interruption, or a stage I injury (scapholunate dissociation)
- On the AP view, three arcs should be identified (Figure 1.14)
    - The first arc consists of the radiocarpal row, which should be both smooth and continuous. Disruption of this arc is suggestive of a lunate dislocation
    - The second arc consists of the mid-carpal row, which should similarly be smooth and continuous. Disruption of this arc is suggestive of a perilunate dislocation
    - The third arc outlines the proximal surface of the distal carpal row. Disruption of any of these arcs is a sign of carpal dislocation or fracture
- On the lateral view the radius, lunate, and capitate should all line up in a row (Figure 1.15)
    - The lunate should lie within the radius cup and the capitate should rest within the lunate cup
    - Loss of this normal column configuration implies lunate or perilunate dislocation
    - Stress x-rays obtained with radial and ulnar deviation of the hand may demonstrate scapholunate dissociation

Figure 1.14 Normal AP arcs: Disruption suggests carpal dislocation or fracture. (Image courtesy of

Carl Germann, MD.)

Figure 1.15 Normal lateral arcs: Disruption suggests lunate or perilunate dislocation. (Image courtesy of Carl Germann, MD.)

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- Carpal bone dislocations usually mandate the consultation of a hand surgeon in the ED for reduction and stabilization
- Open fractures and open dislocations require temporary splinting, IV antibiotics and prompt operative intervention (keep NPO)
- Closed reduction and long-arm splint immobilization may be attempted but is frequently unsuccessful. If attempted, it is more likely to be successful with a perilunate rather than lunate dislocation because of the extent of ligamentous disruption in the latter
- If the dislocation is irreducible or the result is unstable, then open reduction with internal

fixation is required

- Many authors believe immediate open reduction with internal fixation is the treatment of choice, citing the extensive ligamentous injury inherent in such injuries, and frequent unstable results that come with closed reduction
- A lunate or perilunate injury with median nerve symptoms requires immediate operative reduction, carpal tunnel release, and ligamentous reconstruction

Prognosis

- Complications of carpal dislocation include median nerve injury resulting in an acute or subacute carpal tunnel syndrome
- Other complications include chronic carpal bone instability with resultant degenerative arthritis, chronic pain, and limitation in range of motion
- Scapholunate advanced collapsed deformity ("SLAC wrist") is the end-stage result for many patients

Metacarpal bone fractures and dislocations

Metacarpal head fracture

Key facts

- Rare
- Usually from a direct blow or crush
- Considered as intra-articular fractures

Clinical presentation

- A direct blow often causes a comminuted fracture
- Examination reveals pain and swelling over the involved MCP joint
- Pain is produced by applying axial pressure to the associated digit
- Lacerations suggest an open fracture or "fight bite" injury

PEARL: A high index of suspicion for a potential "fight bite" should be maintained for any injury that is associated with lacerations, abrasions, or bruising over the metacarpophalangeal (MCP) joints. Joint space infections resulting from a human bite are aggressive and rapidly destructive. The wound should be copiously irrigated and left open to heal by secondary intention. Prophylactic antibiotics should be initiated in the ED in all but the most superficial wounds. For patients with a delayed presentation or clinically obvious infection, a hand surgeon should be consulted and consideration given to bringing the patient to the operating room for open irrigation and debridement with subsequent admission for intravenous antibiotics.

Diagnostic testing

- Radiograph of the involved hand (Figure 1.16)
- The metacarpal heads overlap on lateral radiographs and may be difficult to visualize
- An oblique, or “ball-catchers” view, can be helpful in identifying carpal head fractures
- Occasionally CT is required

Figure 1.16 Metacarpal head fracture. (Image courtesy of Carl Germann, MD.)

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- Immobilize the hand in the “safe” or functional position (20° wrist extension with 90° of MCP joint flexion)
- Referral to hand surgery is required (intra-articular fracture)
- Lacerations or punctures of the dorsum of the MCP should be considered open and contaminated
    - Emergency consultation and open irrigation is recommended
    - Prophylactic antibiotics such as penicillin with a beta-lactamase inhibitor and aminoglycoside should be provided in the ED

Prognosis

- Any displacement of an intra-articular fracture predisposes the patient to a poor result
- Metacarpal head fractures are associated with severe long-term complications such as:
    - Avascular necrosis
    - Early arthritis of the MCP joint
    - Malunion
    - Muscle and extensor tendon fibrosis
    - Non-union

Metacarpal neck fracture

Key facts

- Very common
- Usually from a direct impact such as a punch with a closed fist
    - Boxer's fracture: fracture of the neck of the fifth metacarpal
- Often angulated and unstable given the muscular forces

Clinical presentation

- Dorsal angulation of the apex of the fracture is common because of the forces of interosseous muscles
- Examination reveals pain and swelling over the involved metacarpal joint
- Pain is produced by applying axial pressure to the associated digit
- Lacerations suggest an open fracture or fight bite injury

Diagnostic testing

- Radiographs of the involved hand (Figure 1.17)
- Metacarpal heads overlap on lateral views and may be difficult to visualize
- An oblique, or "ball-catchers" view, can be helpful in identifying carpal neck fractures
- Occasionally CT is required

Figure 1.17 Metacarpal neck fracture. (Image courtesy of Carl Germann, MD.)

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- There is greater mobility of the metacarpals as you move from index (second) to little (fifth digit), therefore less angulation is allowed in the second digit
- Closed reduction should be performed if there is greater than:
  - 15° in the second and third metacarpal
  - 35° in the fourth metacarpal
  - 45° in the fifth metacarpal
- Rotational malalignment should be reduced
- A hematoma block may be used
- Reduction is performed by applying axial traction with flexion of the MCP joints and simultaneous pressure over the metacarpal shaft

- Often difficult to reduce or maintain reduction
- If closed reduction is not successful, early hand surgeon referral is required
- Immobilization should be performed with a **radial or ulnar gutter splint** from the elbow to, but not including, the PIP joint. The metacarpophalangeal joints should be splinted at 90° of flexion
- Referral to hand surgery

PEARL: Closed reduction should be performed in metacarpal neck fractures if there is greater than:

- 15° angulation in the second and third metacarpal
- 35° angulation in the fourth metacarpal
- 45° angulation in the fifth metacarpal

Prognosis

- Results are often favorable with little or no deformity
- Significant displacement predisposes the patient to a poor outcome
- Metacarpal neck fractures are associated with severe long-term complications such as early arthritis, chronic pain, malunion, non-union and functional disability

Metacarpal shaft fracture

Key facts

- The proximal phalanx has no tendonous attachment
- The FDS and extensor tendons attach to the middle phalanx

Clinical presentation

- A direct blow often causes a transverse or comminuted fracture
- A twisting mechanism often causes a spiral or oblique fracture pattern
- Volar angulation is common, resulting from the extensor tendon and interosseous muscles

Diagnostic testing

- Radiographs of the involved hand (Figure 1.18)
- Skeletal alignment can be assessed radiographically. Rotational alignment is judged clinically by examining the symmetry related to adjacent fingers
  - Normally, all of the fingers of a closed hand lie in parallel and point to the scaphoid
  - The non-injured hand can also be used for comparison

PEARL: Rotation alignment of the fingers is determined clinically, not radiographically. All the fingers of the closed hand should lie in parallel and point to the scaphoid. Any rotation deformity must be reduced.

Figure 1.18 Metacarpal shaft fracture. (Image courtesy of Carl Germann, MD)

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- Closed reduction should be performed if there is:
  - Any angulation of the second and third metacarpal
  - Greater than 10° and 20° in the fourth and fifth metacarpal, respectively
- Rotational malalignment should be reduced
- Immobilization should be performed with a **radial or ulnar gutter splint** from the elbow to, but not including, the PIP joint
- Referral to hand surgery
- Multiple displaced or communited fractures, fractures with rotational deformity, and irreducible transverse fractures will require internal fixation

PEARL: Closed reduction should be performed if there is:

- Any angulation of the second and third metacarpal Greater than 10° and 20° angulation in the fourth and fifth metacarpal, respectively

Prognosis

- Results are often favorable with little or no deformity
- Significant displacement or non-union predisposes the patient to a poor result and long-term complications such as early arthritis, chronic pain, and functional disability

Metacarpal base fracture

Key facts

- Often results from a direct blow or axial force
- Mobility of the thumb allows for 20 to 30° of angulation without impairment
- Generally stable, with three exceptions:
  - Bennett fracture (Figure 1.19): intra-articular fracture of the base of the thumb metacarpal. Small fragment remains aligned with the trapezium while the abductor pollicis longus subluxes the distal portion of the first metacarpal
  - Rolando fracture (Figure 1.20): intra-articular comminuted fracture of the base of the thumb metacarpal. The comminution is often "Y-" or "T"-shaped
  - Reverse Bennett fracture: the same injury pattern as a Bennett fracture, but in the fifth metacarpal. This fracture pattern is equally unstable because of the lateral traction on the distal metacarpal segment by the extensor carpi ulnaris

Figure 1.19 Bennett fracture: Note that the proximal metacarpal fragment remains aligned with the trapezium. (Image courtesy of Timothy Sweeney, MD.)

Figure 1.20 Rolando fracture: Intra-articular comminuted fracture of the base of the first metacarpal. (Image courtesy of Timothy Sweeney, MD.)

Clinical presentation

- Often results from a direct blow or axial force
  - Bennett, reverse Bennett, and Rolando fractures classically occur because of an axial load to a flexed and adducted digit
- Tenderness at the metacarpal base, rotational deformity may be present
- Ring (fourth) and little (fifth) finger fractures may cause ulnar nerve injury and paralysis

Diagnostic testing

- Radiograph of the involved hand (Figure 1.21)
- Skeletal alignment can be assessed radiographically, rotational alignment is judged clinically by examining the symmetry related to adjacent fingers

Figure 1.21 Metacarpal base fracture. (Image courtesy of Carl Germann, MD.)

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- Finger fractures should be immobilized with a bulky compressive dressing or volar splint and referred to a hand surgeon
- A thumb metacarpal fracture with greater than 20 to 30° of angulation requires closed reduction. All thumb metacarpal fractures should be placed in a thumb spica splint. Unstable fractures require open reduction internal fixation (ORIF)
    - Bennett's and Rolando's fractures require a thumb spica splint and early referral to a hand surgeon for surgical reduction
- Reverse Bennett's fractures require an ulnar gutter splint and prompt referral to a hand surgeon for operative repair

Prognosis

- Results are often favorable with little or no deformity
- Chronic carpal metacarpal joint pain and stiffness may result in displaced or comminuted intra-articular fractures

Carpometacarpal joint dislocation

Key facts

- The CMC joints are supported by strong dorsal, volar, and interosseous ligaments
- Dislocations are uncommon and often missed
- Dislocations commonly result from high-energy trauma such as motor vehicle crashes, falls, crush injuries, and closed-fist injuries

Clinical presentation

- Ecchymosis, swelling, and pain over the dorsum of the hand
- Tenderness over the involved CMC joint(s)

Diagnostic testing

- Radiograph of the involved hand and wrist. (Figure 1.22)
- Fracture lines and dislocations may be subtle on PA radiographs because of superimposition
- Dislocations are usually more obvious on lateral view

Figure 1.22 Carpometacarpal joint dislocation: Dorsal displacement of the metacarpal is more easily seen on lateral views. (Image courtesy of Carl Germann, MD.)

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- Regional anesthesia should provide adequate analgesia for reduction. Consider doing a radial, median, or ulnar nerve block as needed
- Reduction is performed by applying traction and flexion of the hand with longitudinal pressure on the metacarpal base
- Even if closed reduction is successful, prompt hand-surgery referral is required for wire fixation
- Unstable joints or irreducible dislocations should be **immobilized with both dorsal and volar splints** and immediately referred to a hand surgeon

Prognosis

- Stiffness, pain, and weakness may persist because of traumatic arthritis
- Chronic dislocation may occur if there is imprecise alignment

Phalangeal bone fractures and dislocations

Proximal and middle phalangeal fracture

Key facts

- Characterized as extra-articular or intra-articular
- The proximal phalanx has no tendonous attachment
- The flexor digitorum superficialis (FDS) and extensor tendons attach to the middle phalanx
- Rotational deformities often occur secondary to forces of flexor tendons

Clinical presentation

- A direct blow often causes a transverse or comminuted fracture
- A twisting mechanism often causes a spiral or oblique fracture pattern
- Volar angulation is common, resulting from the pull of extensor tendons and interosseous muscles

Diagnostic testing

- Radiograph of the involved hand
- Skeletal alignment can be assessed radiographically, rotational alignment is judged clinically by examining the symmetry related to adjacent fingers

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- Approximately 75% of fractures are stable and non-displaced. These do not require reduction and can be immobilized by a **radial** or **ulnar gutter splint** or by "buddy-taping." This provides support for the injured digit while allowing for motion of the uninvolved phalangeal joints
- Displaced fractures are often easily reduced in the ED and maintained with external splinting
- Unstable fractures that cannot be reduced in the ED require internal fixation

Prognosis

- The most common complication of phalanx fracture is malunion

Distal phalanx fracture

Key facts

- Distal phalanx fractures (tufts fractures) are the most common fractures of the hand
- Characterized as extra-articular or intra-articular
- Tufts fractures are often comminuted and associated with soft tissue and nail or nailbed injuries
- Associated tendon injuries may occur
    - Flexor profundus tendon attaches to the volar aspect of fingers
    - Extensor tendon attaches to the dorsal aspect of fingers
    - Flexor pollicis longus inserts to the volar base of the distal thumb phalanx
    - Extensor pollicis longus attaches to the dorsal base of the distal thumb phalanx

Clinical presentation

- Often a result of a crush injury
- Tenderness and swelling are present over the distal phalanx
- Deficits in range of motion may reflect tendon avulsion

Diagnostic testing

- Radiograph of the involved digit(s)

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc

- **Short volar finger splint** is recommended for comfort and to protect the finger (~3 days)
- Immobilization should not include the PIP joint

Prognosis

- Generally uncomplicated
- Complications include numbness, hyperesthesia, and cold sensitivity
- Nail bed trauma may result in abnormal nail growth

Phalanx dislocation (MCP, PIP, and DIP)

MCP joint dislocation

Key facts

- The MCP joint is stabilized by two collateral ligaments and a volar fibrocartilaginous plate
- Dislocations are usually in a dorsal direction
- Dislocations commonly result from hyperextension forces that rupture the proximal volar plate
- The most common digits involved are the middle finger followed by the little finger

Clinical presentation

- Ecchymosis, swelling, and pain of the involved joint(s)
- Tenderness and swelling are present over the distal phalanx
- Deficits in range of motion may reflect a tendon avulsion

Diagnostic testing

- Radiograph of the involved hand
- Dislocations are usually obvious on a lateral view
- PA views may show widening of the joint. Sesamoids may be found within the joint space

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- Reduction is performed by flexing the wrist while applying firm pressure to the dorsum of the proximal phalanx in a volar direction
- The MCP joint should then be splinted in flexion (between zero and 15°) with either a **thumb spica** or a **dorsal splint** to prevent extension of the MCP joint beyond 0°
- All dislocations should be referred to a hand surgeon

Prognosis

- Complications include entrapment of the volar plate during reduction. Closed reduction is difficult in this scenario and operative repair is often required
- Uncomplicated reductions have a favorable prognosis; however, hand surgery referral is recommended

PIP joint dislocation

PEARL: PIP joint dislocations are the most common ligamentous injury in the hand and more common than MCP and DIP dislocations.

Key facts

- The PIP joint is stabilized by two collateral ligaments and a volar fibrocartilaginous plate
- Dislocations can be in a dorsal, lateral, and volar direction
- Dislocations commonly result from hyperextension and axial loading forces

Clinical presentation

- Ecchymosis, swelling, and pain of the involved PIP joint(s)
- Inability to extend the joint. Tenderness over the joint and deformity may be present

Diagnostic testing

- Radiograph of the involved digit(s)
- Dislocations are usually obvious on lateral view
- Small avulsion fractures may be seen on radiographs and are associated with ligamentous attachment points

PEARL: Avulsion fractures involving 33% or more of the articular surface are usually unstable and require operative repair.

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- A digital nerve block can be used for analgesia to aid in reduction
- Reduction is performed by applying longitudinal traction and mild hyperextension followed by firm dorsal pressure on the proximal aspect of the middle phalanx
- If stability is maintained during active range of motion, the digit should be immobilized in 20 to 30° of flexion in a dorsal splint for 3 weeks
- Unstable joints or irreducible dislocations should be splinted and referred to a hand surgeon

Prognosis

- The prognosis is good, although stiffness, pain, and swelling may persist for weeks to months
- Recurrent dislocation usually does not occur unless the finger is hyperextended

DIP joint dislocation

Key facts

- The DIP joint structure is similar to the PIP joint; however, it has additional stability of the insertions of the flexor and extensor tendons
- Dislocations are usually in a dorsal direction and are often associated with an open wound
- Dislocations commonly result from hyperextension and axial loading forces

Clinical presentation

- Ecchymosis, swelling, and pain of the involved DIP joint(s)
- Inability to extend the joint, tenderness and deformity of the joint may be noticed

Diagnostic testing

- Radiograph of the involved digit(s)
- Dislocations are usually obvious on lateral view
- Small avulsion fractures may be seen on radiographs and are associated with ligamentous attachment points

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- A digital nerve block should provide adequate analgesia for reduction
- Reduction is performed by applying longitudinal traction and mild hyperextension followed by firm dorsal pressure on the proximal aspect of the distal phalanx
- If stability is maintained during active range of motion, the digit should be immobilized in slight flexion with a **dorsal splint** for 3 weeks
- Unstable joints or irreducible dislocations should be splinted and referred to a hand surgeon
- Any open dislocation should be copiously irrigated, sutured, and referred to a hand surgeon. Prophylactic antibiotics are recommended

Prognosis

- The prognosis is good, although stiffness, pain, and swelling may persist for weeks to months
- Recurrent dislocation usually does not occur unless the finger is hyperextended

Nail bed injuries

Subungal hematoma

Key facts

- Results from a crush injury or blunt trauma

Clinical presentation

- Pain and blood underneath the nail. Potential distal phalanx instability/fracture

Diagnostic testing

- Radiograph of the involved digit(s) should be performed if the fingertip is unstable or the mechanism of injury suggests a distal phalanx fracture

Treatment

- Small hematomas do not require drainage
- Large hematomas are painful and should be relieved by nail trephination with a heated paperclip or microcautery device
- Anesthesia is not necessarily required as pain relief occurs with decompression
- If a fracture is present, the digit should be splinted
- Studies suggest that the outcome of nail trephination is similar to that of formal nail bed repair, regardless of the hematoma size

PEARL: Trepination does not usually require anesthesia. The nail is insensate, and the blood lifts the nail off the nailbed so it is unlikely that you will make contact with the nailbed, which is what would cause the patient pain.

Prognosis

- The prognosis is generally good, although patients with large hematomas should be warned that they may lose the nail

Nail avulsion/nailbed laceration

Key facts

- Results from a crush injury or blunt trauma

Clinical presentation

- Pain and blood underneath the nail
- Potential distal phalanx instability
- Injury to the nail, partial avulsion or laceration may be present

Diagnostic testing

- Radiograph of the involved digit(s) should be performed if the fingertip is unstable or the mechanism of injury suggests a distal phalanx fracture

Treatment

- Simple lacerations should be repaired using 5–0 or 6–0 absorbable sutures
- Trephination should be performed to allow drainage of blood after the nail is reinserted into the nail fold
- The nail may be sutured in place through the trephinated hole(s) or taped in place
- A nail-shaped adaptic or non-adherent gauze may be placed under the nail fold if the original nail is misplaced or unusable
- Placing one of the above objects under the nail fold will help prevent synechiae and will help encourage nail regrowth

Prognosis

- These injuries do well with early primary repair
- Complete nail growth may take 70 to 160 days
- Patients should be informed that they are at risk of nail deformity and losing the nail entirely

Tendon, ligament, vascular, and nerve injuries

Tendon injuries

PEARL: Blood vessels and nerves often travel closely with flexor tendons. Injury to one necessitates an evaluation for injury to the other two.

Jersey finger

Key facts

- This injury is a disruption of the flexor digitorum profundus (FDP) which is responsible for flexion at the DIP joint
- Jersey finger is often seen in tackling sports. This occurs when a digit is forced into extension

while actively being flexed, as might occur when grabbing a jersey during a tackle
- More than 75% of Jersey finger injuries involve the ring finger
- Avulsion fractures may accompany Jersey finger injuries

Clinical presentation

- Pain, swelling, and tenderness of the involved DIP joint
- An injury to the flexor tendon may not be evident if the fingers are extended
- An abnormal position or asymmetry of the involved digit during flexion suggests flexor tendon injury
- The FDP and FDS should be tested separately during functional examination
- Partial tendon injuries may be clinically occult. Such injuries may present with pain and functional weakness of the digit against resistance
- Complete tendon injuries prevent the patient from flexing the digit at the DIP joint when the PIP joint is held in extension by the examiner

PEARL: FDP function is tested by having the patient actively flex the DIP joint. The FDS tendon is evaluated by having the patient flex the proximal joint of the finger while the remaining fingers are extended.

Diagnostic testing

- The diagnosis is based upon physical examination
- Radiographs of the involved digit are recommended to evaluate for avulsion fracture

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- Immediate or delayed operative repair is recommended for FDP injuries
- A **volar** or **dorsal splint** should be applied to produce approximately 70° of MCP flexion and slight flexion of the DIP and PIP joints. This prevents further tendon injury and retraction

Prognosis

- Outcomes are dependent on early surgical repair
- With surgical repair, most patients have good outcomes
- Postoperative complications include adhesions, trigger finger, and epidermoid cyst formation

Mallet finger

Key facts

- A closed disruption of the distal extensor apparatus resulting in a flexion deformity (Figure 1.23)
- Most common in the long, ring, and little fingers
- Extensor apparatus disruption most often results from a sudden forced flexion of an extended finger when an object, such as a ball, strikes the tip of the finger
- Avulsion fractures may accompany mallet finger

Figure 1.23 Mallet finger: Injury to the extensor mechanism creates forced flexion because of unopposed action of the flexor digitorum profundus. (Image courtesy of Timothy Sweeney, MD.)

Clinical presentation

- Pain, swelling, and tenderness of the involved DIP joint, typically on the dorsal side
- The distal phalanx is held in flexion because of unopposed forces of the flexor digitorum profundus
- Inability to extend the joint actively

Diagnostic testing

- The diagnosis is based upon physical examination
- Radiographs of the involved digit are recommended to evaluate for an avulsion fracture (Figure 1.24)

Figure 1.24 Avulsion fracture: Commonly associated with mallet finger. (Image courtesy of Timothy Sweeney, MD.)

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- Treatment is aimed at continuous DIP joint extension to allow the extensor apparatus to heal
- A **volar or dorsal splint should be applied to produce slight hyperextension** for 6 to 8 weeks. If the joint is flexed the 6 to 8 week treatment plan should be restarted
- The PIP and MCP joints should be allowed to move freely

Prognosis

- The prognosis is good with 80% of patients achieving successful outcomes with splinting
- Complications include chronic pain, dorsal deformity, and swan-neck deformity
    - Swan-neck deformity occurs when the lateral bands displace laterally and dorsally resulting in increased extension forces on the PIP

Boutonniere deformity

Key facts

- The extensor mechanism is disrupted from the central slip attachment at the dorsal aspect of the middle phalanx
- The proximal end migrates proximally, and the pull of the lateral bands of the extensor mechanism opens the hole further
- This allows the force of the extensor mechanism to bypass the PIP joint, which remains flexed, and divert it to the DIP joint which becomes hyperextended

Clinical presentation

- The most common mechanism is forced flexion of the extended PIP joint as in a basketball player receiving a pass
- Patients present with flexion of the PIP joint and hyperextension of the DIP and MCP joints (Figure 1.25)
- In these patients, the PIP joint can be passively brought to full extension but active extension is not possible
- On physical examination, location of maximal tenderness leads the physician to the proper diagnosis. The patient will usually have tenderness about one or both of the collateral ligaments
- The area of maximal tenderness will be over the central slip on the dorsal aspect of the PIP joint. Generally, this area will also be ecchymotic

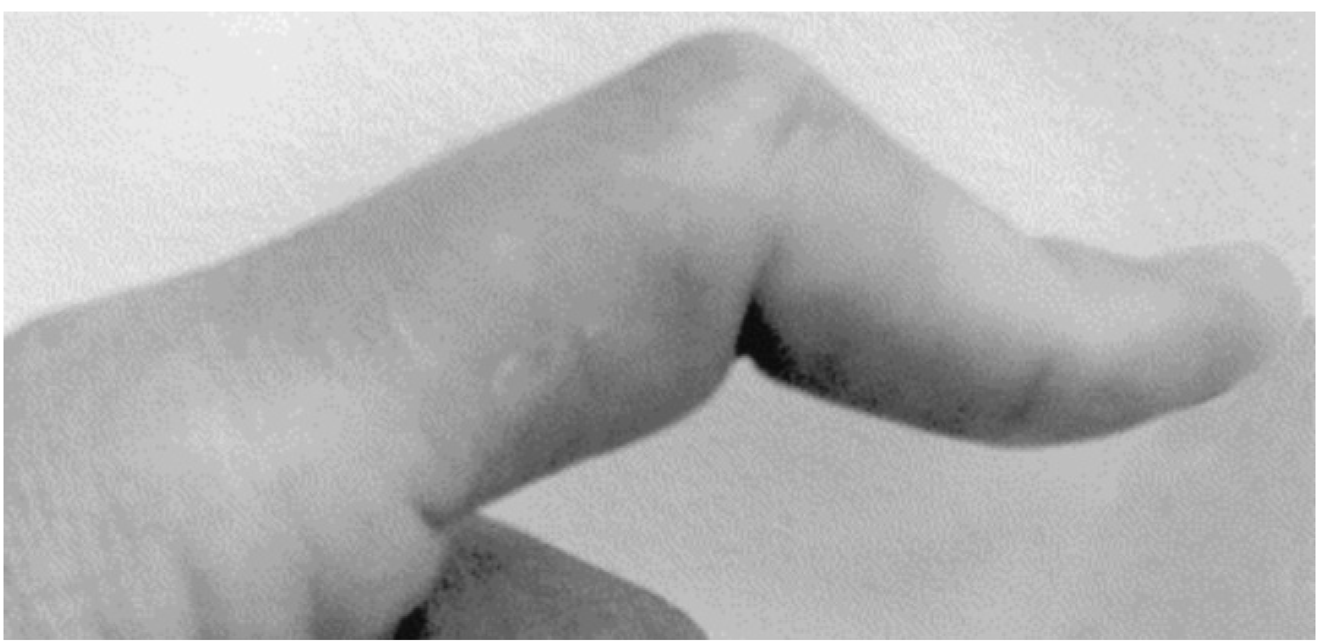

Figure 1.25 Boutonniere deformity: Forces of the lateral bands of the extensor mechanism flex the

PIP joint while extending the DIP and MCP joints. (Image courtesy of Timothy Sweeney, MD.)

Diagnostic testing

- Physical examination will make the diagnosis of central slip injury but may not clarify whether the structure is partially or completely torn
- The prudent course, therefore, is initially to treat all central slip injuries as though they are complete ruptures
- Radiographs may reveal an avulsion fracture of the volar base of the middle phalanx

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- The **PIP joint should be splinted in extension** leaving the DIP and MCP joints to move freely
- The patient should be instructed to continue to move the DIP joint so as not to develop an extension contracture
- Prompt referral should be made to a hand surgeon
- Operative repair may be required for a boutonniere injury associated with a displaced avulsion fracture

Prognosis

- The key to achieving the greatest degree of range of motion and reduction in deformity is to have the finger diagnosed and splinted as early as possible

Ligament injuries

PEARL: Ligamentous injuries are graded as type I, II, or III. Type I reflect minor ligament fiber tears associated with pain and full function. Type II are partial tears with moderate loss of function. Type III are complete tears and are associated with instability and complete loss of function.

Ulnar collateral ligament (UCL) injury

Key facts

- Also called skier's thumb, UCL injuries are the most common upper extremity injury in skiing and result from hyperextension of the thumb on a ski pole while falling
- Ten times more frequent than a radial collateral ligament injury

Clinical presentation

- The mechanism is hyperextension of the abducted thumb causing injury to the ulnar collateral ligament (UCL) and is often associated with an avulsion fracture
- The physical exam will be remarkable for tenderness at the UCL, laxity at the MCP of the thumb, and an inability to actively oppose the thumb (Figure 1.26)
- Most UCL ruptures occur at the distal attachment
- Complete and partial ruptures can usually be differentiated by physical examination
- If the injured joint demonstrates 40° of radial angulation or 15° of laxity beyond the range of the uninjured thumb during stressing, a complete ligament rupture should be assumed

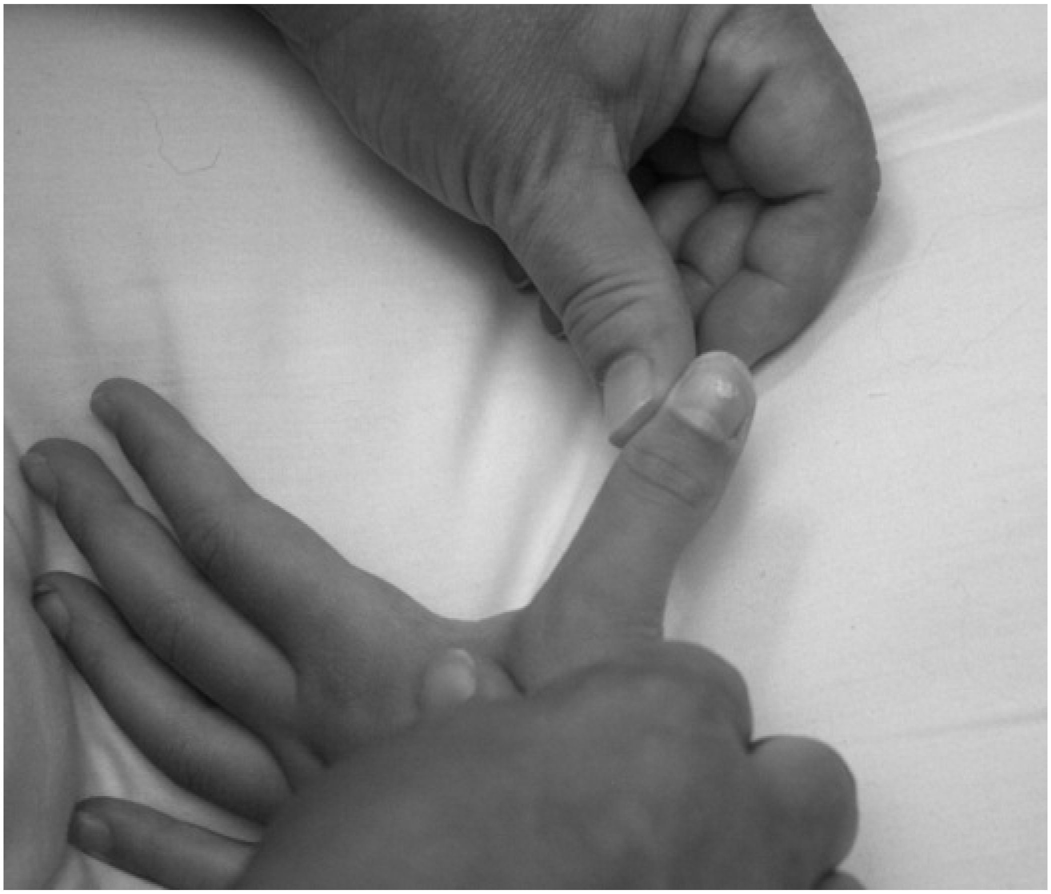

Figure 1.26 UCL stressing: Laxity of the thumb with valgus stress suggests an ulnar collateral ligament injury. (Image courtesy of Timothy Sweeney, MD.)

Diagnostic testing

- Radiographs should be obtained to evaluate for an avulsion fracture (Figure 1.27)
- Clinical examination usually reveals the diagnosis; however, this injury is commonly misdiagnosed as a simple sprain

Figure 1.27 UCL avulsion fracture: Note the fracture at the base of the proximal phalanx. (Image courtesy of Timothy Sweeney, MD.)

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Treatment is immobilization in a **thumb spica splint**, NSAIDS, and referral to a hand surgeon. Complete ruptures require surgical repair

Prognosis

- Repair within 3 weeks will often result in a good outcome
- Long-term complications include chronic pain, instability, and a loss of pinch strength
- Complications include chronic pain, stiffness, loss of sensation, cold-intolerance, non-union, and necrosis

Vascular injuries

Key facts

- The vascular supply to the hand and digits is duplicated, therefore isolated arterial injuries

rarely result in ischemia
- Because digital nerves are often superficial to the digital arteries, an arterial lesion should raise suspicion of a nerve injury
- Lacerations and amputations of the hand rarely cause life-threatening hemorrhage

Clinical presentation

- A history of pulsatile bleeding is suggestive of an arterial injury
- Circulatory status is determined by examination of the radial and ulnar pulses, assessment of capillary refill, and the observation of cyanosis or pallor
- Ischemic pain is the most common finding in vascular insufficiency
- Swelling, discoloration, and tenderness may also be present

Diagnostic testing

- A good history and physical examination will identify most vascular injuries
- Circulation is routinely tested by palpation of the radial and ulnar pulse and examination of capillary refill
- Doppler assessment can also be helpful in assessing radial and ulnar pulses

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- Usually the hemorrhage can be controlled with direct pressure and limb elevation
- If necessary, a blood pressure cuff can be inflated to 30 mmHg above the patient's systolic blood pressure to control bleeding
- Operative repair may be required if there are symptoms of ischemia or nerve injuries
- Injuries to radial, ulnar, and palmar arch arteries often require surgical exploration and repair

Prognosis

- Even completely transected large vessels in the hand and wrist usually retract, constrict, and clot
- The prognosis of vascular injuries is typically good but depends on early and aggressive diagnosis and repair

Nerve injuries

Key facts

- Nerve injuries may result from a direct blow, laceration, crush injury, or amputation
- Nerve injuries are divided into three categories:
    - Neuropraxia: The axon and endoneural tube remain intact. There is a loss of function that

usually resolves within days
    - Axonotmesis: The endoneural tube remains intact, but the axon is severed. The loss of function may slowly return as the proximal axon regenerates
    - Neurotmesis: There is complete disruption of all nerve elements. Regeneration does not occur unless the severed nerve endings are reapproximated

Clinical presentation

- Physical examination will reveal a loss of motor and sensory function
- Injury most often involves one of the digital nerves
- Severe injuries to the hand warrant examination of the sensory function of the digital nerves
    - The digital nerves divide into volar and dorsal branches to supply sensation to the fingers
- Injuries to the forearm or wrist warrant examination of the radial, median, and ulnar nerves
    - The median and ulnar nerves have mixed motor and sensory function of the hand while the radial nerve only has sensory function of the hand (Figures 1.28 and 1.29)
        - The median nerve (C5 to T1) supplies motor function to the abductor pollicis brevis, superficial head of the flexor pollicis brevis, and opponens pollicis
        - The ulnar nerve supplies motor function to the hypothenar muscles, ulnar lumbricals, interossei, adductor pollicis, and the deep head of the flexor pollicis longus

PEARL: The median nerve can be tested by having the patient flex the distal phalanx of the thumb against resistance. The ulnar nerve can be assessed by having the patient spread the fingers against resistance. Radial nerve function can be examined by having the patient extend the wrist.

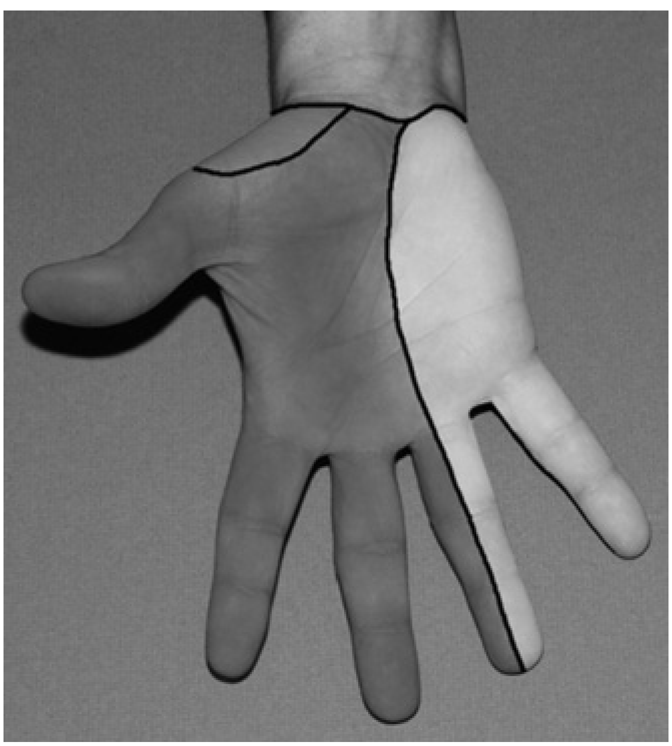

Figure 1.28 Hand sensory distribution: Dorsal view. (Image courtesy of Douglas Dillon, MD.)

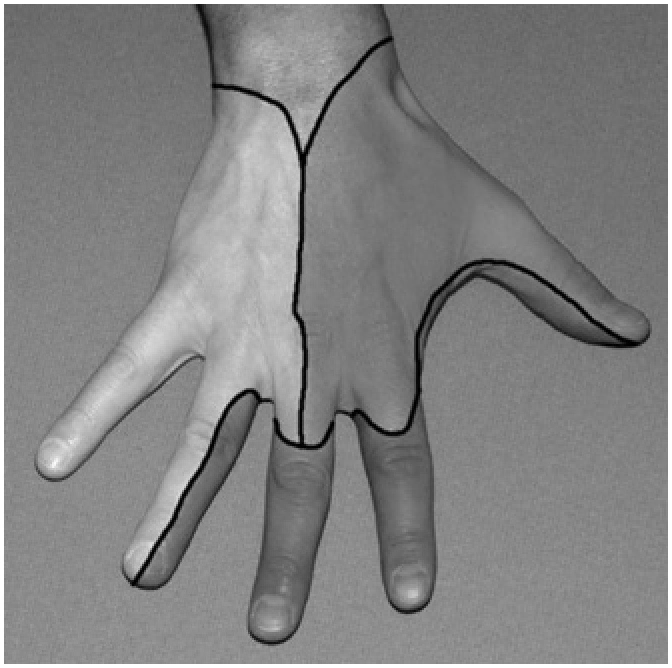

Figure 1.29 Hand sensory distribution: Palmar view. (Image courtesy of Douglas Dillon, MD.)

Diagnostic testing

- Diagnosis is made based on the history and physical examination
- If function does not return in a few weeks, electromyograms and nerve conduction studies can differentiate neurotmesis from axonotmesis and determine the need for surgery

Treatment

- Provide adequate pain control
- Lacerated nerves require reapproximation by a hand surgeon
- In general, injuries to the motor branches of the median and ulnar and digital nerves located proximal to the DIP should be considered for repair
- Patients with closed injuries without evidence of compartment syndrome should be referred to a hand surgeon as an outpatient
- All digits with suspected nerve injury should be splinted in the position of function

Prognosis

- Complications include long-term motor and sensory loss, atrophy, and sympathetic dystrophy
- In general, sensory function recovers more often than motor function, although functional recovery is rarely complete

Amputation

Key facts

- Amputations may be complete or partial

- Fingertip amputations are the most common upper extremity amputation
- Most occur distal to the DIP joint
- Reimplantation should be considered for amputations proximal to the DIP joint

Clinical presentation

- Traumatic amputation usually results from a crush injury or a guillotine mechanism

Diagnostic testing

- Clinical examination provides the diagnosis
- A careful examination of neurologic, vascular, and musculotendinous function should be performed
- Radiographs should be obtained to evaluate for an associated fracture

PEARL: Indications and contraindications for reimplantation.

- Indications:
- Multiple digits amputated
    - Thumb amputation
    - Wrist and forearm amputation
    - Single digits amputated between the PIP and DIP joints (distal to the flexor digitorum superficialis insertion)
    - All pediatric amputations
- Contraindications:
    - Amputations in unstable patients secondary to other life-threatening injuries
    - Multiple-level amputations
    - Self-inflicted amputations
    - Single-digit amputations proximal to the flexor digitorum superficialis insertion
    - Serious underlying disease
    - Extremes of age

Treatment

- Provide adequate pain control (digital block)
- Control bleeding
- The management of distal fingertip amputation is controversial and should be individualized
- Most amputations distal to the DIP are managed with local wound care and allowed to heal by secondary intenion
- If bone if exposed, it may be trimmed back with a rougeur to just below the skin level
- Meticulous wound cleaning and irrigation is required
- A non-adherent dressing should be placed
- Intravenous antibiotics covering for *S. aureus* followed by an oral course is recommended
- Crush injuries or wounds with significant soft tissue or bone loss require surgical repair by a hand surgeon

- Final judgement regarding whether reimplantation will be performed by a surgeon is based upon microscopic examination of the blood vessel and nerves, level of injury, patient age and health-related factors
- If reimplantation is being considered, the amputated portion should be:
  - Assessed for the degree of tissue injury
  - Irrigated with normal saline; local antiseptics should be avoided
  - Covered with saline-moistened sterile dressing
  - Placed in a dry plastic bag and placed in ice water
- Tetanus status should be addressed

Prognosis

- Warm ischemia may be tolerated for 6 to 8 hours; cooling may extend this time to 12 to 24 hours

Selected readings and references

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Chapter 2 Shoulder and elbow emergencies

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Orthopedic Emergencies, ed. Michael C. Bond, Andrew D. Perron, and Michael K. Abraham. Published by Cambridge University Press.

Glenohumeral dislocations

Key facts

- Anterior shoulder dislocations are usually clinically obvious
- Posterior shoulder dislocations can be difficult to identify
- The shoulder is the most commonly dislocated joint in the body
- 95% of shoulder dislocations will be anterior
- Patients < 30 years of age have a high risk of recurrence

Clinical presentation

- The shoulder is the most commonly dislocated joint in the body
- 95% of shoulder dislocations will be anterior
  - Patients have a squared-off appearance to the shoulder
  - The arm is held in slight abduction
- Posterior dislocations can be difficult to detect by appearance alone
  - Patients often hold the arm adducted to the side
  - Seizures are classically associated with posterior dislocations
- A thorough neurovascular exam of the affected extremity is essential to exclude a neurovascular injury
  - The axillary nerve is most commonly injured

PEARL: Patients over the age of 40 should be evaluated for a possible rotator cuff tear, which may occur in greater than one-third of patients with glenohumeral dislocations.

Diagnostic testing

- Plain films of the shoulder are the test of choice
  - Perform an AP (Figure 2.1A) and a lateral projection (axillary lateral or scapular Y-view) (Figure 2.1B)

PEARL: Failure to obtain a lateral projection can result in missing a posterior dislocation in up to 50% of cases.

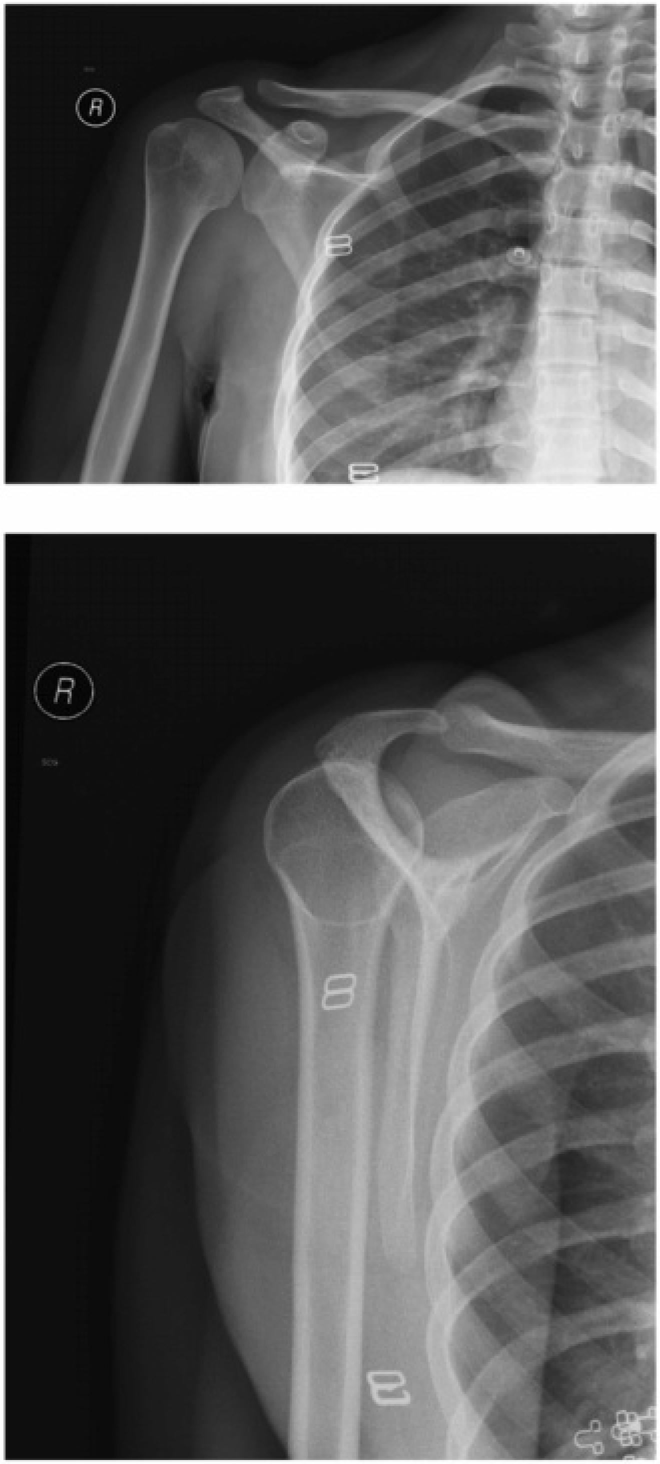


Figure 2.1A and 2.1B Radiographs of a posterior shoulder dislocation.
A: An AP projection is shown with no obvious dislocation.
B: A lateral projection (scapular Y-view) for the same patient shows the humeral head to be dislocated posteriorly. (Reproduced with permission of the Department of Emergency Medicine, Feinberg School of Medicine, Northwestern University.)

Treatment

- Emergency Department management
    - Provide adequate analgesia
        - Procedural sedation has been the historical mainstay for joint reductions
        - Reduction performed with an intra-articular anesthetic injection is an acceptable

    alternative
- Reduce the shoulder
    - There are a multitude of techniques
    - Be familiar with more than one – no technique has a 100% success rate
- Perform pre- and post neurovascular exams
- Perform confirmatory radiographs
- Place the patient in a standard sling or shoulder immobilizer
    - External rotation slings may provide better anatomic alignment but are not often available in many EDs
    - External rotation slings have been shown to reduce the recurrence rate of first-time dislocators
- Referral to an orthopedic surgeon in 7–10 days is appropriate

PEARL: Reductions performed with intra-articular anesthetic injections have been safely performed with equivalent success rates, similar patient comfort, shorter ED length of stays, and lower complication rates.

Prognosis

- Most patients can return to a pre-injury level of function after several weeks
    - Patients < 30 years of age have a high risk of recurrence and may benefit from surgical stabilization
    - Patients > 40 years of age may have greater morbidity if the rotator cuff has been injured

Procedures

- Intra-articular injection of lidocaine (Figure 2.2)
    - Supplies needed
        - 1–3 cc syringe
        - 1–20 cc syringe
        - 2–18-gauge needles
        - 1–27-gauge needle
        - 1–20-gauge 3.5 inch spinal needle
        - Chlorhexidine/betadine scrub
        - 4 × 4 gauze pads
        - Sterile gloves
        - 30 cc vial of 1% lidocaine solution
    - Technique
        - Positioning
            - Place the patient in the seated position with the affected arm adducted to the side
        - Preparation
            - Prep the lateral aspect of the shoulder with betadine or chlorhexidine solution
            - Apply sterile gloves and perform procedure with standard aseptic technique
            - Draw 1 cc of 1% lidocaine into the 3 cc syringe and cap with the 27-gauge needle; set aside for use as local skin anesthesia

        - Draw 15 cc of 1% lidocaine into the 20 cc syringe and cap with the 20-gauge spinal needle
        - Identify the lateral aspect of the acromion (identified by the squared-off shoulder)
            - Make a sterile mark 1 cm below the inferior-most aspect of the acromion
    - Procedure
        - Make a small skin wheal at the marked site using the 3 cc syringe with lidocaine
        - Holding negative pressure, insert the 20 cc syringe with attached spinal needle into the lateral aspect of the shoulder perpendicular to the skin
        - Continue advancing until the glenohumeral joint is entered
            - Hemarthrosis may be apparent
            - Change in resistance from entering the joint space can be felt
        - Inject 15 cc of 1% lidocaine into the joint space
        - Remove the needle and place a sterile dressing
        - Allow 15 minutes for the anesthetic to take effect

- Glenohumeral reduction
    - Various different techniques exist with excellent success rates (Table 2.1)
    - External rotation method: can be performed safely by a single provider and does not require a lot of strength for success (Figure 2.3)
        - Place the patient in the supine position
        - Hold the affected extremity adducted to the side with the elbow flexed at 90°
        - Bring the shoulder into 20° of forward flexion
        - The physician should hold the patient's wrist with one hand, stabilize the elbow with the other hand and gently externally rotate the forearm
        - The physician should stop and hold the position when resistance is felt until the muscles relax and then proceed further
        - Once reduction is achieved, the arm can be returned to an internally rotated position and placed in a sling

Table 2.1 ***Comparison of common glenohumeral reduction techniques.***

Technique	No. of operators	Position	Description	Disadvantages	Success rate
Modified Hippocratic (traction – countertraction)	Two	Supine	One operator provides a longitudinal traction force with the arm slightly abducted. Second operator provides countertraction (typically with a bed sheet wrapped around the thorax in the axilla)	Requires significant force	86%
Kocher	One	Seated	Starting position: arm should be adducted at the side with elbow flexed. Gently adduct the arm further and externally rotate the elbow. When resistance is felt, the arm is forward flexed upwards and then internally rotated	Higher incidence of fracture	72–100%
Milch	One	Supine	Starting position: arm fully abducted above the head with extended elbow. Apply longitudinal traction and external rotation of arm	None	70–90%
Scapular manipulation	Two	Prone	One operator provides downward traction to arm forward flexed 90°. Second operator attempts to adduct and medially rotate inferior border of scapula	Difficult to monitor sedation; operator dependent	79–90%
External rotation	One	Supine/ seated	Starting position: arm fully adducted at side with elbow flexed. Perform slow passive external rotation of arm	None	80–90%

Technique	No. of operators	Position	Description	Disadvantages	Success rate
Stimson	One	Prone	Arm hangs off stretcher in 90° forward flexion and 5–10 pound weights attached to affected arm (can combine with scapular manipulation)	Equipment; difficult to monitor sedation	91–96%
Snowbird	Two	Seated	Starting position: patient seated in chair with arm adducted and flexed at elbow; Operator applies downward traction by placing foot in a loop of stockinette wrapped around the patient's forearm	None	97%
Spaso	One	Supine	Starting position: arm forward flexed 90° toward the ceiling. Apply longitudinal traction toward ceiling and passive external rotation	Operator back discomfort (rare)	67–91%

Data from Ufberg JW, Vilke GM, Chan TC, *et al*. Anterior shoulder dislocations: beyond traction-countertraction, *J Emerg Med*. 2004; 27(3):3001–6. Reproduced with permission from Malik, *et al*. 2010.

Figure 2.2 Intra-articular injection of lidocaine.
After sterile prep, the needle enters the shoulder perpendicular to the skin, just below the lateral edge of the acromion, until the glenohumeral joint is entered. (Reproduced with permission of the Department of Emergency Medicine, Feinberg School of Medicine, Northwestern University.)

Figure 2.3 The external rotation method for glenohumeral reduction.
A: Place the patient in the supine position with the affected extremity adducted to the side and the elbow flexed at 90° and shoulder forward flexed at 20°. The physician should hold the patient's wrist with one hand and stabilize the elbow with the other.
B: Gently externally rotate the forearm, stopping periodically when resistance or muscle spasm is felt, to allow for muscle relaxation.
C: Once reduction is felt, the arm should be checked through a range of motion and may be returned to an internally rotated position with a sling. (Reproduced with permission of the Department of Emergency Medicine, Feinberg School of Medicine, Northwestern University.)

Scapular fractures

Key facts

- The scapula links the axial skeleton to the upper extremity and serves as the stabilizing platform for arm motion
- Scapular fractures result from a high-energy mechanism and require a thorough trauma assessment to exclude life-threatening injuries

Clinical presentation

- Scapular fractures account for only 1% of all fractures and 5% of shoulder fractures
  - The majority of fractures occur in the body of the scapula
- Scapular fractures often occur with a high-energy mechanism and may be associated with more serious injuries
  - In one series, patients with scapular fractures had an average of 3.9 additional major injuries
- Mechanism of injury
  - High-energy direct blow/trauma to the shoulder area
  - Fall on to an outstretched arm
  - Shoulder dislocations may result in a glenoid fracture
- Physical examination findings
  - Injured patients often hold the arm adducted to the side
  - Significant pain with ipsilateral arm motion
  - Localized tenderness over the scapula
  - Swelling, crepitus, and ecchymosis may be present over the scapula
  - Perform a careful neurovascular examination to rule out arterial injury or brachial plexopathy
    - May occur in 13% of scapular fractures

PEARL: Evaluate closely for associated pulmonary contusions that may lead to significant morbidity and mortality.

Diagnostic testing

- Plain radiography is the initial test of choice in the evaluation of suspected scapular fractures
  - Dedicated scapular series includes an AP/lateral/scapular views
  - Scapular fractures may be obscured by overlying structures
  - Os acromiale may be confused for a mid-acromion fracture
    - Normal variant in 15% of patients
    - Rounded edges and bilateral appearance are reassuring
- CT scans of the chest or scapula may better identify fractures
- Electromyogram (EMG) testing can be performed at a later date to evaluate suspected nerve injuries
  - Optimal results > 3 weeks after injury
  - May evaluate the extent of the injury and potential for recovery

Treatment

- Emergency Department management
  - Pain control
  - Sling
  - Encourage early ROM
  - Referral to an orthopedic surgeon
  - Treat concurrent injuries
- Long-term management
  - Majority of fractures are treated non-surgically
    - Scapular body fractures
  - Surgical intervention may be considered for
    - Glenoid fractures
    - Displaced scapular neck fractures

Prognosis

- 86% scapular body fractures heal with excellent or good results
- 82% glenoid fractures treated operatively heal with excellent or good results
- Complications are uncommon
  - Glenoid fractures managed non-operatively may lead to shoulder instability
- Most fractures heal in approximately 6 weeks
  - Full functional recovery may take up to a year
- Healing with slight non-union does not result in significant disability
  - Associated with fractures of glenoid, acromion, and coracoid

Clavicle fractures

Key facts

- Clavicle fractures often result from high-mechanism trauma
- Adequate pain control is a key aspect in the management of clavicle fractures
- The majority of clavicle fractures can be managed conservatively with a simple sling
- Displaced mid-shaft clavicle fractures have a higher risk of non-union and should be referred to an orthopedic surgeon for operative consideration (Figure 2.4)

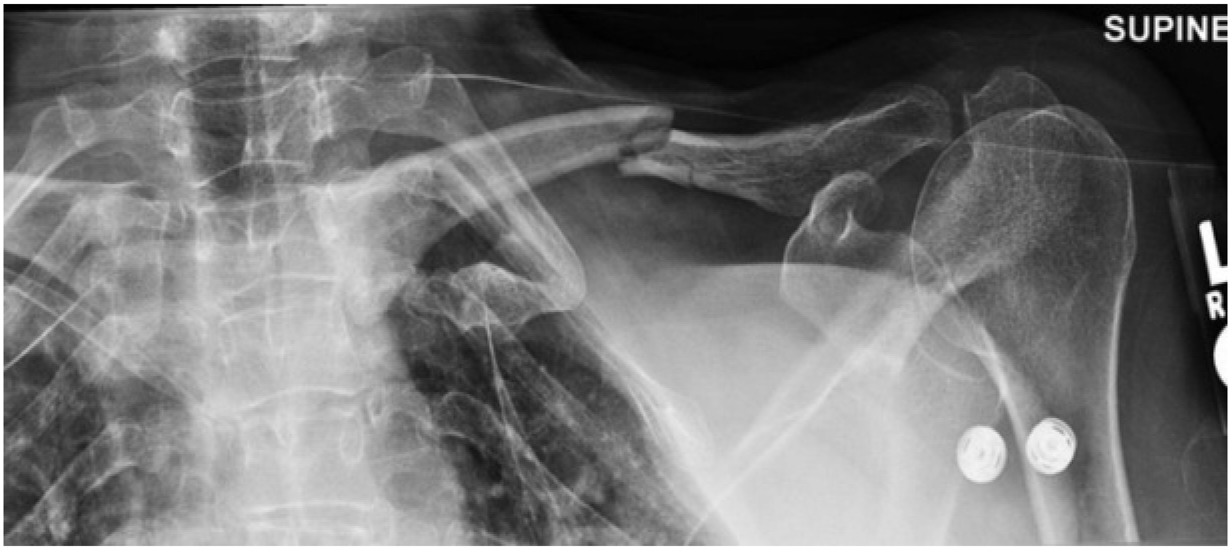


Figure 2.4 Displaced mid-shaft clavicle fracture. (Reproduced with permission of the Department of Emergency Medicine, Feinberg School of Medicine, Northwestern University.)

Clinical presentation

- The majority of patients will present with pain over the clavicle or shoulder region
- Males between the ages of 15–30 years are the most likely to suffer this injury
- Mechanism of injury
  - Young patients generally require a high-impact direct trauma
    - Sporting injuries
    - Falls
    - Motor vehicle collisions
  - Elderly patients may have a more minor mechanism such as a simple fall from standing height
- Physical examination findings are straightforward
  - Affected limb held adducted to the side
  - Tenderness over the clavicle
  - Limited shoulder abduction and forward flexion because of pain
  - Deformity is often apparent because of the subcutaneous location of the clavicle
- A thorough neurovascular examination of the affected extremity is essential to exclude an associated neurovascular injury

Diagnostic testing

- Plain radiographs are the preferred test for evaluation of suspected clavicle fractures
  - Standard clavicle plain films
    - AP and 45° cephalic tilt views
  - Serendipity view: 40° cephalic tilt view
    - Better evaluates the medial clavicle
  - Zanca view: AP view where the x-ray beam is directed at the acromioclavicular joint with 10-degree cephalic tilt
    - Better evaluates the distal clavicle and AC joint

Classification

- Middle-third fractures (Allman Type I)
  - Most common type (69–80%)
- Lateral-third fractures (Allman Type II)
  - 21–25% of clavicle fractures
  - More common in elderly
- Medial-third fractures (Allman Type III)
  - Rare (2%)
  - More common in elderly

Treatment

- Emergency Department management for all clavicle fractures
  - Adequate pain control
  - Sling for comfort
  - Figure-of-8 bandages are an alternative
    - Reports of greater discomfort
    - Higher risk of brachial plexus injury
  - Restrict from overhead activity
- Long-term management
  - Majority of clavicle fractures can be managed non-operatively with recovery in 6–8 weeks
- Referral to an orthopedic specialist in 1–2 weeks

PEARL: Shortened or displaced (> 2 cm), mid-shaft clavicle fractures or fractures of the lateral third have a higher risk of non-union and should be referred early to an orthopedic surgeon for consideration of operative management.

Prognosis

- The majority of patients have an excellent recovery from clavicle fractures

Sternoclavicular injuries

Key facts

- Sternoclavicular (SC) injuries are relatively rare
- Anterior dislocations are unstable and often remain so after treatment
- Posterior sternoclavicular dislocations may result in concurrent injuries to mediastinal structures in 30% of cases
- Reduction of a posterior SC dislocation is best performed in the operating room with orthopedic and cardiothoracic surgery support

Clinical presentation

- SC dislocations are uncommon
- Injuries to patients < 25 years of age are often physeal injuries as opposed to true dislocations
- Patients present complaining of shoulder and/or chest pain
- Both anterior and posterior dislocations may occur
- Mechanism of injury:
    - Anterior dislocations
        - Anterolateral force resulting in posterior pressure on the shoulder and medial directed pressure on the clavicle
    - Posterior dislocations
        - Posterolateral force resulting in an anterior directed pressure on the shoulder and a simultaneous medial directed force on the clavicle
        - Direct hit to the medial clavicle
- Physical examination findings
    - Tenderness at the SC joint
    - Painful shoulder ROM
    - Prominent medial clavicle in anterior dislocations
    - Affected arm may be held adducted with elbow flexed
- A thorough examination is warranted to exclude associated injuries
    - Venous congestion of the neck or ipsilateral arm, hoarseness, cough, shortness of breath may be concerning findings

PEARL: Presence of a posterior SC dislocation should prompt evaluation for associated injuries to the trachea, esophagus, and great vessels, which are in close proximity to the SC joint.

Diagnostic testing

- Plain radiography with a clavicle series or chest radiograph is often non-diagnostic
    - A serendipity view to better evaluate the medial clavicle and SC joint may be obtained
- CT imaging is the test of choice for evaluation of the SC joint
- For posterior dislocations, additional evaluation for concurrent injuries should be considered
    - CT angiography
    - Chest radiography
    - Bronchoscopy
    - Endoscopy

Treatment

- Adequate pain control should be provided for all dislocations
- Anterior dislocations
    - Anterior dislocations are unstable and may remain so even after treatment
    - Closed reduction should be attempted in the ED
    - Procedural sedation is often required
    - Post reduction, the patient should be placed in a figure-of-8 brace or a clavicle harness for 4–6 weeks
    - Referral to an orthopedic surgeon for follow-up is advised

- Posterior dislocations
  - Associated injuries should be thoroughly evaluated and treated as appropriate
  - An emergent orthopedic consultation should be obtained
  - Reduction is best performed in the operating room
    - Closed reduction may be successful in the first 48 hours, but open reduction is often required
    - Consultation with a cardiothoracic surgeon is advised to address any complications from the reduction
  - Post reduction, the patient should be placed in a figure-of-8 brace for 6–8 weeks

PEARL: Management of a posterior SC dislocation is best performed in consultation with an orthopedic and cardiothoracic surgeon.

Prognosis

- Anterior dislocations often remain unstable post treatment but rarely cause any long-term functional impairment
- Posterior dislocations are generally stable post reduction
  - Associated injuries with a posterior dislocation can result in poorer outcomes

Procedure

- Closed reduction of anterior SC dislocation
  - Local anesthesia or procedural sedation may be used for analgesia at the provider's discretion
    - Cardiopulmonary monitoring as indicated
  - Place the patient supine on the gurney with a towel roll or firm pad in between the shoulder blades
  - Technique
    - Bring the affected arm into 90° abduction and 10° extension
    - Apply traction to the affected arm
    - An assistant should provide a posterior force on to the medial aspect of the clavicle until the deformity has resolved
  - After reduction is complete, place the patient in a valpeau bandage or figure-of-8 brace

Acromioclavicular injuries

Key facts

- Acromioclavicular (AC) injuries are the most common shoulder injuries in contact sports
- Type I AC injuries are radiographically normal and may be missed without an adequate physical examination
- Classification of injuries using the Rockwood classification can be helpful in determining management and prognosis (Table 2.2)

- Emergency department treatment should be focused on adequate pain control and a sling for comfort
- Early referral to an orthopedic surgeon is advised for Type III–VI injuries (Figure 2.5)

Table 2.2 ***Rockwood classification of AC injuries.***

Type	Pathology	Clinical findings	Radiographic findings	ED management	Definitive management
Type I	AC sprain, CC intact	AC tenderness	Normal	Sling 7–10 days, pain control	Conservative
Type II	AC torn, CC sprain	AC tenderness	AC > 3 mm	Sling 2–3 weeks, pain control	Conservative
Type III	AC torn, CC torn, D and T torn	AC tenderness, deformity	AC > 3 mm CCD > 13 mm 25%–100% displacement	Sling, pain control	Controversial, non-operative*
Type IV	AC torn, CC torn, D and T torn, posterior displacement of clavicle through trapezius	Prominent acromium	AC > 3 mm CCD > 13 mm Posterior displacement of clavicle on axillary lateral	Sling, pain control, neurovascular assessment	Surgical
Type V	AC torn, CC torn, D and T torn, severe superior displacement of clavicle	Deformity	AC > 3 mm CCD > 13 mm 100%–300% displacement	Sling, pain control	Surgical
Type VI	AC torn, CC intact, inferior displacement of clavicle subcoracoid	Associated trauma	AC > 3 mm CCD decreased	Sling, pain control, neurovascular assessment	Surgical

Abbreviations: AC, acromioclavicular; CC, coracoclavicular; CCD, coracoclavicular distance; D, deltoid attachment at clavicle; T, trapezius attachment at clavicle. *Management of Type III injuries is controversial. Non-operative management is most common but surgical management may be considered in some populations.

Reproduced with permission from Malik, *et al*. 2010.

Figure 2.5 Grade III AC separation. Note the elevation of the distal clavicle relative to the acromion suggestive of injuries to both the acromioclavicular and coracoclavicular ligaments. (Reproduced with permission of the Department of Emergency Medicine, Feinberg School of Medicine, Northwestern University.)

Clinical presentation

- Acromioclavicular injuries involve injuries to the acromioclavicular and coracoclavicular ligaments
- AC injuries are the most common shoulder injury in contact sports
- Mechanism of injury
  - Fall directly on the adducted shoulder
  - Fall on outstretched hand (FOOSH)
- Physical examination findings
  - Tenderness over the acromioclavicular joint
  - Pain with cross-arm abduction test
  - Deformity may be apparent in higher-grade AC injuries
- A thorough neurovascular examination of the affected extremity is essential to exclude an associated neurovascular injury

Diagnostic testing

- The diagnosis of AC injuries is often apparent on physical examination
- Plain radiographs of the shoulder are the preferred test for further evaluation of suspected AC injuries and assist in identifying the severity of the injury
  - Type I AC sprains will be radiographically normal
  - Widening of the AC joint greater than 3 mm is suggestive of an acromioclavicular ligament injury

    - Widening of the coracoclavicular distance greater than 13 mm is suggestive of a coracoclavicular ligament injury

PEARL: A normal shoulder film does NOT exclude the diagnosis of an AC sprain.

Classification

Treatment

- Emergency Department management for all AC injuries
    - Adequate pain control
    - Sling for comfort
    - Early range of motion
    - Restrict the patient from overhead activity
- Referral to an orthopedic specialist in 1–2 weeks
    - Consider earlier referral for Type III–VI AC injuries as they may be candidates for operative repair

PEARL: Type III AC separations have controversial management and should be referred to an orthopedic surgeon for further evaluation.

Prognosis

- Recovery may be 2–6 weeks depending on the severity of injury
- The majority of patients with lower-grade AC injuries will have a complete recovery of prior function

Proximal humerus fractures

Key facts

- More than 80% of proximal humerus fractures are non-displaced (Figure 2.6) or minimally displaced and do not require surgery
- The rotator cuff tendons are at risk for concurrent injury given their insertion on to the greater and lesser tuberosities
- Early range of motion exercises improve functional recovery

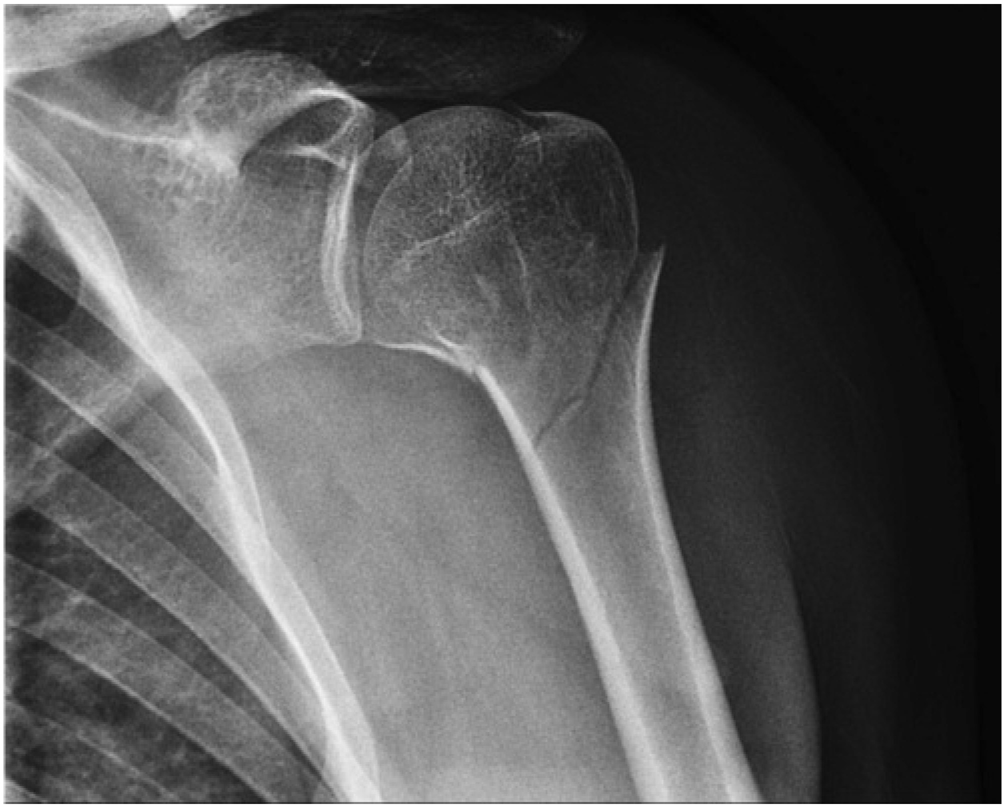


Figure 2.6 Non-displaced proximal humerus fracture. (Reproduced with permission of the Department of Emergency Medicine, Feinberg School of Medicine, Northwestern University.)

Clinical presentation

- Proximal humerus fractures are the third most common fractures in the elderly
  - Increased incidence with elderly age and female gender
- Mechanism of injury
  - Fall on to an oblique angle on an outstretched hand
  - Fall on to the shoulder from a standing height
  - High-impact direct trauma to the shoulder in young patients
- Physical examination findings
  - Distinct point of tenderness over the proximal humerus
  - Painful range of motion
  - Arm often held in slight abduction
  - Deformity not often apparent
  - A thorough neurovascular examination of the affected extremity is essential
    - Axillary nerve injuries are associated with displaced fractures or fracture–dislocations
    - Brachial plexus also at risk of injury

PEARL: Fractures of the anatomic neck compromise the blood supply to the humeral head and are at risk of avascular necrosis.

Diagnostic testing

- Plain radiographs are the test of choice to evaluate the shoulder

    - AP view of the scapula and glenohumeral joint
    - Axillary view and lateral Y-view of the scapula
- Findings
    - Pseudo-subluxation of the humeral head inferiorly suggests hemarthrosis
    - Greater tuberosity fractures are associated with anterior shoulder dislocations
        - Should raise suspicion for concurrent rotator cuff tear

Classification

Table 2.3 ***Neer classification of proximal humerus fractures.***

Type	**Description**
1-part fractures	Non-displaced or minimally displaced
2-part fractures	A single segment is displaced*
3-part fractures	Surgical neck fracture with displaced fracture of one of the two tuberosities
4-part fractures	Surgical neck fracture with displaced fractures of both tuberosities*
Fracture–dislocations	Displacement of humeral head in addition to fracture fragments

The Neer classification separates the humerus into four anatomic parts based on old epiphyseal lines (anatomic neck, surgical neck, greater and lesser tuberosities). A fragment is defined as being displaced if separation is > 1 cm or angulation > 45°. *Note: Two-part anatomic neck fractures and four-part fractures are at highest risk for AVN.

Treatment

- Emergency department management
    - Adequate pain control
    - Immobilize with sling for 1–3 weeks
    - Encourage early range of motion
    - Urgent orthopedic consultation is advised for:
        - Anatomic neck fractures
        - Four-part fractures
        - Fracture/dislocations
- Long-term treatment

- Definitive treatment based primarily on the number of segments involved and degree of displacement
    - Non-displaced fractures managed conservatively with immobilization in a sling, early motion and orthopedic follow-up
        - Recovery may be 2–3 months
    - Multiple part fractures may benefit from operative management
        - Elderly patients may have acceptable results with non-operative treatment

PEARL: Early range of motion exercises can decrease pain and result in improved functional outcomes.

Prognosis

- The majority of patients have adequate recovery from proximal humerus fractures

Humeral shaft (diaphyseal) fractures

Key facts

- Humeral shaft fractures typically occur by direct trauma to the arm or shoulder in the middle-age population
- Humeral shaft fractures associated with an ipsilateral forearm fracture result in a floating elbow that requires urgent intervention
- Associated radial nerve injuries can lead to wrist drop
- Pain control and adequate immobilization are the key aspects to the emergent care of humeral shaft fractures

Clinical presentation

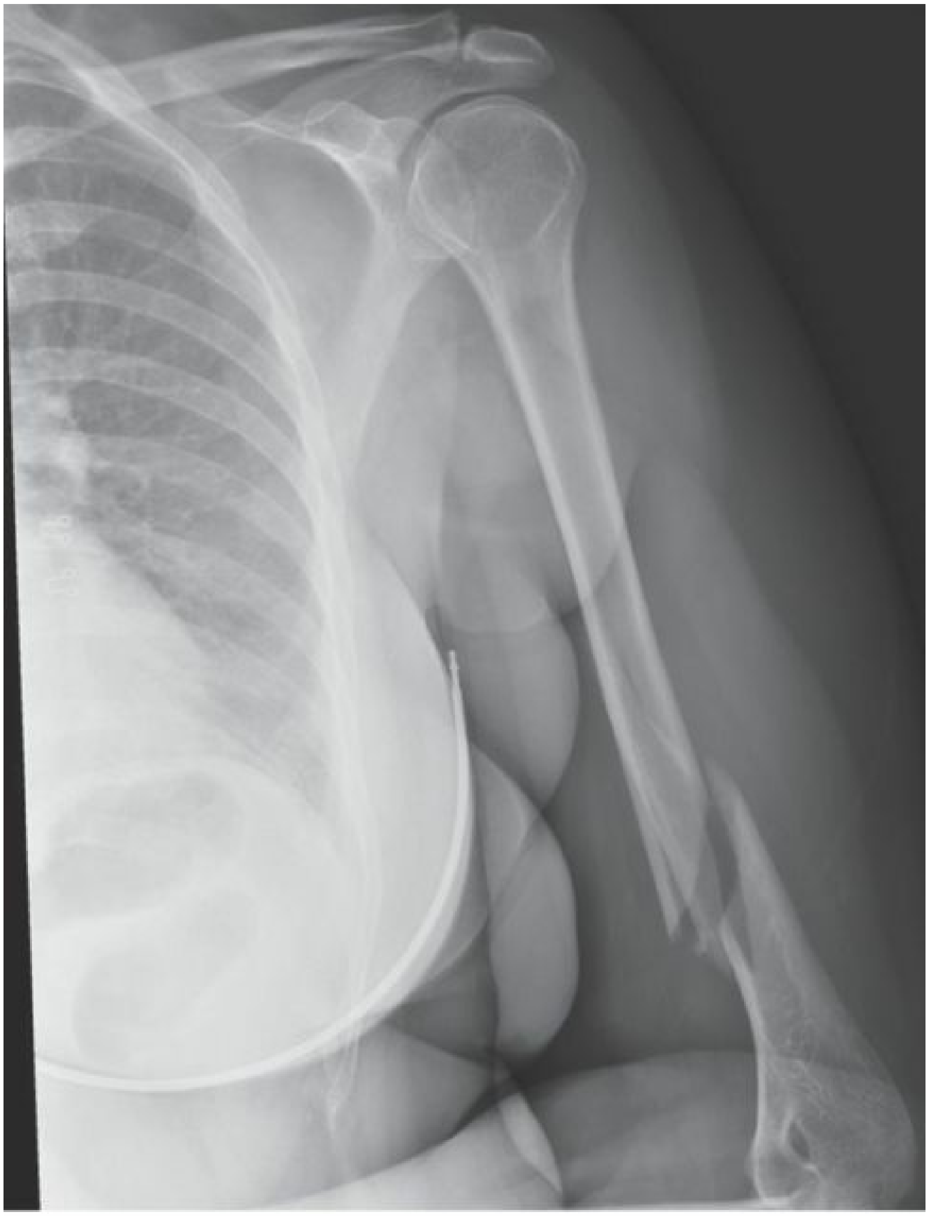
- Humeral shaft fractures are much less common than proximal humerus fractures
- Mechanism of injury
    - Transverse fractures
        - Benign fall with a direct strike to the elbow producing a bending force
    - Spiral fractures
        - Fall on to an outstretched hand with axial loading
- Physical examination findings
    - Localized tenderness and swelling
    - Painful deformed arm
    - Arm shortening in the setting of displacement
        - Associated radial nerve palsy (wrist drop) occurs in 15–18%
        - Extension of the wrist and digits should be examined

PEARL: Perform a careful neurovascular examination. Radial nerve injury following a humerus shaft fracture may occur.

Diagnostic testing

- Plain radiographs are the preferred test for evaluation of suspected humeral shaft fractures (Figure 2.7A, B)
  - AP and lateral views of the humerus
  - Trans-thoracic and axillary views of the shoulder
  - Both the shoulder and elbow should be visualized radiographically

PEARL: Consider additional forearm views to exclude concurrent fractures.



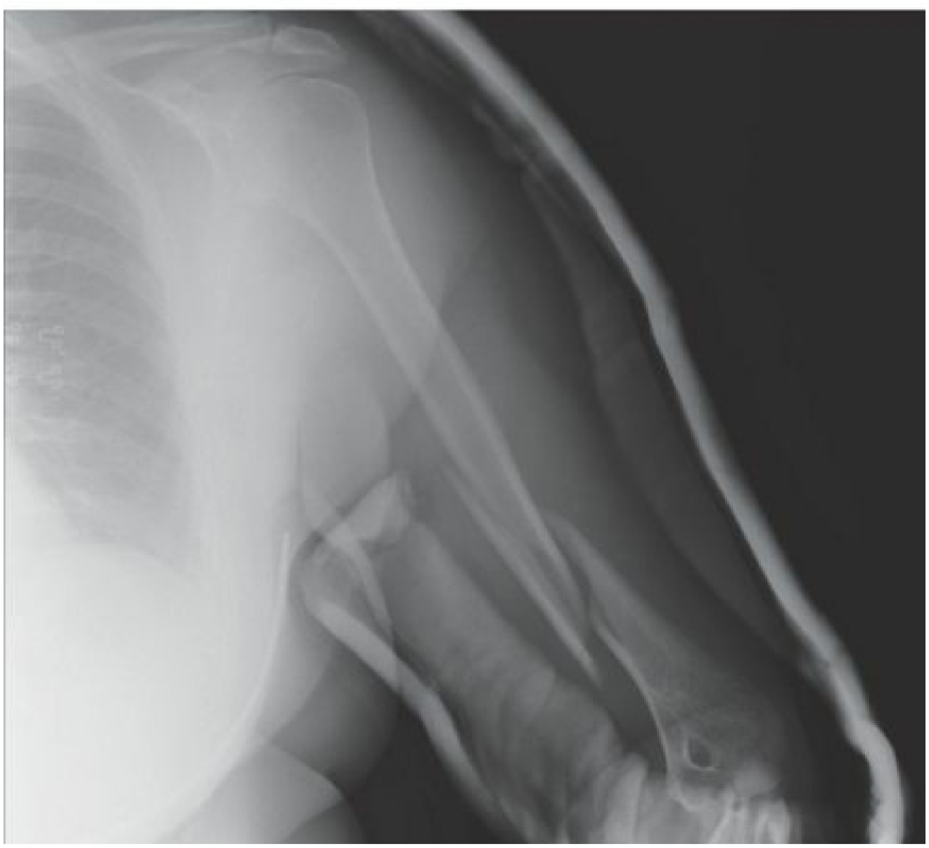


Figure 2.7 A: Humeral shaft fracture. B: Post-reduction film of a humeral shaft fracture stabilized in a coaptation splint. Note the persistent angulation and shortening. (Reproduced with permission of the Department of Emergency Medicine, Feinberg School of Medicine, Northwestern University.)

Treatment

- Emergency Department management
  - Adequate pain control
  - Fracture reduction is often not necessary, as reduction is difficult to maintain
    - 30–40° of angulation is acceptable because of the shoulder's ability to compensate
  - Immobilization can be achieved with a coaptation splint
    - Hanging cast may be considered
    - Sling and swathe may be acceptable alternative for non-displaced fractures in children and the elderly
  - Majority of fractures are managed conservatively with orthopedic follow-up

PEARL: Floating elbow (ipsilateral humerus and forearm fracture) requires urgent ED orthopedic consultation and operative repair.

- Long-term management
  - Majority of humeral shaft fractures are managed non-operatively with an expected recovery in 3–4 months
  - Consider operative treatment for:
    - Unacceptable reduction
    - Radial nerve palsy
    - Floating elbow
    - Pathologic fractures

Prognosis

- The majority of patients have an excellent recovery from humeral shaft fractures
  - Expected union rate > 90%
  - 75–90% of radial nerve deficits recover after 3–4 months

Procedure

- Application of a coaptation splint (Figure 2.8)
  - Supplies
    - 4-inch plaster
    - 4-inch Webril™ or equivalent cotton padding
    - 4-inch elastic bandage
    - Scissors
    - Basin for water

        - Chux
        - Tape
        - Sling
    - Technique
        - Place two to three layers of padding on the affected extremity, extending from the distal clavicle to the proximal forearm in the usual fashion
        - Prepare the plaster splint
            - Holding the arm abducted slightly, measure out an appropriate length plaster splint to extend from the axilla around the flexed elbow and up the lateral aspect of the arm covering the deltoid and acromion
            - Include eight to ten layers of plaster
        - Wet the plaster splint and remove excess water
        - Apply the plaster splint in a U-shaped manner surrounding the elbow and humerus, extending from the axilla medially to the deltoid and acromion on the lateral side
        - Secure the splint with an elastic bandage
        - Tape the superior-most aspect of the splint near the acromion
        - Place the affected arm in a sling

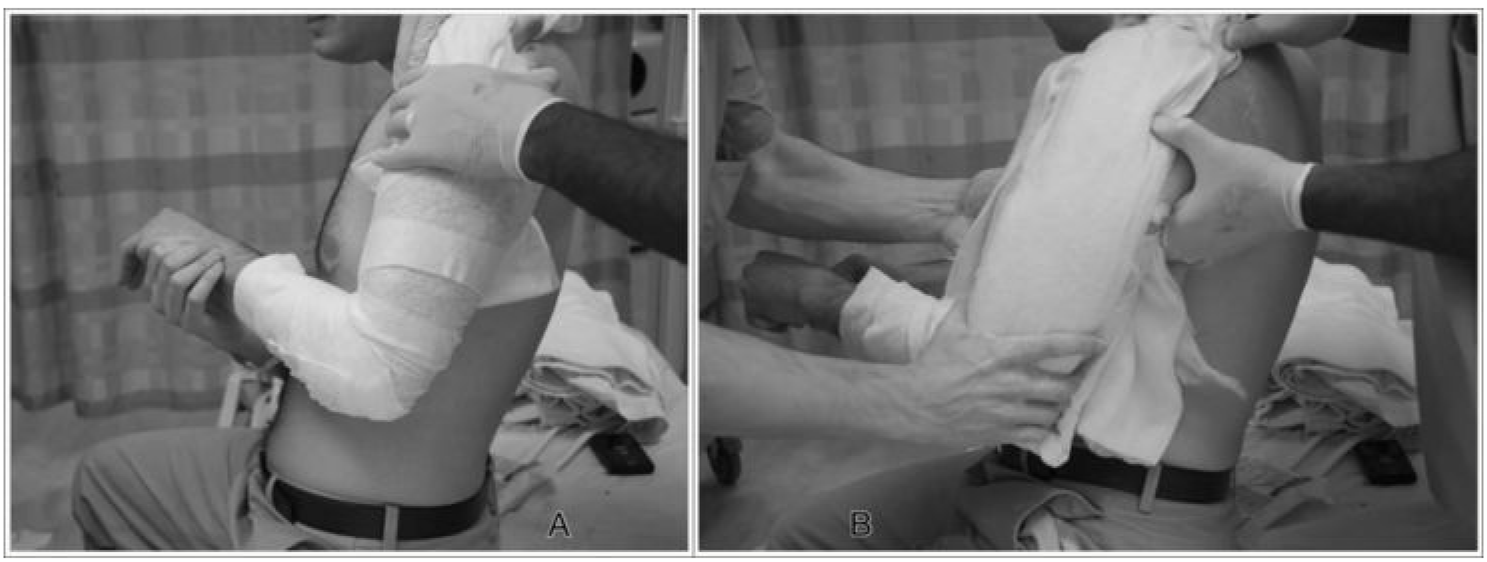


Figure 2.8 Application of a coaptation splint.
A: The cotton padding extends from the forearm to above the acromion. B: The splint material extends from the axilla medially in a U-shaped fashion around the flexed elbow to the acromion laterally. This will be secured with an elastic bandage and tape. (Reproduced with permission of the Department of Emergency Medicine, Feinberg School of Medicine, Northwestern University.)

Upper extremity nerve injuries

Key facts

- Injuries to upper extremity nerves may result in pain, paresthesias, and weakness
- The brachial plexus is formed by the C5–T1 cervical nerve roots and is the most common plexopathy
- Bilateral upper extremity neuropathic symptoms should be presumed to be caused by a cervical

spine injury until proven otherwise

Clinical presentation

- Injuries to the upper extremity nerves often occur in combination with other traumatic injuries
- Patients complain of unilateral weakness and/or numbness
- Mechanism of injury
  - Nerve injuries may occur by repetitive compression or direct trauma
  - Brachial plexus injuries
    - Longitudinal stretching of the plexus caused by traction of the arm and opposite distraction of the head
      - Injury with the arm adducted to the side often leads to upper trunk injuries
      - Injury with the arm raised lends to lower trunk injuries
    - Motorcycle accidents (most common)
    - Contact sports such as football – “stinger” or “burner”
    - Neuropraxia from backpacks – “Rucksack palsy”
    - Direct blow to the supraclavicular region (Erb’s point)
  - Axillary nerve injuries
    - Occurs in approximately 13.5% of glenohumeral dislocations
    - Surgical neck humeral fractures also at risk
- Physical examination findings
  - Symptoms dependent on the nerve root distribution affected (see Table 2.4)
  - Pain, paresthesias, and weakness may occur

PEARL: An ipsilateral Horner’s syndrome (ptosis, miosis, anhidrosis, enopthalmosis) may suggest a lower brachial plexus injury.

- Spurling’s test
- Axial loading of the head with the cervical spine extended and rotated toward the affected shoulder
  - A positive test successfully reproduces the patient’s symptoms
  - Helpful in identifying cervical root irritation
  - Do not perform unless cervical spine injury has been excluded
- Motor and sensory testing of suspected nerves
- A vascular examination to exclude an associated vascular injury is imperative

PEARL: Bilateral symptoms should raise suspicion for a spinal cord injury.

Table 2.4 ***Upper-extremity nerve syndromes.***

Nerve	Muscles	Motor test	Sensation
C5	Deltoid	Shoulder abduction, external rotation	Lateral upper arm
C6	Biceps	Elbow flexion, supination	Thumb
C7	Triceps	Elbow extension	Middle finger
C8	Flexor digitorum profundus, interossei	Finger flexion	Fifth finger
T1	Interossei	Finger abduction	Medial forearm
Axillary	Deltoid, teres minor	Shoulder abduction	Lateral upper arm
Long thoracic	Serratus anterior	Scapular winging	None
Suprascapular	Supraspinatus, infraspinatus	Shoulder abduction, external rotation	None
Upper-trunk brachial plexus (C5–6)	Deltoid, rotator cuff, biceps	Shoulder abduction, forearm flexion/supination	Lateral arm and forearm
Lower-trunk brachial plexus (C8–T1)	Forearm flexors, hand intrinsics	Forearm pronation, finger flexion	Medial arm, forearm and hand
Musculocutaneous	Biceps brachialis	Elbow flexion, forearm supination	Lateral forearm
Median	Forearm flexors, thenar muscles	Thumb flexion, opposition (OK sign)	Volar aspect of radial 3.5 digits (index finger)
Ulnar	Hand intrinsics	Finger abduction	Volar aspect of ulnar 1.5 digits (fifth digit)
Radial	Triceps, wrist extensors	Wrist extension	First dorsal webspace

Several upper-extremity nerves and their representative muscles, motor and sensory functions are listed above.

Diagnostic imaging

- Diagnosis of upper extremity nerve injuries is clinical
- Plain radiographs may be helpful to exclude alternative etiologies of symptoms
  - Cervical spine series
  - Clavicle series
  - Shoulder series
- CT or MRI should be performed as needed to exclude cervical spine injuries
- Further evaluation can be performed on an outpatient basis
  - MRI
  - CT myelography can assess cervical roots
  - Electromyogram/nerve conduction velocity studies (EMG/NCV)
    - Can help localize nerve lesion
    - Perform at least 3 weeks after injury

Treatment

- Emergency Department management
  - Most brachial plexopathies and peripheral nerve syndromes are managed conservatively
    - Initial rest followed by early range of motion
    - Anti-inflammatory agents
    - Moist heat
  - Injuries due to cervical rib, mid-shaft clavicular fractures, or penetrating trauma should be referred for surgical evaluation
  - Outpatient management
    - Referral to a specialist skilled in management of nerve injuries is recommended
    - Medical management with bracing and therapy can be trialed initially
    - Nerve transfers and root grafting may enhance outcomes in the reconstruction of brachial plexus injuries

Prognosis

- Prognosis is dependent on location and extent of nerve damage
- Athletic "stingers" have excellent outcomes with the majority of patients having a full return to function
- Pre-ganglionic injuries (proximal to the dorsal root ganglion) have poorer prognosis

Elbow dislocations

Key facts

- Most elbow dislocations are posterior, resulting from a fall on to an extended arm
- Simple dislocations can be reduced in the Emergency Department
- Patients should be observed in the ED for a few hours to monitor for delayed signs of vascular injury
- Stiffness and loss of full extension are the most common long-term deficits after this injury

Clinical presentation

- The elbow is the second most commonly dislocated major joint in the body
  - > 90% are posterior
  - Approximately 1/3 are associated with a fracture
- Mechanism of injury
  - Posterior dislocation: fall on to an extended and abducted arm
  - Anterior dislocation: high-energy force/mechanism to the posterior aspect of the flexed elbow
- Physical examination findings
  - Patient usually in significant pain
  - Elbow held in flexion and patient is unable to extend the forearm fully

    - A prominent olecranon and effusion are often palpable
        - Deformity may be subtle
    - Neuropraxia, typically of the ulnar nerve, may occur in approximately 20% of cases
        - Median nerve deficits should raise concern for arterial injury

PEARL: Have a high index of suspicion for injuries to the brachial artery and median nerve with anterior or open dislocations of the elbow.

Diagnostic testing

- Plain radiographs with a standard elbow series with AP and lateral projections are recommended (Figure 2.9)

Figure 2.9 Posterior elbow dislocation. (Reproduced with permission of the Department of Emergency Medicine, Feinberg School of Medicine, Northwestern University.)

Classification

- Simple: no associated fracture
- Complex: dislocation with associated fracture
    - Terrible triad: dislocation with coronoid process fracture and radial head fracture

Treatment

- Emergency Department management

- Adequate analgesia should be provided
    - Procedural sedation
    - Intra-articular anesthetic injections
- Emergent orthopedic consultation is recommended for
    - Open dislocations
    - Anterior dislocations
    - Complex dislocations
    - Neurovascular compromise
- Emergent vascular surgery consultation should be obtained for any patient with signs of a vascular injury
- Simple posterior dislocations
    - Reduce the elbow
    - Place a long-arm posterior splint and sling
    - Obtain post-reduction films
    - Failure at closed reduction may suggest bone or nerve entrapment

PEARL: Patients should be observed post reduction for a few hours to detect delayed signs of a vascular injury or evolving compartment syndrome.

- Long-term management
    - Orthopedic follow-up is suggested for all elbow dislocations
    - Complex dislocations are often managed surgically
    - Simple dislocations typically treated non-operatively
        - Short-term (1 week) immobilization followed by early range of motion
            - Immobilization longer than 3 weeks results in poorer outcomes

Prognosis

- 95% of patients are able to return to their previous job and functional status
    - Many patients will experience loss of full extension by approximately 10–20° and some mild loss of full flexion
    - Recurrent dislocations are uncommon

Procedure

- Reduction of posterior elbow dislocation
    - Place the patient in the supine position on the stretcher
    - An assistant should provide counter-traction to the humerus
    - The operator should hold the patient’s wrist with one hand and stabilize the olecranon with the other hand
        - With the forearm supinated and in 30° flexion, the operator should pull in-line traction on the forearm
        - The hand on the olecranon should provide medial or lateral translation of the olecranon as appropriate
        - Reduction is often felt with a palpable clunk

    - If difficulty arises, additional forearm flexion or manual manipulation of the olecranon with the second hand may be helpful
    - If reduction is unsuccessful, there may be entrapment of the medial epicondyle or an osteochondral fragment
        - Orthopedic consultation is advised
    - Post-reduction management
        - Check range of motion to ensure stability
        - Place a long-arm posterior splint with the elbow in flexion and supination
        - Obtain a post-reduction radiograph

Nursemaid's elbow

Key facts

- Radial head subluxation (also commonly referred to as nursemaid's elbow or pulled elbow) occurs almost exclusively in young children
- Radiographs are not necessary for patients with a classic presentation
- Counseling parents on how to avoid recurrent episodes is essential
- The hyperpronation method for reduction has excellent first-attempt success rates

Clinical presentation

- The "nursemaid's elbow" refers to a subluxation of the radial head
    - The annular ligament slides over the radial head and becomes interposed between the radial head and capitellum
- Typically occurs in children 1–4 years of age
- History can be very vague
    - Child may refuse to use the arm
    - No trauma is recalled but may be presumed by the parents
    - Specific questioning about the circumstances may suggest the classic mechanism
- Mechanism of injury is a sudden pulling of the extended and pronated arm
    - E.g., parent tugs on child's outstretched forearm while walking
- Physical examination findings:
    - Child usually holds arm in slight flexion and pronation
        - Refuses to use the arm
        - Parents often assume a wrist or elbow injury
        - The child should not be focally tender on palpation
        - No external signs of trauma are visible

Diagnostic testing

- History and physical examination are all that is necessary in the majority of cases
- Plain radiographs should be performed to exclude fracture if there is uncertainty regarding the diagnosis or suspicion for a fracture

    - Radiographic findings for nursemaid's elbow are non-specific
    - Reduction often occurs from the positioning required to obtain the films

Treatment

- Emergency Department management
    - Reduction (may be performed prior to radiographs if classic presentation)
        - Two common methods
            - Supination/flexion method
            - Hyperpronation method
            - Both with high success rates
- Hyperpronation with greater success on first attempt
    - Reduction generally felt with a click
    - > 90% positive success rate
    - No immobilization is necessary
    - Observe the child for 15–30 minutes post reduction
    - Consider alternative diagnosis if the child does not return to normal use of the extremity without limitation
    - Obtain radiographs if reduction is difficult or if the child does not regain use after reduction
    - If unable to reduce, orthopedic consultation is advised
        - Place a sling or long-arm posterior splint
    - Counsel the parents on how to avoid recurrent episodes in the future

PEARL: Care should be taken to evaluate for signs of other common injuries such as supracondylar fractures prior to attempting a nursemaid's reduction.

Prognosis

- Long-term prognosis is excellent
    - The annular ligament gains strength with age
    - Recurrence unlikely after age 5

Procedures

- Reduction of a nursemaid's elbow
    - Supination/flexion method
        - Grasp the child's wrist with one hand and the elbow with the other hand
            - Flex the elbow to 90°
            - Gently supinate the wrist 90°
            - Flex at the elbow further, bringing the wrist up to the shoulder
        - Reduction is usually felt with a click
    - Hyperpronation method (Figure 2.10)
        - Grasp the child's wrist with one hand and the elbow with the other hand
            - Flex the elbow slightly
            - Gently hyperpronate the wrist

- Reduction is usually felt with a click

Figure 2.10 Hyperpronation technique for reduction of a nursemaid's elbow.
Grasp the child's wrist with one hand and the elbow with the other hand. Flex the elbow slightly and gently hyperpronate the wrist until a click is felt. (Reproduced with permission of the Department of Emergency Medicine, Feinberg School of Medicine, Northwestern University.)

Epicondylitis

Key facts

- Lateral epicondylitis or "tennis elbow" is an overuse injury of the forearm extensor and supinator muscles
- Medial epicondylitis or "golfer's elbow" is an overuse injury of the forearm flexor and pronator muscles
- Conservative management with rest, icing and anti-inflammatories is adequate in most cases
- Patients should be counseled on preventative measures such as proper technique and equipment usage to reduce recurrence and morbidity
- Corticosteroid injections may be considered

Clinical presentation

- Lateral epicondylitis
    - Overuse tendinopathy of the extensor muscles originating at the lateral epicondyle
        - Caused by microscopic tearing at the origin of the extensor carpi radialis brevis (ECRB)
    - Results from repetitive movement
        - Tennis players

        - Repetitive lifting > 1 kg
    - Physical exam findings
        - Maximal tenderness 5–10 mm distal to the lateral epicondyle, in the area of the ECRB muscle
        - Pain near lateral epicondyle with resisted wrist and long finger extension
        - Chair raise test
            - Patient stands behind chair
            - Attempts to raise it by putting their hands on the top of the chair back and lifting
            - Pain is a positive finding
    - Medial epicondylitis
        - Overuse tendinopathy of the origin of the forearm flexor muscles at the medial epicondyle
        - Results from repetitive movement
            - Golfing
            - Throwing sports
            - Bowling
            - Weight lifting
        - Patients often describe pain in the acceleration phase of throwing
        - Physical exam findings
            - Tenderness over the medial epicondyle
            - Pain with resisted flexion and pronation of the forearm and wrist

PEARL: Medial epicondylitis is associated with an ulnar neuropathy in 20% of cases.

Diagnostic testing

- Epicondylitis is a clinical diagnosis
- Plain radiographs can be helpful to exclude alternative etiologies of pain
    - Calcifications in the degenerative tissue may be present near the epicondyles in up to 20–30% of cases

Treatment

- Conservative treatment is adequate for most cases in the Emergency Department
    - Rest from repetitive motion
    - Icing
    - Non-steroidal anti-inflammatories (NSAIDS)
    - Bracing[31]
        - Lateral epicondylitis
            - Wrist extension splint
            - Counter-force strap brace – placed around the muscle bellies of the wrist extensors just distal to the elbow
        - Medial epicondylitis
            - Counterforce strap brace
    - Corticosteroid injection may be considered for short-term relief of symptoms in refractory

cases
        - The long-term benefits of corticosteroid injections are questionable
        - Orthopedic referral for follow-up in 1–2 weeks is advised
            - Alternative outpatient treatments include
                - Physical therapy
                - Surgical interventions
                - Newer potential therapies
                    - Platelet-rich plasma (PRP) injections
                    - Prolotherapy Injection of an otherwise non-pharmacological and non-active irritant solution into the region of tendons or ligaments for the purpose of strengthening weakened connective tissue and alleviating musculoskeletal pain

Prognosis

- 70–80% patient's symptoms will resolve at 1 year without surgical intervention

Procedure

- Corticosteroid injection for lateral epicondylitis
    - Supplies needed
        - 3 cc syringe
        - 1–18-gauge needle
        - 1–22-gauge needle
        - 1–2 ml of 1% lidocaine
        - 20–30 mg of methylprednisolone or 20 mg of triamcinolone
        - Sterile gauze
        - Chlorhexidine or betadine scrub
        - Sterile gloves
    - Technique
        - Place the patient in the seated position with the arm pronated and elbow flexed at 90°
        - Palpate the lateral epicondyle
        - Sterile prep the region with chlorhexidine or betadine scrub
        - Draw 1–2 cc of 1% lidocaine and 20 mg of triamcinolone (or equivalent steroid) into the 3 cc syringe
        - Using 22-gauge needle, inject the contents of the syringe at the site of maximal tenderness just distal to the lateral epicondyle
        - Injection should be careful to avoid injection directly into the tendon
- The technique for medial epicondylitis is similar but extra care should be taken to avoid injection into the ulnar nerve which courses adjacent to the medial epicondyle

Radial head fractures

Key facts

- Radial head fractures are the most common fracture of the elbow in adults
- Non-displaced radial head fractures may be difficult to see on initial radiographs
- Closed reduction and prolonged immobilization may result in stiffness and loss of function in the elbow
- Open reduction and internal fixation is currently the treatment of choice for unstable and displaced radial head fractures

Clinical presentation

- Radial head fractures account for 33% of elbow fractures
- In conjunction with the medial collateral ligament (MCL), the radial head serves to stabilize the elbow against valgus stress and longitudinal forces
- Mechanism of injury
    - Fall on to an outstretched hand with a pronated forearm or elbow in slight flexion
    - Direct blow to the lateral elbow
- Physical examination findings
    - Tenderness over the radial head distal to the lateral epicondyle
    - Pain over the lateral elbow with pronation/supination of the forearm
    - Decreased range of motion
    - It is important to check for associated injuries
        - Posterior interosseus nerve (radial)
            - May occur with displaced fractures
            - Examine for inability to extend fingers
        - MCL instability
            - Perform valgus stress test with elbow at 30° of flexion
        - Distal radioulnar joint (DRUJ) injury – (Essex–Lopresti)
            - Tenderness over distal radius/ulnar articulation

Diagnostic testing

- Plain radiographs are the test of choice
    - Standard series includes AP and lateral views
    - Additional views include oblique and radial head–capitellum views

- Radiographic findings
    - Fractures of the radial head are often not readily apparent on the plain film
    - Secondary signs of fracture include
        - Displaced anterior fat pad – sail sign
        - Posterior fat pad
        - Displacement of fat pads suggest an effusion commonly caused by a fracture in the setting of an acute injury

PEARL: Ensure that the radial head aligns with the capitellum on all views as disruption of the radiocapitellar line is suggestive of a radial head dislocation.

Classification

- Mason classification system
  - Type I: fractures without displacement (62%) (Figure 2.11)
  - Type II: fractures with displacement (20%)
  - Type III: comminuted fractures involving the entire head (18%)
  - Type IV: radial head fracture with elbow dislocation

Figure 2.11 Mason Type I fracture of the radial head. Note the presence of a posterior fat pad and a displaced anterior fat pad suggestive of an effusion and occult fracture. Upon close inspection, a radial head fracture is noted. (Reproduced with permission of the Department of Emergency Medicine, Feinberg School of Medicine, Northwestern University.)

Treatment

- Emergency Department management
  - Adequate pain control
  - Non-displaced (Type I) fractures
    - May be placed in a **sling** or **posterior mold splint** in ED

        - Early mobilization
        - Motion within 2 days shown to have better outcomes with improved range of motion and functional recovery
        - Referral to orthopedic specialist
    - Mason Type II and III fractures
        - Place **posterior mold splint**
        - Early referral to orthopedics
            - Minimally displaced Mason Type II fractures may be treated conservatively with early motion
            - Displaced (> 2 mm or angulation > 30°) or comminuted fractures typically should be considered for surgical repair
- Long-term management
    - Non-displaced fractures
        - Early motion
        - Functional bracing
        - Physical therapy
    - Displaced and comminuted fractures
        - Mechanical stability with anatomic reduction and stable internal fixation minimizes long-term complications
        - ORIF preferential in most cases

Prognosis

- Bony union is generally achieved in 6–8 weeks
- Non-displaced fractures have an excellent prognosis
- Elbow stiffness and loss of full extension are the most common complications after radial head fracture
    - More common in displaced or comminuted fractures

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Chapter 3 Pelvic emergencies

Michael C. Bond

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Pelvic fractures

Key facts

- Pelvic fractures represent 3% of all fractures, and are associated with significant morbidity and mortality
- The mortality rate for high-energy pelvic fractures is between 10% and 20%
- Pelvic fractures can result in significant hemorrhage, and a large volume of blood loss (up to 4 liters)
  - About 50% of the patients admitted with pelvic fractures will require a blood transfusion
  - Non-displaced fractures are not associated with large volume blood loss, so if the patient is hypotensive with this type of injury a search for another more serious injury needs to ensue
- Twenty percent of pelvic fractures are associated with neurologic injuries
  - Acetabular and sacroiliac fractures are most highly associated with neurologic injuries
  - Fractures medial to the sacral foramina have an incidence of 57% of a neurologic injury
- The pelvis is an anatomic ring that typically will have two disruptions in the ring. This can consist of two fractures, or a fracture and dislocation

Anatomy

- The pelvis consists of the ilium, pubis, and ilium on each side forming the innominate bones that are then joined at the pubis symphysis anteriorly and the sacrum posteriorly
- Some of the strongest ligaments in the body secure the innominate bone to the sacrum. Disruption of these ligaments will affect normal weight bearing
- Strong interpubic ligaments hold the pubic symphysis in place. Disruption of these ligaments can result in an “open book” pelvis

Signs of pelvic fracture

- Destot’s sign: a superficial hematoma above the inguinal ligament or on/in the scrotum
- Earle’s sign: a large hematoma, or abnormal bony prominence, or tender fracture line that is felt on a rectal examination
- Roux’s sign: radiologic sign. Sign is present when the distance measured from the greater trochanter to the pubic spine is diminished on one side

Physical examination

- The patient should be disrobed in order to look for signs of ecchymosis, lacerations, deformity or swelling
- Special attention should be accorded to the rectum and penis/vagina to ensure there is no bleeding that could denote a more serious injury
- Pelvic instability can often be felt on physical examination though retesting should not be performed if instability is noted as this increases the risk of pelvic bleeding from disruption of bone fragments or a hematoma
- Test for instability by applying internal and external compression forces on the iliac wings to check for instability
- Vertical instability can be checked by applying traction and axial loading to the leg while one hand is palpating the iliac wing on the ipsilateral side
- Sensation should be checked over the perineum and in both legs, as sacral fractures can cause neuropathies, and acetabular fractures are associated with injuries to the sciatic nerve
- Radiographs should be obtained
  - Plain radiographs are a good initial screening test to look for displaced pelvic fractures
  - CT may be needed for non-displaced fractures and for operative planning of complex fractures

Classification system

- Several classification systems have been developed to describe pelvic fractures
- The initial classification system was developed by Pennal and Sutherland and was based on the mechanism of injury
- The Pennal and Sutherland system was modified by Burgess and Young in an attempt to correlate the injury with the degree of hemodynamic instability
- The Burgess and Young system is the most commonly used one now
  - Based on mechanism of injury
  - Subdivided by degree of predicted hemodynamic instability
  - Does not address fractures not involving the pelvic ring
    - Avulsion fractures
    - Coccyx fractures

Specific pelvic fractures

Avulsion fractures

- Mechanism: Generally caused by a forceful muscular contraction that causes an apophyseal center to be pulled off the pelvic ring
  - Can occur at:
    - Anterior–superior iliac spine at the insertion of the sartorius muscle
    - Anterior–inferior iliac spine at the insertion of the rectus femoralis muscle

    - Ischial tuberosity at the insertion of the hamstring muscles

Symptoms

- Typically have pain and tenderness over the site
- Often have increased pain with ambulation, and with ischial tuberosity fractures can have increased pain when sitting down

Diagnosis (Figure 3.1)

- Often based on symptoms and plain radiographs
- If there is significant ambulatory dysfunction may need to obtain a CT in order to exclude more serious fractures

Figure 3.1 Avulsion fracture of the anterior inferior iliac spine (AIIS) is noted on the right. The AIIS is the insertion site of the rectus femoralis muscle. (Image courtesy of Michael C. Bond, MD.)

Treatment

- Treatment is non-operative and is aimed at controlling symptoms
- Anterior–superior iliac spine fractures:
    - 3 to 4 weeks bed rest with the hip in flexion and abduction
    - Complete recovery can take more than 8 weeks
- Anterior–inferior iliac spine fractures:
    - 3 to 4 weeks bed rest with the hip in flexion but not abducted

- Ischial tuberosity fracture:
  - Bed rest with the thigh in extension with external rotation and slight abduction
  - A donut pillow can help when sitting
- All patients would benefit from analgesics
  - Ibuprofen 800 mg orally every 6–8 hours as needed
  - Naproxen 500 mg orally every 6–8 hours as needed
  - Oxycodone/acetaminophen 5/325 mg; one or two tablets every 4–6 hours as needed for severe pain
  - Hydrocodone/acetaminophen 5/325 mg; one or two tablets every 4–6 hours as needed for severe pain

Non-displaced pelvic fractures

Pubic ramis fractures

Mechanism

- Fractures involving a single pubic ramis are usually caused by a fall in the elderly, though in the young it is often the result of persistent tension/stress on the adductors or hamstrings resulting in a fracture at their site of origination
- Fractures through both pubic rami are typically caused by direct trauma (i.e., horizontal or compressive forces)

Symptoms

- Patients will often complain of persistent groin pain after a fall (i.e, elderly) or with a more insidious onset in the young
- The pain is often worse with deep palpation or walking/running
- A lateral compression force will often exacerbate fractures involving both rami

Diagnosis

- Pain on palpation over the pubic ramis
- Plain radiographs (AP view of the pelvis) are normally enough to make the diagnosis
- CT of the pelvis with 3-D reconstruction views may be needed to exclude a more serious injury, especially if there is tenderness over the sacroiliac joint

Treatment

- Single pubic rami fractures (Figure 3.2)
  - Symptomatic treatment
    - Pain control with NSAIDs or narcotics as needed
    - Weight-bearing as tolerated for 8–12 weeks. Patients benefit from crutches to limit the

amount of weight (i.e., crutch walking)

- Dual pubic rami fractures are generally stable though these fractures should be referred to orthopedics early as they may require operative repair if there is any posterior pelvic injury
    - Symptomatic treatment
        - Pain control with NSAIDs or narcotics as needed
        - Weight-bearing as tolerated for 8–12 weeks. Patients benefit from crutches to limit the amount of weight (i.e., crutch walking)
- Straddle fracture is a fracture through both pubic rami bilaterally as can happen when falling from a height and landing on the perineum. Figure 3.3 demonstrates this fracture pattern

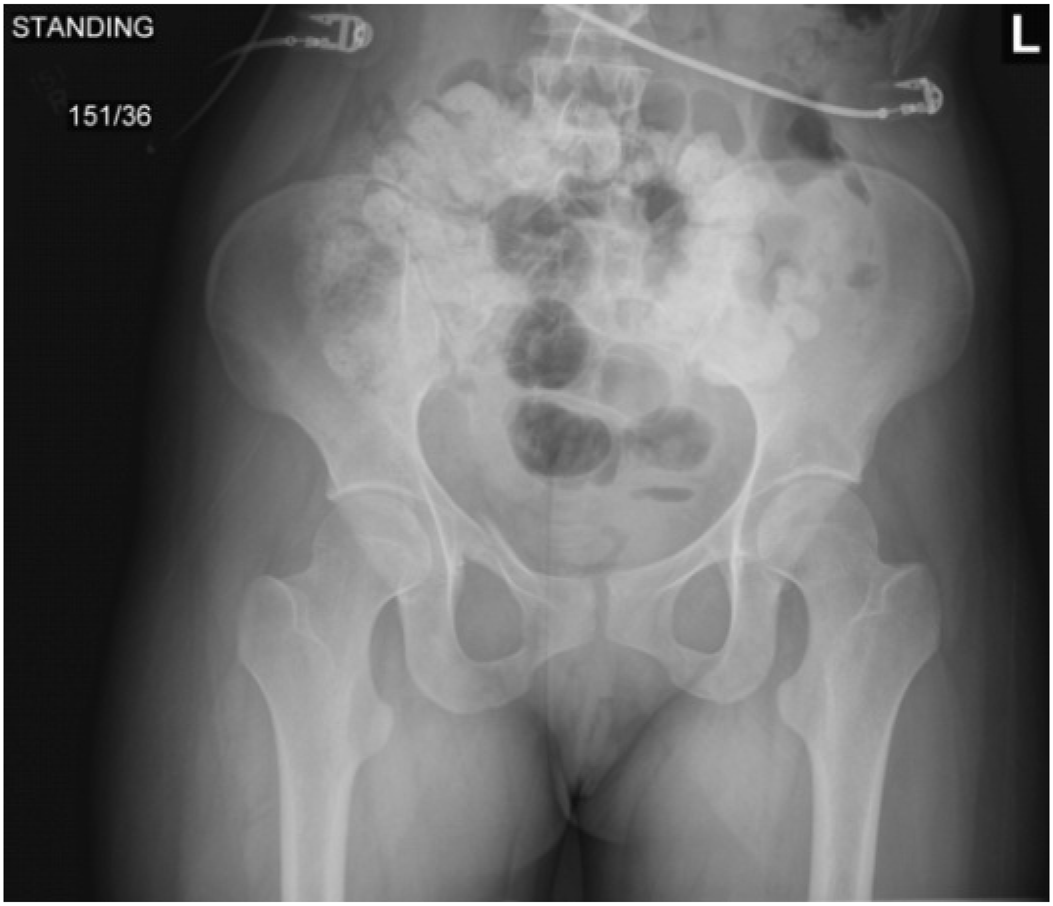


Figure 3.2 Fracture of the superior pubic rami on the right. (Image courtesy of Michael C. Bond, MD.)

Figure 3.3 A straddle fracture. Notice the bilateral dual pubic ramis fractures. (Image courtesy of Michael C. Bond, MD.)

Ischial body fractures

Mechanism

- Typically caused by a fall on to the buttocks. Can be associated with fractures of the lumbar and thoracic spine

Symptoms

- Patients will often complain of buttock pain that is worse with deep palpation or contraction of the hamstrings

Diagnosis

- Pain on palpation over the ischial body
- Plain radiographs (AP view of the pelvis) are normally enough to make the diagnosis
- CT of the pelvis with 3-D reconstruction views may be needed to exclude a more serious injury

Treatment

- Symptomatic treatment

    - Pain control with NSAIDs or narcotics as needed
    - Bed rest for 4 to 6 weeks with physical therapy to prevent loss of range of motion
    - Inflatable seat cushion (i.e., donut pillow) for comfort when seated

Ilium fractures

Mechanism

- Iliac wing fractures: Result from a medially directed force against the iliac wing. Because of the high energy needed for these fractures the emergency provider should ensure that other injuries are not also present, such as
    - Acetabular fractures
    - Solid and hollow organ injuries
    - Thoracic injuries
- Ilium body fractures are usually the result of a direct force on the ilium that pushes the ilium postomedially

Symptoms

- Iliac wing fractures: Patients will complain of pain over the iliac wing that is worsened by palpation, walking or stressing of the hip abductors
- Ilium fractures: Patients will have tenderness over the posterior pelvis near the sacrum that is often exacerbated by straight-leg raises, and anterior and lateral compressive forces

Diagnosis

- Pain on palpation over the iliac wing or ilium. Worse with compression or distraction
- Plain radiographs (AP view of the pelvis) are normally enough to make the diagnosis. Oblique views may help demonstrate the fracture better
- CT of the pelvis with 3-D reconstruction views may be needed to exclude a more serious injury

Treatment

- Iliac wing fractures
    - Symptomatic treatment
        - Pain control with NSAIDs or narcotics as needed
        - Bed rest for 4 to 6 weeks or until there is no pain with stressing of the hip abductors
- Ilium fractures
    - Early referral to orthopedics
    - Symptomatic treatment
        - Pain control with NSAIDs or narcotics as needed
        - Pelvic sling or belt may help provide comfort and stability
        - Bed rest that will be advanced to crutch walking by orthopedics
        - Typically takes 3 to 4 months to return to baseline

Sacral fractures

Mechanism

- Horizontal fractures result from a direct blow to the sacrum or from a fall with the patient landing in the seated position
- Vertical fractures are the result of anterior forces on the pelvis that drive the pelvic ring posteriorly

Symptoms

- Patients will complain of pain over the sacrum, and ecchymosis may be noted. Patients will also have increased pain on rectal examination if pressure is applied to the sacrum. Pain is often increased with lateral and anterior compression applied to the pelvis. Patients may have loss of sensation or neurologic dysfunction if the sacral nerves are compressed as they exit the sacral foramina

Diagnosis

- Pain on palpation over the sacrum. A digital rectal examination needs to be performed to ensure that the fracture is not open as evidenced by a laceration of the rectum
- Plain radiographs (AP view of the pelvis) are normally enough to make the diagnosis. An AP outlet view is often better at noting displayed fractures
- CT of the pelvis with 3-D reconstruction views may be needed to exclude a more serious injury

Treatment

- Vertical fractures should be referred to orthopedics early because of the higher risk of neurologic involvement
    - Vertical fractures can also be treated with a pelvic binder/belt
- Fractures that are associated with any neurologic dysfunction need immediate referral to orthopedics for possible operative repair
- Symptomatic treatment
    - Pain control with NSAIDs or narcotics as needed
    - Bed rest to advance to crutch walking as tolerated
    - An inflatable seat cushion can be used for comfort
- Open fractures require immediate antibiotic coverage and orthopedic consultation

Coccyx fractures

Mechanism

- Usually caused by a fall and landing in a sitting position

Symptoms

- Patients will complain of pain over their buttocks near their rectum. Spasms of the anococcygeal muscle may also be noted during bowel movements or when trying to sit

Diagnosis

- Pain on palpation over the coccyx, and pain on digital rectal examination with palpation of the coccyx. Rectal examination must be done to ensure there is no rectal laceration
- Plain radiographs (AP view of the pelvis and lateral coccyx view) are normally enough to make the diagnosis
- CT of the pelvis with 3-D reconstruction views may be needed to exclude a more serious injury

Treatment

- Symptomatic treatment
  - Pain control with NSAIDs or narcotics as needed
  - Bed rest as needed
  - An inflatable seat cushion can be used for comfort
  - Stool softeners should be prescribed in order to prevent straining with bowel movements

Displaced pelvic fractures

Mechanism

- Varies depending on fracture pattern seen as outlined in Table 3.1. All of these fractures are the result of high-energy forces and can be associated with other significant injuries

Table 3.1 ***Burgess and Young classification system of pelvic ring injuries.***

Lateral compression (LC)
LC 1: Pubic rami fracture (transverse) and ipsilateral sacral compression LC 2: Pubic rami fracture (transverse) and iliac wing fracture LC 3: Pubic rami fracture (transverse) and contralateral "open-book" injury
Anteroposterior compression (APC)
APC 1: Symphyseal diastasis (1–2 cm) with normal posterior ligaments APC 2: Symphyseal diastasis or pubic rami fracture (vertical) with anterior SI joint disruption APC 3: Symphyseal diastasis or pubic rami fracture (vertical) with complete SI joint

disruption

Vertical shear (VS)

Symphyseal diastasis or pubic rami fracture with complete SI joint disruption, iliac wing, or sacrum (with vertical displacement)

Combined mechanical (CM)

Combination of other injury patterns (LC/VS or LC/APC)

Symptoms

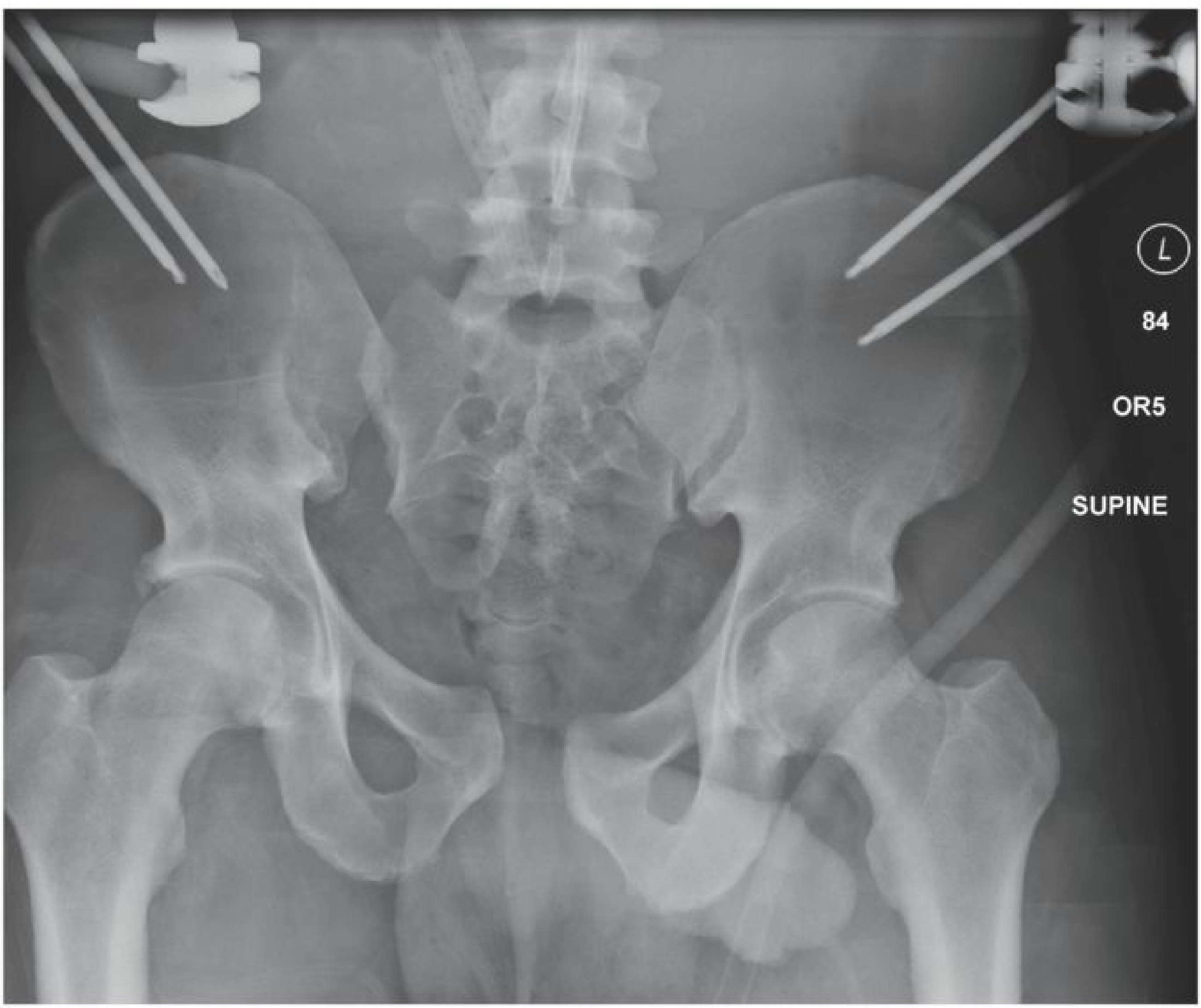
- Patients will complain of pain and tenderness over their pelvis, may have gross deformity (e.g., open book pelvis), be hypotensive, and one may even note leg length discrepancies
- Associated injuries may distract the patient from these injuries so a careful examination needs to be performed

Diagnosis

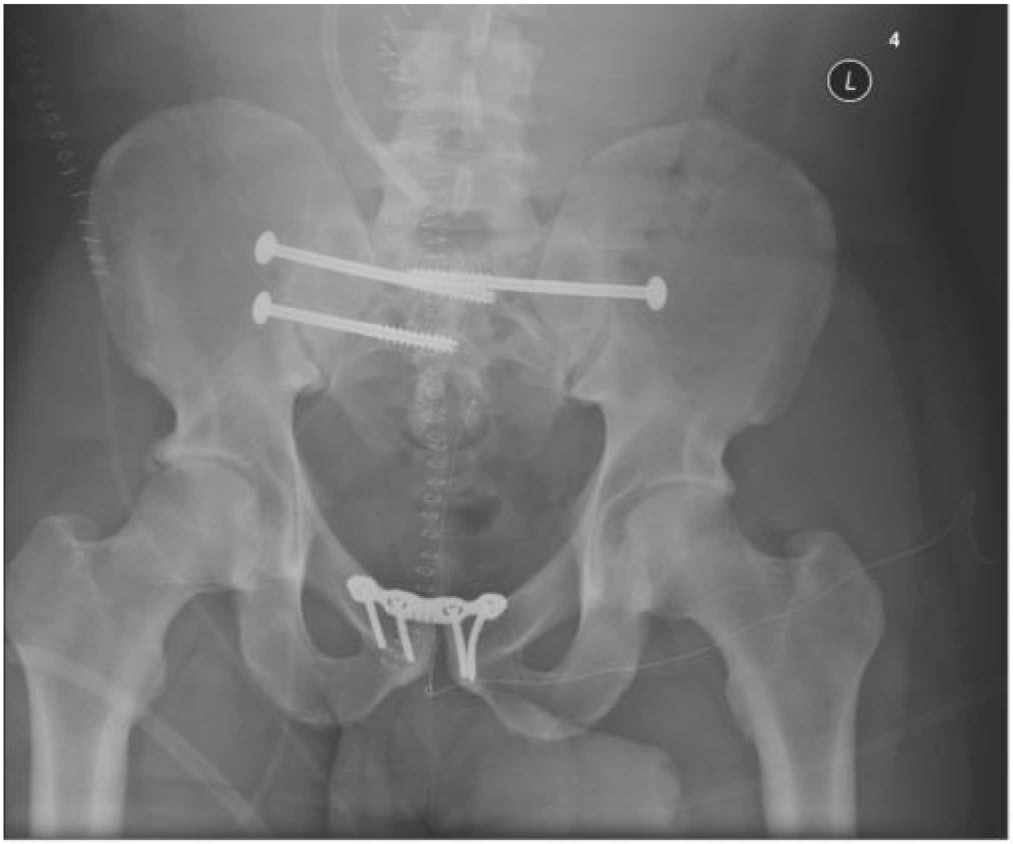
- Pain on palpation of the pelvis, or pelvic instability may be noted when lateral, medial, or anterior compressive forces are applied to the pelvis
- Plain radiographs (AP view of the pelvis) can make the diagnosis
  - Figure 3.4A, B, C: Anterior–posterior compression fracture class 3
  - Figure 3.5: Lateral compression fracture
- CT of the pelvis with 3-D reconstruction views is often needed to exclude secondary injuries and for operative planning

Figure 3.4 Anterior–posterior compression fracture class 3. **A** shows the original "open book" fracture pattern with diastasis of the pubic symphysis, and fractures through the sacroiliac joints. **B** shows the application of an external fixator to stabilize the pelvis. **C** shows the patient post-ORIF with stabilization of the sacroiliac joints and pubic symphysis. (Image courtesy of Michael C. Bond, MD.)

A



B



C

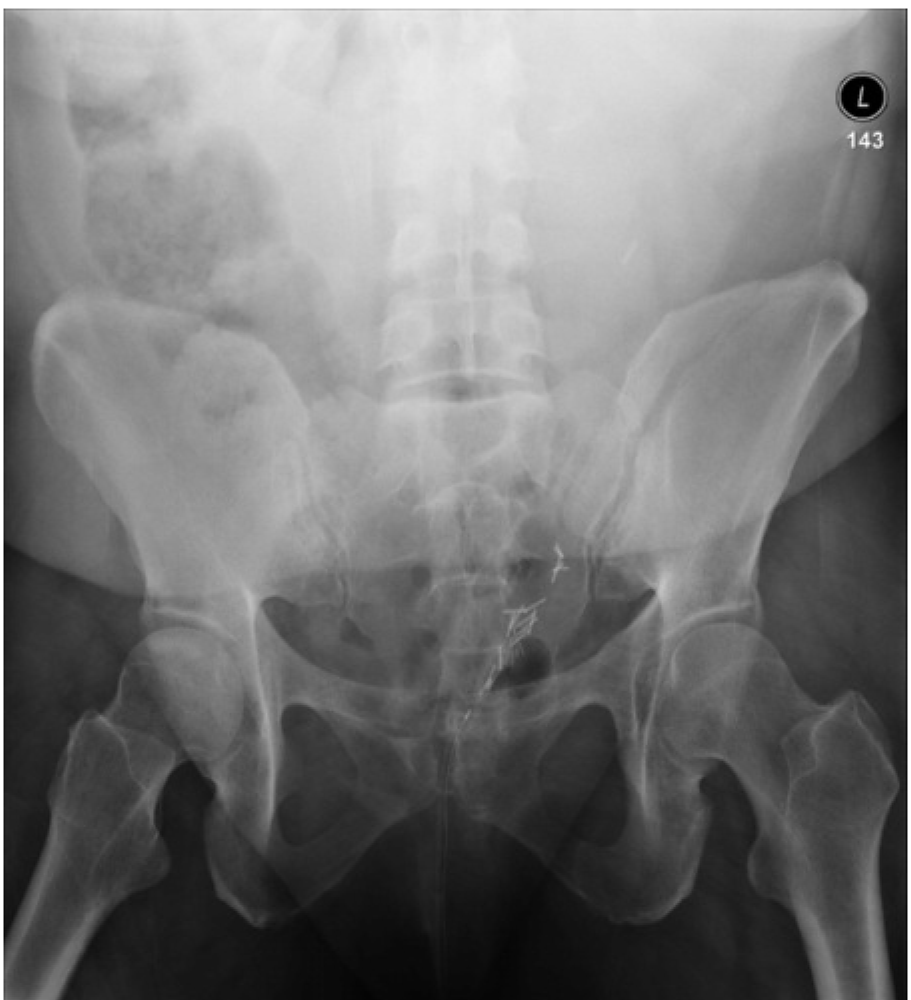


Figure 3.5 Lateral compression fracture with fractures noted of the left iliac wing, sacrum, and inferior pubic symphysis. (Image courtesy of Michael C. Bond, MD.)

Treatment

- Immediate orthopedic consultation
- The pelvic cavity should be returned to its normal size with the use of a pelvic binder, sheet or external fixation device
    - For pelvic binder application follow the directions of the device manufacturer
    - For placement of a sheet one should:
        - Take a long bed sheet and place it behind the patient at the level of the ischial wings
        - Two providers each grab the end of the sheet that is furthest from them
        - The providers then pull the opposite end of the bed sheet toward themselves, until the pelvis is reduced
        - Reduction is assumed when there is no gross deformity and the pelvic girdle appears normal in appearance
        - The edges of the sheet are then twisted together and then tied in order to prevent loosening
        - This procedure alone can have a profound effect on reducing blood loss into the pelvis
    - Associated injuries need to be excluded
        - Uretheral, vaginal, and rectal injuries
        - Abdominal or thoracic injuries
        - Lower-extremity fractures
    - Symptomatic treatment
        - Pain control with narcotics as needed
        - Bed rest

Acetabular fractures

Anatomy

- The acetabulum consists of four parts:
    - Anterior column: from iliac crest to the symphysis pubis and includes the anterior wall
    - Posterior column: from the sciatic notch to the ischial tuberosity and includes the posterior wall
    - Anterior wall
    - Posterior wall
- Fractures of the posterior column are more common, and are often associated with posterior hip dislocations

Mechanism

- The result of high-energy trauma
- A medially directed force can drive the femoral head into the acetabulum and fracture it
    - If femur is internally rotated at time of impact a posterior column fracture occurs
    - If femur is externally rotated at time of impact an anterior column fracture occurs
- A blow to the knee with the hip flexed can drive the femur back into the acetabulum causing a

transverse acetabular fracture or posterior column fracture

Symptoms

- Patients will complain of pain and tenderness over their pelvis near their hip. They may have leg length shortening, and will have increased pain with weight-bearing
- Can be associated with vascular and neurologic injuries

Diagnosis

- Pain on palpation of the pelvis and hip can confirm diagnosis
- Plain radiographs (AP view of the pelvis, and Judet views) can make the diagnosis (Figure 3.6)
  - 80% of intra-articular fragments are not seen on plain radiographs
- CT of the pelvis with 3-D reconstruction views is often needed to evaluate the fracture fully and for operative planning

Figure 3.6 A posterior dislocation with fracture of the posterior rim wall is noted on the right. (Image courtesy of Michael C. Bond, MD.)

Treatment

- Immediate orthopedic consultation
  - Patients will require surgical repair if:
    - Femoral head is subluxed
    - Fracture fragments are displaced > 2 mm
  - Non-operative care can range from bed rest to weight-bearing

        - Early immobilization is a primary goal
- Associated injuries need to be excluded
    - Vascular
    - Visceral
    - Neurologic: Sciatic nerve injury can be seen in 10%–13% of cases
- Symptomatic treatment
    - Pain control with narcotics as needed

Hip fractures

Anatomy

- The hip joint is the articulation of the proximal femur with the acetabulum of the pelvis
- The joint's integrity is maintained by:
    - A joint capsule that is attached to the acetabulum and femoral neck
    - Three ligaments strengthen the joint capsule
        - Iliofemoral ligament – located anteriorly and strongest of the three ligaments
        - Pubofemoral ligament – inferior
        - Ischiofemoral ligament – posterior ligament that is the widest
    - Ligomentum teres – attaches the femoral head to the acetabulum centrally
- The blood supply to the proximal femur is limited and consists of three sources
    - Femoral circumflex and retinacular arteries – disruption of this blood supply often leads to avascular necrosis (AVN) of the femoral head
    - Medullary vasculature
    - Vessel of the ligamentum teres

Fracture classification

- Five major classes within two subdivisions
    - Intracapsular
        - Femoral head fractures
        - Femoral neck fractures
    - Extracapsular
        - Intertrochanteric fractures
        - Trochanteric fractures
        - Subtrochanteric fractures

Femoral head fractures

- Described as single fragment or communited (multiple fragments)

Mechanism

- Single fragment fractures are usually the result of a dislocation
- Communited fractures are usually the result of high-energy direct trauma

Symptoms

- Patients will complain of pain and tenderness over their hip that increases with weight-bearing

Diagnosis

- Pain on palpation of the pelvis and hip can confirm diagnosis
- Plain radiographs (AP view of the pelvis, and hip views [oblique and lateral]) can make the diagnosis
- CT or MRI of the femur may be needed for occult fractures (~5% incidence) in patients where the provider has a high index of suspicion but initial radiographs are non-diagnostic

Treatment

- Orthopedic consultation
  - Arthoplasty is often needed for communited fractures
  - Simple fractures may be managed with bed rest and immobilization
- All patients should be placed on bed rest and have the hip immobilized
- Dislocations should be reduced
- Symptomatic treatment
  - Pain control with narcotics as needed

Femoral neck fractures

PEARL: Femoral neck fractures are at very high risk for development of avascular necrosis.

Mechanism

- More common in the elderly who have osteoporotic bones. Can occur with no trauma in these patients
- In young patients these are caused by high-energy trauma

Symptoms

- Patients may have suffered a fall, or only complain of thigh or knee pain when they have an impacted fracture
- Patients will complain of pain and tenderness over their hip that increases with weight-bearing or ROM

Classification system

- Garden system which is based on the degree of displacement present on the AP radiograph
    - Type I – Incomplete or impacted fractures
    - Type II – Complete, but non-displaced
    - Type III – Partially displaced or angulated fractures
    - Type IV – Displaced fractures with no contact between the fragments
- Type I and II can be described as non-displaced and Type III and IV as displaced fractures

Diagnosis

- Plain radiographs (AP view of the pelvis, and hip views [oblique and lateral]) can make the diagnosis (Figure 3.7)
- CT or MRI of the femur may be needed for occult fractures (~5% incidence) in patients where the provider has a high index of suspicion but initial radiographs are non-diagnostic

Figure 3.7 A subcapital fracture of the right femur is noted. (Image courtesy of Michael C. Bond, MD.)

Treatment

- Orthopedic consultation
  - Operative management has improved outcomes
    - Operative care – 10% mortality
    - Supportive care with bed rest – 60% mortality
  - Displaced fractures will often require immediate operative repair or reduction in order to reduce the risk of AVN
  - Non-displaced fractures will often need operative repair though it can be done in a less urgent manner
- All patients should be placed on bed rest and have the hip immobilized
- Symptomatic treatment
  - Pain control with narcotics as needed
  - Consider a femoral nerve block in the elderly, who may have increased sedation with narcotics

Intertrochanteric fractures

General

- Most common proximal femoral fracture
- Classified as:
  - Stable – single fracture line through the cortex without any displacement
  - Unstable – multiple fracture lines or communition with associated displacement

Mechanism

- Mostly caused by direct trauma – fall on to the hip, specifically the greater trochanter
- Indirect trauma (e.g., trauma to femur or knee) can be transmitted up the femoral shaft and cause a fracture

Symptoms

- Patients may have suffered a fall and complain of pain over the hip
- Leg is often shortened and externally rotated

Diagnosis

- Plain radiographs (AP view of the pelvis, and hip views [oblique and lateral]) can make the diagnosis (Figure 3.8)
- CT or MRI of the femur may be needed for occult fractures (~5% incidence) in patients where the provider has a high index of suspicion but initial radiographs are non-diagnostic

Figure 3.8 An intertrochanteric fracture of the femur is noted. (Image courtesy of Michael C. Bond, MD.)

Treatment

- Orthopedic consultation for operative repair
- All patients should be placed on bed rest
- Symptomatic treatment
  - Pain control with narcotics as needed
  - Consider a femoral nerve block in the elderly, who may have increased sedation with narcotics

Trochanteric fractures

General

- Uncommon
- Classified as:
  - Displaced
  - Non-displaced

Mechanism

- Mostly caused by direct trauma – fall on to the hip
- Can also be the result of a forceful muscle contraction and avulsion of a trochanter from the femur
- Lesser trochanter fractures are often pathologic and should prompt an additional evaluation into its cause

Symptoms

- Patients will complain of pain over their hip and thigh that is often worse with abduction (greater trochanter) or flexion and rotation of the hip (lesser trochanter)

Diagnosis

- Plain radiographs (AP view of the pelvis, and hip views). Consider getting internal and external rotation views to fully visualize the trochanters
- CT or MRI of the femur may be needed for occult fractures (~5% incidence) in patients where the provider has a high index of suspicion but initial radiographs are non-diagnostic

Treatment

- Consult orthopedics
    - Displaced fractures are treated with operative repair. General guidelines are:
        - Greater trochanteric fracture displaced more than 1 cm
        - Lesser trochanteric fracture displaced more than 2 cm
    - Non-displaced fractures are treated symptomatically with crutch walking as tolerated
- Symptomatic treatment
    - Pain control with narcotics as needed

Subtrochanteric fractures

General

- Includes all fractures within 5 cm of the lesser trochanter

Mechanism

- In the elderly this fracture is typically caused by a fall with a rotational force involved
- In the young it is secondary to a high-energy trauma

Symptoms

- Patients may have pain and swelling of the hip and thigh
- Increased pain with weight-bearing if possible
- In the young, associated injuries of the ankle, knee, and leg may also be present

Diagnosis

- Plain radiographs (AP view of the pelvis, and hip views, and femur) can make the diagnosis (Figure 3.9)
- CT or MRI of the femur are rarely needed for this fracture type

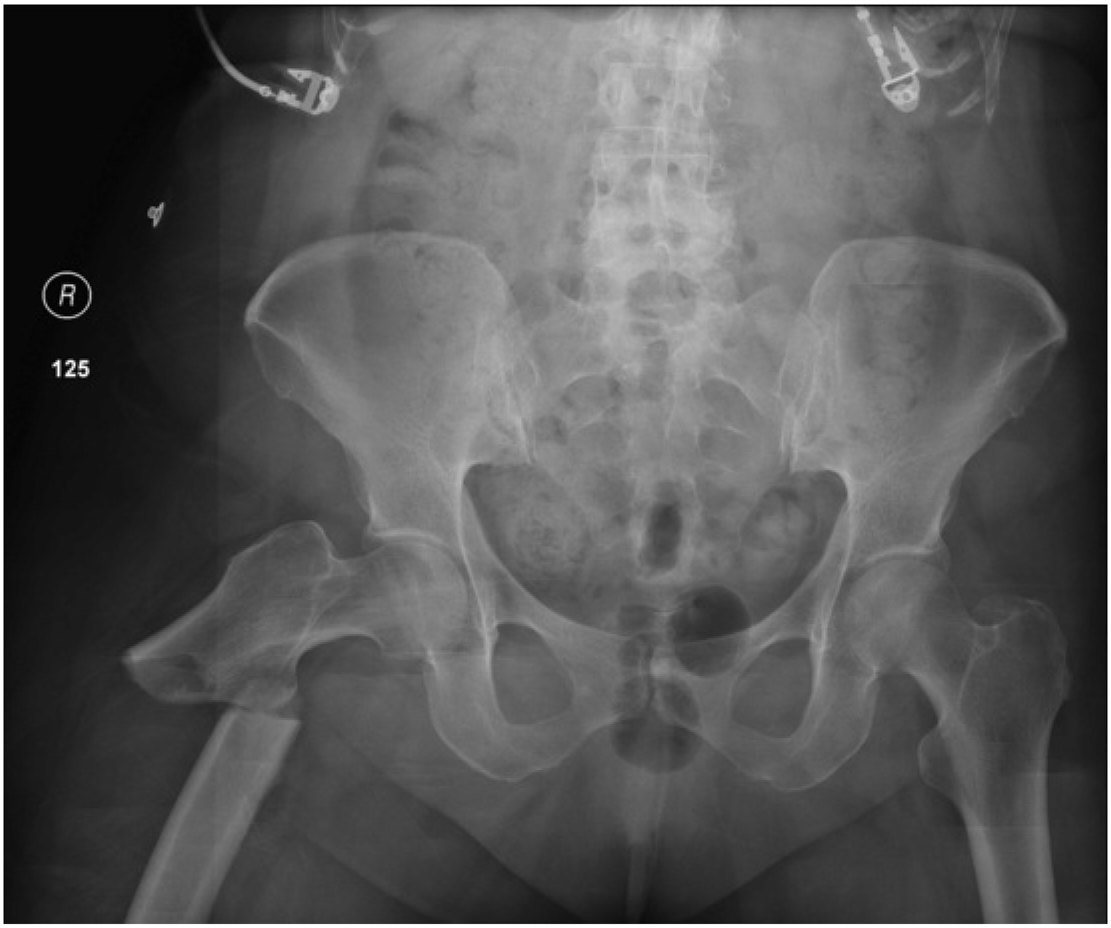


Figure 3.9 A subtrochanteric fracture of the femur is noted. (Image courtesy of Michael C. Bond, MD.)

Treatment

- Orthopedic consultation for operative repair
- All patients should be placed on bed rest
- Immobilize the leg in a splint or consider placing in traction
- Symptomatic treatment
  - Pain control with narcotics as needed
  - Consider a femoral nerve block in the elderly, who may have increased sedation with narcotics

Hip dislocations

General

- Represent ~5% of all joint dislocations
- Posterior dislocations are the most common and account for 90 to 95% of all hip dislocations
- Anterior dislocations are second most common
- Inferior dislocations are extremely rare but have been reported

Classification of posterior hip dislocations

- Grade I – a simple dislocation with no fracture
- Grade II – a dislocation with an acetabular rim fracture that is stable post reduction
- Grade III – a dislocation associated with an unstable or communited fracture
- Grade IV – a dislocation associated with a femoral head or femoral neck fracture

Mechanism

- Most native hip dislocations are secondary to a high-energy trauma
- Most dislocations are secondary to a blow to the knee while the hip is flexed causing transmission of the force down the femur, and pushing the femoral head out of the acetabulum
- Lower-energy trauma can result in a dislocation in the young and those with prosthetic hips

Symptoms

- Patient will complain of hip pain that is increased with weight-bearing, if able, and movement
- Leg is often shortened, internally rotated, and the hip adducted
- The femoral head may be palpable in the buttock

Diagnosis

- Plain radiographs (AP view of the pelvis, and hip view) is often all that is needed to confirm the diagnosis (Figure 3.10)
- CT or MRI of pelvis and hip may be needed if there is suspicion of an occult fracture
  - If you suspect a femoral neck fracture, this should be confirmed, before closed reduction is attempted. Closed reduction increases the risk of disrupting the blood flow and increases the incidence of AVN in those patients with a femoral neck fracture
- Associated injuries:
  - Femoral head fracture
  - Acetabular fractures
  - Femoral neck fractures
  - Avascular necrosis of the femoral head
  - Sciatic nerve injury
  - Ipsilateral knee injuries
  - Vascular injuries, rare with posterior dislocations, but can occur with anterior dislocations

Figure 3.10 A posterior hip dislocation with associated fracture of the posterior wall is shown. (Image courtesy of Michael C. Bond, MD.)

Treatment

- Reduction should occur within 6 hours in order to minimize risk of AVN
- Dislocations with fractures should be evaluated by orthopedics emergently for consideration of open reduction in the operating room
- All patients should be placed on bed rest
- Reduction techniques (see Chapter 9: Procedures for orthopedic emergencies)
- Symptomatic treatment
  - Pain control with narcotics as needed
  - Consider a femoral nerve block in the elderly, who may have increased sedation with narcotics

Femur fractures

General

- The mortality rate of femoral shaft fractures was as high as 50% when they were treated conservatively with bed rest. Now that operative repair is the norm, the mortality rate is much lower
- The femoral shaft has an excellent blood supply so these fractures tend to heal very well
- Classification of femoral shaft fractures is based on the operative management:
  - Spiral, transverse or oblique fractures

- Comminuted fractures. Further divided into four grades based on the size of the fracture fragment and degree of comminution
  - Grade I – minimal or no comminution
  - Grade II – fracture fragment is 25–50% of the width of the femoral shaft
  - Grade III – large butterfly fragment (> 50%)
  - Grade IV – circumferential comminution with complete loss of contact with the two ends of the cortices (Figure 3.11 and Figure 3.12)
- Open fractures

Figure 3.11 A mid-shaft femur fracture is noted with complete loss of contact of the two ends of the cortexes. (Image courtesy of Michael C. Bond, MD.)

Figure 3.12 An oblique comminuted fracture of the femur is shown. A traction rod can be seen. (Image courtesy of Michael C. Bond, MD.)

Mechanism

- Result of high-energy trauma as seen in motor vehicle collisions, falls, direct blows, or gunshot wounds
- Femoral shaft fractures in children aged 1 to 5 are associated with child abuse in up to 35% of cases

Symptoms

- Patients will complain of pain in their thigh, and may have shortening of the leg with a rotational deformity
- Ecchymosis may be noted
- Femoral shaft fractures can result in significant blood loss (1–1.5 L) so hypotension should be treated aggressively with intravenous fluids and blood

Diagnosis

- Plain radiographs (AP and lateral view of femur) are often all that is needed to confirm the diagnosis
  - Consider adding views of the hip, knee, and pelvis to exclude additional fractures/dislocations
- Associated injuries:
  - Arterial injuries
  - Neurologic injuries
  - Secondary bony injuries at the hip, knee, or pelvis

Treatment

- Orthopedic consultation for operative repair
- Immobilize the leg. Traction may be needed initially to restore the leg to its proper length and realign the two ends of the bone
  - Traction and immobilization alone can provide significant pain relief and stop the powerful quadriceps muscles from spasming
- Symptomatic care
  - Narcotic pain medication as needed
  - Can consider a femoral nerve block
- For open fractures –
  - Clean the skin
  - Dress the wound appropriately
  - Update tetanus status
  - Start antibiotics
    - Cefazolin 2 gm IV

Bursitis

- There are four bursa of the hip that are clinically important:
  - Deep trochanteric – lies between the greater trochanter and the tendinous insertion of the gluteus maximus
  - Superficial trochanteric – lies between the greater trochanter and the skin
  - Iliopsoas – lies between the iliopsoas muscle and the iliopectineal eminence that is along the anterior surface of the joint capsule
  - Ischiogluteal – lies on top of the ischial tuberosity

Mechanism

- The bursae typically get inflamed from overuse, excessive pressure, or trauma
- Can also be caused by systemic inflammatory diseases such as –
  - Sepsis
  - Gout

Symptoms

- Deep trochanteric bursitis – pain and tenderness localized to the posterior portion of the greater trochanter
  - Increased pain with flexion and internal rotation of the hip
  - May have Trendelenburg's sign
    - A positive sign occurs when you ask the patient to stand on the affected leg and the pelvis drops to the unaffected side
    - Caused by inhibition of the gluteus muscle
- Superficial trochanteric bursitis – pain and tenderness over the bursa that is increased with extreme adduction of the thigh
- Iliopsoas bursitis – pain and tenderness over the lateral edge of the femoral triangle
  - Can irritate the femoral nerve, which will refer pain to the anterior thigh
  - Common in individuals that use hip flexors a lot (e.g., dancers, soccer players)
  - Pain is increased with extension, abduction, and internal rotation
  - Therefore, the patient typically holds the leg flexed, adducted, and externally rotated
- Ischiogluteal bursitis – seen often in individuals who sit for prolonged periods on hard surfaces
  - Pain and tenderness over the ischial tuberosity
  - Pain can radiate down the leg into the hamstrings and be confused with a radiculopathy

Diagnosis

- Clinical diagnosis. Radiographs and laboratory studies are not required unless you are attempting to exclude another disease process or a specific cause (e.g., gout)

Treatment

- Rest
- Heat
- Non-steroid anti-inflammatory agents
- Ischiogluteal bursitis can also benefit from the use of a seat cushion or donut pillow
- Chronic cases can be referred for possible corticosteroid injection or, if really severe, surgical excision of bursae

Chapter 4 Knee and leg emergencies

Arun Sayal

Orthopedic Emergencies, ed. Michael C. Bond, Andrew D. Perron, and Michael K. Abraham. Published by Cambridge University Press.

Knee injuries – general approach

Key facts

- With its location between two long bones, the knee is exposed to significant forces in different planes (axial, anterior/posterior, medial/lateral, and rotatory)
- Injuries range from minor soft tissue injuries to dislocations with limb-threatening arterial injuries
- High-energy forces are often responsible for the more serious injuries; but for certain groups (e.g., elderly or morbidly obese), serious injury can be seen with a relatively low-energy mechanism
- Because of the limitations of the ED assessment, the suspected discharge diagnosis is often unconfirmed, and close follow-up is required to confirm the diagnosis, monitor symptoms and guide further management
- Important goals of the ED knee assessment are to:
    - Ensure proper anatomic alignment
    - Rule out an occult knee dislocation
    - Rule out a fracture around the knee
    - Rule out an extensor mechanism injury
- ED follow-up is guided by the judgement of the clinician and local orthopedic resources/preferences

PEARL: Fifty percent of knee dislocations will spontaneously reduce before the patient is evaluated in the ED.

Clinical presentation

- The history is often the most important part of the knee examination – particularly the patient's age and the exact mechanism of injury
- Other key points on history include: the knee "giving way" or feeling a "pop", events post-injury, presence and timing of swelling, previous injury (to either knee)
- Immediate swelling (within an hour or two) is a hemarthrosis; common causes include an anterior cruciate ligament (ACL) tear and fracture
- Swelling that is delayed (6–12 hours after injury) is usually inflammatory and is often seen with meniscal injuries, capsular stretches, and other less severe soft-tissue injuries
- Always consider that pain in the knee (especially distal anterior/medial thigh) can be referred

from the hip or back – such pain without tenderness should prompt a search for a more proximal cause
- Many important aspects of the history are noticed only days after the injury and therefore are unavailable to the clinician in the ED (e.g., swelling with activity, pain with squatting, intermittent locking or clicking, sense of the knee "giving way" with walking, etc

Physical examination

- Physical exam of the acutely injured knee in the ED is often compromised by acute pain and swelling
- An organized approach to the physical exam helps recognize those patients that need orthopedic consultation (timing of the referral based on the diagnosis)
- Proper assessment requires the patient to be lying on a bed (not sitting in a chair) with the distal thigh and knee fully visualized
- The opposite knee should routinely be inspected and examined for comparison
- A "Look, Feel, Move" approach helps to remember important aspects of the knee exam
- "Look"
    - To ensure the skin is intact – rule out the possibility of an open fracture
    - For alignment – knee or patellar dislocations will be clinically apparent (beware that many of these spontaneously reduce before arrival at the ED)
    - For swelling
        - Large effusions are noted by loss of the "dimple" on the medial side of the knee
        - Mid-sized effusions can be detected by patellar balottement (where one hand compresses the patella medially, inferiorly and laterally; while the other hand pushes posteriorly on the patella, testing for patellar balottement or cushioning – compare to the opposite side)
        - Small effusions are detected with a fluid-bulge sign (milk up the medial side of the knee; then down the lateral side, looking for a medial fluid "bulge")
- "Feel"
    - For warmth and temperature difference, and point(s) of maximal tenderness – specifically palpate for tenderness:
        - Anteriorly – at the patella, distal quadriceps, patellar tendon, tibial tuberosity
        - Medially – at the medial femoral condyle, medial joint line, proximal medial tibia
        - Laterally – lateral femoral condyle, lateral joint line, proximal fibula
    - Distal neurovascular assessment – any vascular compromise is an orthopedic emergency
- "Move"
    - Range of motion (active and passive) – assess if the knee reaches full extension
    - Both passive and active straight leg raise with the patient lying supine
    - An important part of the knee examination is to ensure the extensor mechanism is intact
        - If equivocal, can repeat active knee extension with the patient sitting over the side of the bed
- As indicated, special tests may be performed to assess for injury to the main knee ligaments – (anterior cruciate, posterior cruciate, medial collateral and lateral collateral)
    - Anterior cruciate ligament (ACL): Lachman test (flex the knee 20–30° and attempt to displace the tibia anteriorly on the femur) and anterior drawer (at 90° of knee flexion,

attempt to displace the tibia anteriorly on the femur)
    - Posterior cruciate ligament (PCL): posterior drawer (at 90° of knee flexion, attempt to displace the tibia posteriorly on the femur) and posterior sag sign (with the patient supine, knees flexed and feet on the bed – when viewed from the side, the proximal tibia of the affected knee sags posteriorly)
    - Medial collateral ligament (MCL): Valgus stress (flex the knee 20–30° and apply to the lateral joint line a medially directed force)
    - Lateral collateral ligament (LCL): Varus stress (flex the knee 20–30° and apply to the medial joint line a laterally directed force)

PEARL: If laxity is found in testing three of the four knee ligaments, then a knee dislocation should be assumed to have occurred.

PEARL: Ligament stress testing in the ED is often compromised by pain and swelling causing muscle spasm, making ligament testing less reliable in the acute setting.

Other special knee tests in the ED

- **Patellar apprehension test:** With the knee extended and the quadriceps relaxed, apply to the medial side of the patella a laterally directed force. A reflexive quadriceps contraction or facial grimace is abnormal for meniscal pathology (more difficult to perform in the acutely injured knee)
- **Apley's test:** Flex the knee 90°; examiner pushes up on the foot (axial compression to the tibia); pain with external rotation of the foot suggests medial meniscus pathology; pain with internal rotation of the foot suggests lateral meniscus pathology
- **McMurray's test:** Flex the knee 45°; combine valgus stress, external rotation and extension – a painful 'click' suggests a medial meniscal tear; with a varus stress, internal rotation and extension – a painful 'click' suggests lateral meniscal tear
- **Thessaly's test:** Patient stands on affected leg with the knee flexed at 20°; then rotates the knee and body, internally and externally, three times. Patients with suspected meniscal tears will experience joint-line discomfort
- **External rotation dial test:** For post-traumatic lateral knee pain and posterolateral corner injuries (PLC); with the patient prone, test external rotation of the tibia at both 30° and 90° of knee flexion. A positive test is > 10° difference in external rotation compared to the opposite side

Diagnostic testing

- Plain knee radiographs – only ~7% in the ED are diagnostic
- Ottawa knee rules and Pittsburgh knee rules – both are clinical decision rules that can reduce the number of ED radiographs, reduce ED wait times, and reduce costs. Pittsburgh knee rules may have better specificity
- Ottawa knee rules: Radiographs of the knee are indicated if *any* of the following are noted:
    - Age > 55 years
    - Inability to flex 90°

    - Isolated tenderness of the patella
    - Tenderness at the head of the fibula
    - Inability to walk four steps both immediately after injury and in the ED
- Pittsburgh knee rules
    - Fall or blunt trauma injury to knee *plus*:
    - Either age < 12 years or > 50 years
    - Inability to walk four steps in the ED
- The sensitivity of knee radiographs is not 100%
- Radiographic occult fractures can occur around the knee
    - Particularly small avulsion fractures, osteochondral lesions, patellar fractures and subtle, undisplaced tibial plateau fractures
- Oblique views can increase the sensitivity for detecting a fracture
- A "sunrise" or "skyline" view can increase the sensitivity for a patellar fracture (Figure 4.1)

PEARL: Ottawa and Pittsburgh knee rules can significantly reduce the number of radiographs needed in patients presenting with knee pain.

- A lipohemarthrosis is a fat–fluid level that may be seen on a lateral radiograph; its presence is associated with an intra-articular fracture – even if the fracture is not seen on radiograph (the fat comes from the bone marrow) (Figure 4.2)
- A fabella is a small sesamoid bone found in the lateral head of the gastrocnemius; it is a normal variant and is rarely symptomatic
- Advanced knee imaging in the ED:
    - Computed tomography (CT) of the knee is uncommonly required by the ED provider – consultants may request CT imaging in the ED to define more clearly fracture patterns and treatment plans
    - CT angiograms or arteriograms may be emergently indicated in select knee dislocation cases
    - Magnetic resonance imagery (MRI) for acute knee injuries is rarely required by the ED provider, though may be requested by the physician providing follow-up care as an outpatient

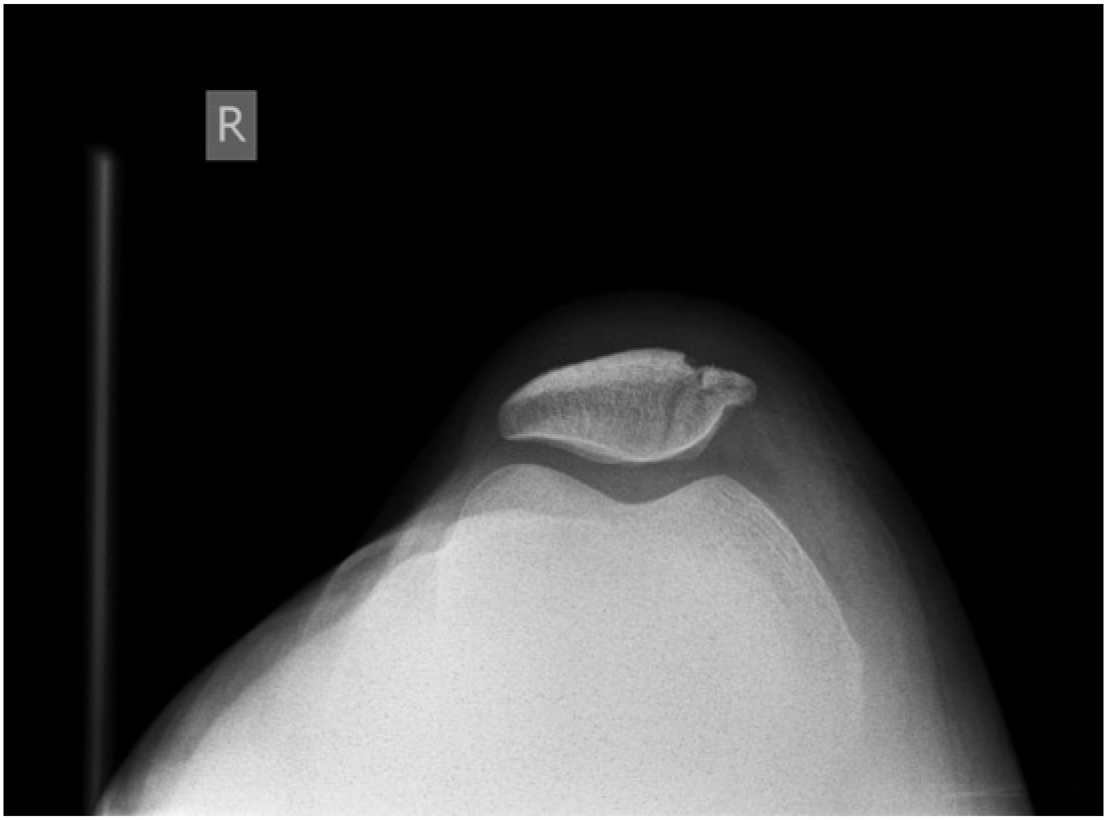


Figure 4.1 "Sunrise" or "skyline" view: Additional view that can increase sensitivity of the radiograph for patellar fractures. Here a fracture is noted. (Image courtesy of Arun Sayal, MD.)

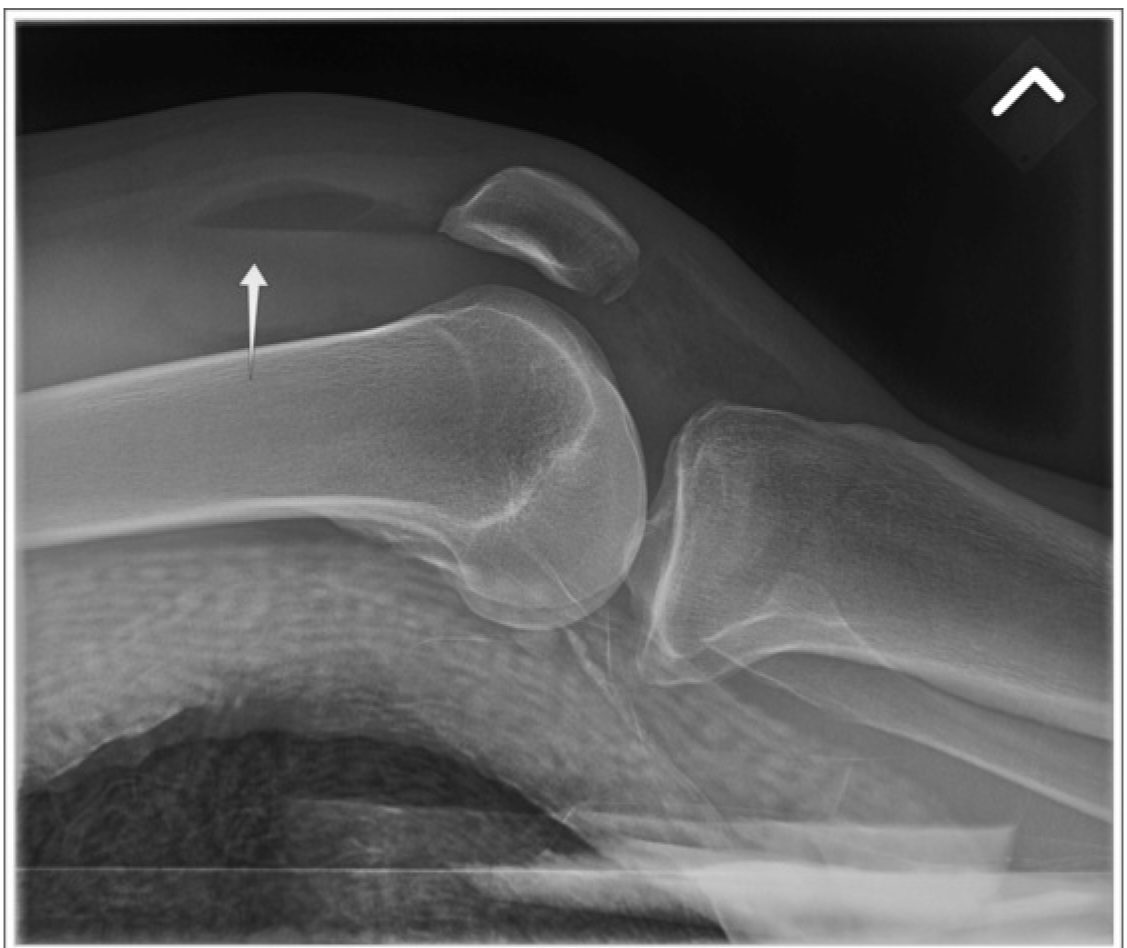


Figure 4.2 Lipohemarthrosis. White arrow shows "fat–fluid line" (fat on top) – associated with an intra-articular fracture. (Image courtesy of Arun Sayal, MD.)

Treatment

- The specific diagnosis of the acutely injured knee may be suspected, but often remains unconfirmed after ED assessment
- For the acutely injured knee that is anatomically aligned and with negative radiographs (if done), management is based on the clinical suspicion of the ED provider
- In the rare instance where a knee dislocation is suspected, then immobilization in 20–30°of flexion and immediate orthopedic consultation in the ED is indicated
- When an occult, non-displaced fracture is suspected, then management should include immobilization in ~30° of flexion, crutches, non-weight-bearing status, and follow-up with orthopedic surgery within a few days. Though not absolutely indicated, local practice patterns may elect to confirm the presence or absence of a fracture in the ED with advanced imaging (CT)
- Most commonly, a "soft tissue injury" is diagnosed. In these cases, follow-up should be arranged to confirm the diagnosis, ensure clinical improvement, and guide further management
- Relatively minor soft tissue injuries can weight bear as tolerated, should avoid returning to sports, and can typically be followed up by a primary care physician within a week
- For more significant soft tissue injuries (ligament, meniscal, etc.), ED management depends on local referral patterns and consultant preferences
- One ED strategy includes close follow-up with ice, compression, ROM exercises, protected weight-bearing as tolerated, crutches as needed, and immobilization only if needed – this reduces the incidence of stiffness and atrophy that often follow immobilization of the knee
- However, some orthopedic consultants may prefer immobilization and non-weight-bearing status at ED discharge with close follow-up
- Follow-up arrangements are determined by multiple factors including provisional diagnosis, consultant preferences, patient's athletic demands, access to care, age, and co-morbidities

Prognosis

- Prognosis of knee injuries in the ED can vary from minor injuries that recover fully and quickly, to injuries that may never return to baseline function and are destined to have operative management and/or premature osteoarthritis
- In appropriate patients, encouraging range of motion exercises and allowing weight-bearing as tolerated reduces the complications of stiffness and weakness that often accompany knee immobilization

Knee dislocations

Key facts

- Knee dislocations are an orthopedic emergency
- It is a rare but potentially devastating injury that must be admitted and monitored closely by orthopedic specialists
- Mechanism varies from high-velocity dislocations (e.g., pedestrian struck) to low-velocity

dislocations in susceptible individuals (e.g., morbidly obese individual stepping down off a curb)

- The popliteal artery is tethered proximally and distally as it passes behind the knee; as such, an arterial injury can be seen with any knee dislocation (up to 30% in all dislocations; up to 50% in anterior–posterior dislocations)
- Common peroneal nerve injury ("drop foot") found in ~25% of dislocations, especially with lateral dislocations
- Initial ED presentation of arterial injury varies – the limb can be pulseless, may have diminished pulses, or may have normal pulses. ED providers must have a high index of suspicion and rule out a dislocated knee since these patients need to have their vascular status closely monitored
- An ankle brachial index (ABI) may help guide management in some cases

Clinical presentation

- High-energy mechanisms are most commonly implicated – motor vehicle crash (MVC), pedestrian struck, high-velocity sports, etc. (Figure 4.3)
- May also be seen in susceptible individuals with relatively low-velocity injuries – morbidly obese with twisting knee injuries
- In morbidly obese patients, the dislocation may not be as clinically apparent and only detected on radiographs (Figure 4.4A, B). If the MCL is completely torn, then the joint effusion can extravasate medially and the knee may not appear as swollen
- Passive straight leg raise – gross hyperextension can indicate an occult knee dislocation
- Typically, with acute knee ligament injuries, gross laxity is not seen in the ED owing to acute pain and swelling
- Even though acute ligament testing in the ED is less sensitive, it must be performed to ensure the patient has not suffered a knee dislocation that has spontaneously reduced
- If, on ED assessment, three out of four ligament laxity is noted, then a knee dislocation must be presumed
- Assess through distal neurovascular examination for foot drop, color, temperature, refill, etc
- Pulselessness at any time (pre-reduction or post-reduction) requires an emergent vascular consultation
- Ankle brachial index may be useful to predict vascular complications
    - ABI is the ratio of the doppler blood pressure at the ankle (use the higher reading of dorsalis pedis and posterior tibial artery) and the brachial artery
    - An ABI of > 0.9 is reassuring; < 0.9 is associated with increased risk of vascular complications; you can compare the value to the contralateral leg
- Assess for compartment syndrome of the lower leg (see Chapter 8)

PEARL: If three out of four ligaments are unstable on knee examination, the diagnosis is a knee dislocation until proven otherwise.

Figure 4.3 Lateral knee dislocation during a soccer game. (Image courtesy of Arun Sayal, MD.)

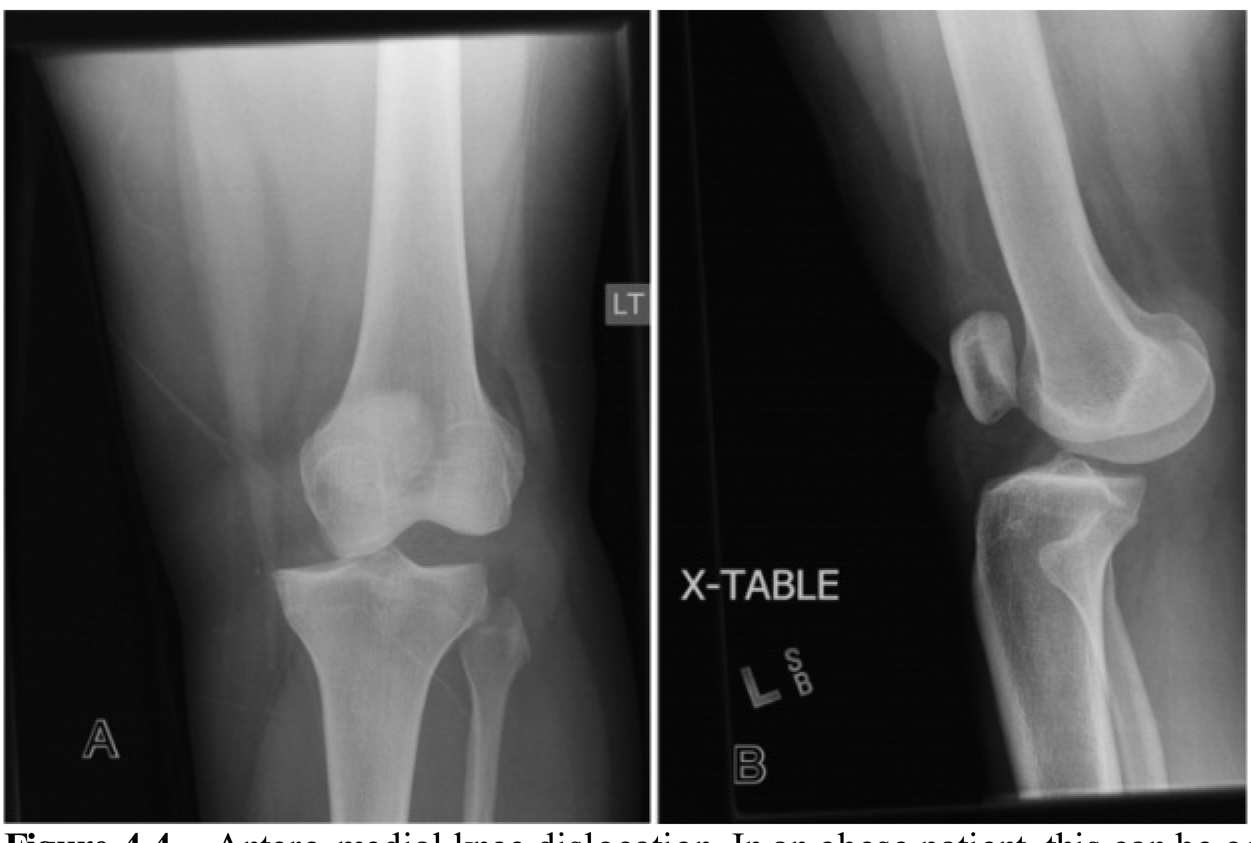


Figure 4.4 Antero-medial knee dislocation. In an obese patient, this can be occult both on history (low velocity) and on physical examination when assessing for alignment. A: AP view. B: Lateral view. (Images courtesy of Arun Sayal, MD.)

Diagnostic testing

- Plain radiographs – diagnostic if the joint is still subluxed/dislocated (Figure 4.5 A, B)
- May be normal if reduced already
- May see associated fractures of the femur or tibia, (including avulsion fractures)

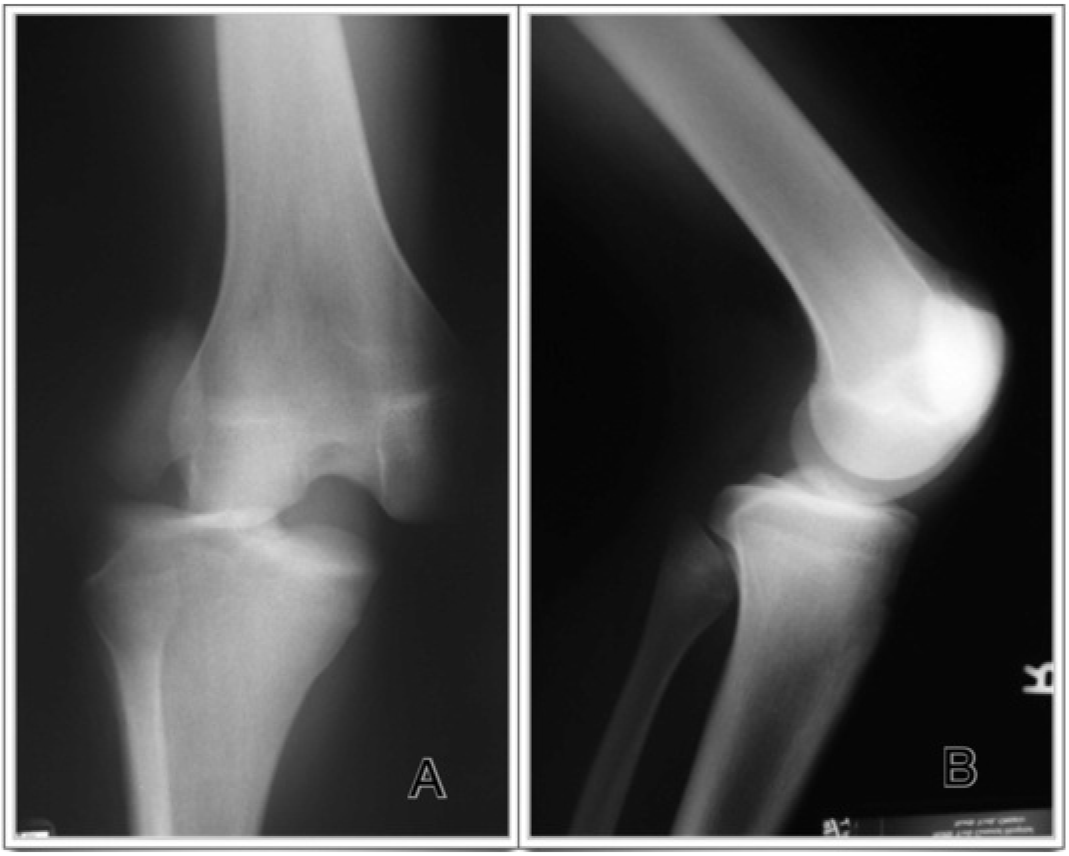


Figure 4.5 Lateral knee dislocation compared to an anterior/posterior knee dislocation, a lateral dislocation is more likely to have a common peroneal nerve palsy, and less likely to have an arterial injury, though both complications can occur with any knee dislocation. A: AP view. B: Lateral view. (Images courtesy of Arun Sayal, MD.)

Treatment (Table 4.1)

- All patients with a documented or suspected knee dislocation require referral to orthopedics and admission
- If the joint remains subluxed or dislocated, immediate reduction is indicated
- Typically, a knee dislocation is so unstable that it reduces fairly easily with gentle traction and repositioning (the same reason why knee dislocations often reduce before they get to the ED)
- Occasionally, soft tissue may be interposed and make the knee irreducible – this warrants emergent referral for open reduction
- After reduction, recheck and document neurovascular status and apply a knee immobilizer (preferably removable) in ~20° of flexion (as full extension can result in posterior subluxation)
- Obtain radiographs post reduction to ensure anatomic alignment
- In the past, angiography was recommended for all cases of knee dislocation
- A selective approach to angiography is now favored by many, with indications based on the vascular assessment

- If definite signs of arterial injury exist (pulseless, expanding popliteal hematoma, cold, white limb, etc.) – then vascular and orthopedic surgery consultations are indicated and the patient should go directly to the operating room
- If signs of possible arterial injury exist (decreased pulses, cooler limb, delayed refill, etc.), then both immediate referral and angiography are indicated
- If no sign of arterial injury (normal pulses, warm foot, normal refill), then orthopedic referral is indicated for admission to a facility with vascular surgery and the patient should have frequent neurovascular assessments
- Evidence of compartment syndrome warrants emergent referral for fasciotomies

PEARL: Knee dislocations are rare but commonly missed (especially if the dislocation spontaneously reduces). The ED provider must consider the diagnosis of a spontaneously reduced knee dislocation in patients with significant knee injuries.

Table 4.1 ***Management of vascular injuries in knee dislocations.***

Physical examination	Testing	Consultations	Disposition
Pulseless, expanding hematoma, cold, pallor	None	Vascular and orthopedic surgery	OR
Decreased pulses, cooler limb, delayed capillary refill	Angiography	Vascular and orthopedic surgery	OR vs. admission
Normal pulses, warm foot, normal capillary refill	None	Orthopedic surgery	Admission with frequent NV checks

Prognosis

- A knee dislocation is a potentially devastating knee injury
- Vascular complications are more commonly seen with dislocations in the anterior–posterior plane
- Nerve palsies are more commonly seen with dislocations in the lateral plane
- Neurovascular complications can occur with dislocations in any direction
- If vascular injury has occurred, time to OR is predictive of amputation rate: < 8 hours, approximately 15% amputate rate; > 8 hours, approximately 80% amputated
- ~1/4 may suffer peroneal nerve damage – majority of which are permanent
- Stiffness and instability are common complications
- Heterotopic ossification may also occur
- Compartment syndrome is common, especially if there is a concomitant arterial injury
- Complete recovery to the patient’s baseline (pre-dislocation) level of activity is highly unlikely

Meniscal injuries of the knee

Key facts

- Menisci are important cartilaginous structures involved in weight distribution and knee stability
- As patients age, degeneration causes the menisci to become thinner and more susceptible to injury
- The "typical" history for a meniscal injury also varies based on patient age
- Many meniscal injuries will heal with conservative management
- Urgent arthroscopy is recommended if the knee is locked (lacks full extension)

Clinical presentation

- In young adults, the mechanism of injury is usually a significant twisting injury with pronounced pain
- In older patients, the mechanism of injury is often a minor twist (e.g., getting up from a squat) and the initial pain can vary
- Meniscal injuries often present with swelling over hours, indicative of inflammation
- Tears in degenerative menisci often have less swelling
- Peripheral rim tears may present with a fairly acute hemarthrosis – rim tears are far less common than central tears
- Other symptoms suggestive of meniscal pathology include pain with squatting, twisting or stairs; swelling with activity, and painful clicking

Physical examination

- The physical examination usually reveals:
  - A joint effusion
  - Joint-line tenderness (typically medial, though often lateral)
- Pain with full flexion or extension
- Joint effusions can present with "fluid bulge" sign for smaller effusions or "patellar ballottement" for larger ones
- A variety of tests can be performed to look for meniscal pathology – Apley's test, Thessaly's test, McMurray's test, etc. – many of these are difficult to perform in the acutely injured knee
- It is important to rule out a "locked" knee (i.e., a knee that lacks full extension) since a locked knee is an indication for urgent arthroscopy (Figure 4.6)
- A few important points regarding a locked knee:
  - Compare to the opposite side (younger patients often hyperextend; so an injured knee that can extend to 0° may actually be "locked")
  - Acute pain and swelling may also prevent full extension – it is not always mechanical
  - Acute mechanical causes of a locked knee include a bucket-handle tear of the meniscus, the stump of the ACL, or a loose body (which often presents with intermittent locking)
  - One clinical tip to detect more subtle cases of locking (see Figure 4.6): Lie the patient prone, with the knees near the end of the bed and the feet hanging over; a persistent elevated heel height on the affected side can indicate a difference in knee extension

PEARL: Failure to extend the knee fully can be a sign of a "locked knee." If caused by a mechanical problem, this is an indication for an urgent arthroscopy. Pain and swelling may also prevent full extension. If a "locked knee" is suspected in the ED, then close follow-up needs to be arranged to distinguish surgical from non-surgical causes.

Figure 4.6 Locked knee. The far (right) heel is elevated compared to the near heel – indicating the right knee does not fully extend. If pushing down on the knee results in a hard, "spring-like" recoil, this suggests a mechanical block (i.e., a true "locked knee"). If the endpoint is soft, and the knee slowly extends further, this suggests pain and swelling may be responsible for the lack of full extension. Subtle cases of a locked knee can be detected by this maneuver. (Image courtesy of Arun Sayal, MD.)

Diagnostic testing

- Plain radiographs are of limited value in the ED assessment of meniscal injuries
- For meniscal pathology, studies suggest, a good clinical examination is equivalent to MRI on both sensitivity and specificity
- MRI may miss meniscal injuries that are present; may detect meniscal injuries that are either asymptomatic or in fact are false positives
- CT and US do not have enough sensitivity to be recommended for use in determining meniscal pathology

Treatment

- Meniscal injuries can be treated with ice, compression, elevation, weight-bearing as tolerated, and crutches as needed
- NSAIDs may help reduce pain and swelling, which will help maintain range of motion and strength

- Restricted activity (walking as tolerated, but no running, twisting or jumping motion) is initially recommended to prevent further injury to the knee
- Sudden knee pain from an existing injury (e.g., a healing meniscal or ligamentous injury) can cause the quadriceps muscles to suddenly relax. If the patient is standing only on the injured leg when this occurs, all the force is put through the unsupported and recently injured knee; this can further damage injured structures (e.g., extend a meniscal tear) or can injure structures not previously injured (e.g., an acute ACL tear)
- Appropriate follow-up should be arranged and documented
- Follow-up examination(s) are required to confirm the suspected diagnosis, reassess for other possible injuries, ensure the knee is not "locked," ensure symptom improvement (pain, swelling) and guide the return to baseline range of motion, strength, and activity level
- Suspected meniscal injuries can be followed in a week or so by an appropriate physician (local resources and referral pattern help decide if that is an orthopedic surgeon, sports medicine physician or primary care physician)

Prognosis

- Many small meniscal tears will heal with conservative management over 6–8 weeks
- Menisci do not regenerate – a meniscectomy removes cartilage, which increases the incidence of osteoarthritis. Therefore a conservative approach is recommended
- Younger patients may be candidates for arthroscopic meniscal repair
- Conservative management includes maintenance of range of motion and strength, weight-bearing as tolerated, and restricted activities (preventing running, twisting or jumping sports)
- As improvement is noted and under the close supervision of the treating physician/therapist, activity level is gradually increased as tolerated

PEARL: Many smaller meniscal injuries can heal non-operatively. From the ED, advising restricted activity and arranging close follow-up are important to determine optimal management for each patient.

Anterior cruciate ligament (ACL) injuries

Key facts

- The ACL is the main crossing ligament in the knee and provides rotational stability to the knee
- If an athlete suddenly decelerates (lands or plants a foot), feels his knee 'pop', is unable to continue playing, and the knee swells within an hour, then on history alone there is an ~85% chance of an ACL injury
- Overall, more males than females will suffer ACL injuries
- However, likelihood studies in athletes reveal that females playing soccer or basketball are 2–4× more likely to injure their ACLs than male counterparts
- Injury to an ACL does not mean definite surgery – the decision is multi-factorial

Clinical presentation

- Typical mechanism: Sudden deceleration injury in sports (often no other player involved)
- May also be seen with trauma to the anterolateral aspect of the knee (i.e., tackles) or knee on knee collisions (valgus strain resulting in the "terrible triad" of ACL, MCL, medial meniscus) or the hyperextension mechanism
- Patient often reports feeling the knee "slip" or "pop", inability to continue playing, and development of significant swelling within an hour or two (a hemarthrosis)
- Common findings on examination are significant pain, inability to bear weight, and a fairly swollen knee
- Absence of significant swelling makes an acute ACL injury far less likely (but if there is a complete MCL tear, the effusion may not be contained)
- Assess for full extension – the patient may have a "locked knee" – this is an indication for an urgent referral and arthroscopy
- Mechanical cause of locking can be an associated meniscal tear or the stump of the ACL can lodge between the tibia and femur
- Pain and swelling may also impede full extension – so any patient with a suspected locked knee in the ED should be closely followed as this may resolve as the pain and swelling subside
- Failure to confirm ACL laxity on physical examination is to be expected on the initial ED assessment – the key to diagnosis is suspecting it based on the history
- Tests for ACL integrity (Lachman , anterior drawer, and pivot shift test) all require muscle relaxation to isolate the ligament. Inability of the patient to relax makes these tests quite insensitive in the ED
- Most sensitive test in the ED is the Lachman test, often negative in ED despite an ACL tear; if positive, compare to the opposite side and inquire about previous injury
- Far less sensitive in the ED are the remaining two tests for ACL integrity
- Anterior drawer test – at 90° of knee flexion, attempt to displace the tibia anteriorly on the femur (even if 90° of knee flexion can be achieved there is usually too much pain to allow the hamstrings to relax)
- Pivot shift – with the knee extended and the hip flexed ~30°, apply to the knee a combination of a valgus stress, flexion and internal rotation of the tibia – feel a shift as the knee reduces itself; rarely positive in the ED
- Failure to confirm ACL laxity on physical examination is to be expected at initial ED assessment– the key to diagnosis is suspecting it on history, not confirming it on physical examination
- Carefully assess the other ligaments of the knee (PCL, MCL, LCL)

PEARL: To diagnose an ACL injury in the ED, the keys are the suggestive history with a swollen knee. Failure to confirm ACL injury on physical examination and with plain radiographs is to be expected.

Diagnostic testing

- Plain radiographs – often show an effusion (fluid density in the suprapatellar pouch) but are rarely diagnostic for an ACL tear
- Two findings to look specifically for:
  - Avulsion of the tibial spine (at the ACL insertion) (see Figure 4.7) – if seen in adults, then

surgery may be indicated to anchor the avulsed fragment (this injury pattern is rarely seen in adults and more commonly seen in pediatric ACL injuries where "ligaments are stronger than bone")

- Segond fracture (see Figure 4.8) – a vertically oriented avulsion fracture off the lateral tibial condyle – low sensitivity (~5%), but high specificity (75–100%), so not often seen with ACL injuries, but if it is seen, then the patient likely has suffered an ACL tear

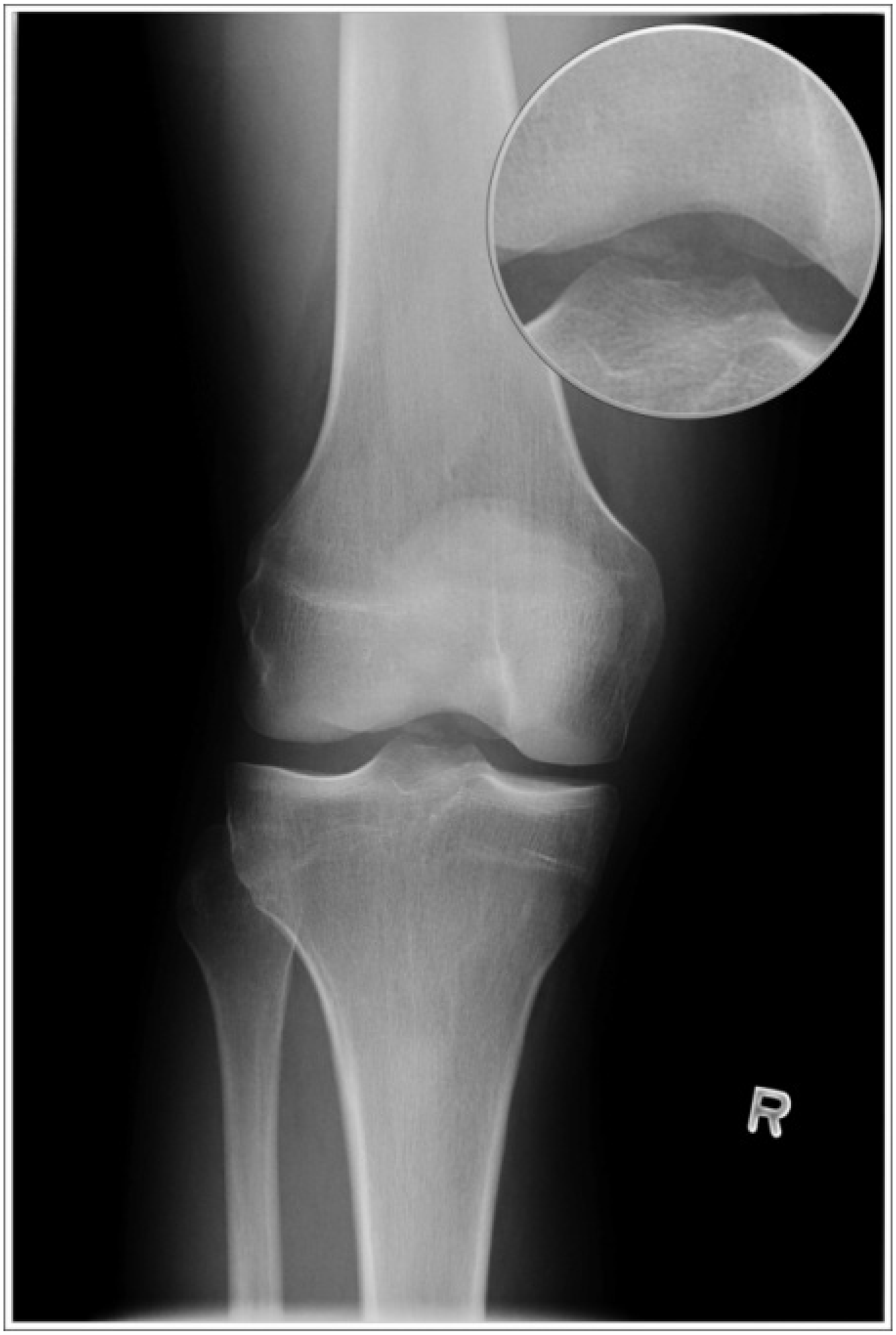


Figure 4.7 Avulsion of the tibial spine. An uncommon radiograph finding for an adult with an ACL tear. This finding is more typically seen in children who suffer ACL tears. Fracture is highlighted by the arrow. Inset shows fracture magnified. (Image courtesy of Arun Sayal, MD.)

Figure 4.8 Segond fracture. Another uncommon radiograph finding suggesting an ACL tear. A vertically oriented avulsion fracture of the lateral capsule; low sensitivity, high specificity (meaning often not seen with ACL tears, but if seen, highly associated with an ACL tear). (Image courtesy of Arun Sayal, MD.)

Treatment

- In the ED, ACL injuries are often suspected based on history and swelling, but difficult to confirm on ACL-specific testing or radiographs
- For ED patients with suspected ACL injuries, close follow-up within a week is required to assess stability and plan treatment
- Follow-up for suspected ACL injuries should ideally be with specialists (orthopedic surgeons or sports medicine physicians) because even if managed non-operatively, there are long-term effects of ACL injuries that need to be clearly explained to the patient
- Goals include: Reduce pain, reduce swelling, and maintain ROM and strength
- Compression, ice, and crutches are often required acutely
- Knee immobilizer may be needed for patients to ambulate, but patients should be encouraged to remove the immobilizer, do ROM exercises, and gently weight-bear as tolerated. This helps maintain range and strength – important aspects of rehabilitation programs

- All patients should be restricted from any running, twisting or jumping activities until cleared by the follow-up physician

Prognosis

- The goal of ACL surgery is to make the knee stable, not to make the knee “normal”
- Achieving a “normal knee” after ACL injury is the exception – the knee is more likely to have premature osteoarthritis with or without surgery
- Not all patients with ACL injuries require surgery
- Some patients compensate well with physiotherapy and non-operative management
- Younger, athletic patients in high-demand sports are more likely to be treated operatively; surgery is less likely if the patient is over 40 years old
- Surgery is also indicated for an unstable knee (i.e., gives way) after appropriate rehabilitation
- Patients with ACL-deficient knees (i.e., injured ACL and treated non-operatively) are more likely to have subsequent meniscal tears – especially if the patient returns to higher-demand sports
- ACL surgery is associated with complications (stiffness, infection, graft failure, etc.) and lengthy postoperative rehabilitation (typically 9+ months to return to sports)
- Surgeons often delay ACL surgery for ~6 weeks to ensure optimal preoperative range of ROM and strength (associated with better surgical outcomes)

Posterior cruciate ligament (PCL) injuries

Key facts

- The PCL can be injured in isolation or associated with other ligamentous injuries
- Injured much less frequently than the ACL

Clinical presentation

- Isolated PCL injuries are often caused by a deceleration injury on a flexed knee (dashboard injury, sports, or falling forward with the proximal tibia striking a solid edge)
- For multi-ligament injuries, various mechanisms can be responsible (e.g., hyperextension, rotatory, etc.)
- In the acute setting, swelling can be variable
- Because of limitations on physical exam, the diagnosis is often made based on the history when the patient presents initially to the ED

Physical examination

- Posterior drawer test – with the knee flexed to 90°, a posterior directed force on the anterior proximal tibia causes the tibia to displace posteriorly
- Posterior sag sign – with the patient supine, knees flexed and feet on the bed, when viewed from the side, the proximal tibia of the affected knee sags posteriorly

- Again, these signs require muscle relaxation and may not be positive on initial exam in the ED

PEARL: If the PCL is injured, and the tibia sags posteriorly, the examiner may mistakenly note a false-positive anterior drawer test (and assume an ACL injury). However, in this case, the mechanism of injury, a posterior sag sign and assessing the opposite knee can help the examiner differentiate between the two.

Diagnostic testing

- Plain radiographs – are rarely diagnostic (i.e., an avulsion off the posterior tibial insertion of the PCL)

Treatment

- Generally, isolated PCL injuries are treated non-operatively
- Younger, high-demand athletes are more likely to be treated operatively
- ED patients with suspected PCL injuries should be referred to an orthopedic surgeon for follow-up within a week
- Crutches, gentle weight-bearing as tolerated, ice, compression, and restricted activity are recommended
- If there is higher clinical concern for more significant derangement of the knee, then brief immobilization and follow-up in a few days may be prudent

Prognosis

- With PCL injuries, poor outcomes are co-related with the number of other ligaments injured and less with the actual degree of the PCL injury
- Most isolated PCL injuries are stable; ongoing symptoms of instability may be treated operatively
- Late sequelae of PCL injury can include degenerative changes in the patellofemoral and/or medial compartments

Medial collateral ligament (MCL) injuries

Key facts

- Most commonly injured of the four major knee ligaments
- Typical mechanism of injury is a valgus strain to the knee; may also be from an external rotation force
- Typically, MCL injuries do not cause a hemarthrosis; if one is noted, it should alert the clinician to the possibility of an associated ACL tear or fracture
- Complete tears of the MCL can cause the medial capsule to open and the effusion to extravasate – this could allow injuries associated with fractures or an ACL tear to appear less swollen than expected

- Isolated MCL injuries generally do well with non-operative management

PEARL: The MCL is the most commonly injured ligament of the knee.

Clinical presentation

- Valgus injury typically caused by a valgus strain – often in sports from being struck on the outside of the knee
- MCL injury is part of the "terrible triad" – ACL, MCL, medial meniscus injury
- Typically, the point of maximal tenderness is the medial femoral condyle (i.e., the origin of the MCL)
- Less commonly, pain is found at the proximal medial aspect of the tibia – the MCL insertion. Tenderness here may portend prolonged healing times
- The MCL has fibers that insert on the medial meniscus, so medial joint-line pain is also common after MCL injury
- Pain with valgus stressing (knee flexed to 30°) is often present in the ED (but pain may hinder accurate assessment of degree of injury)
    - Patients in their late teens and 20s tend to have medial ligament injuries
    - Patients aged > 50 tend to have lateral tibial plateau fractures
- Patients in their 30s and 40s can have either medial ligament injuries or tibial plateau fractures

Physical examination

- Compare degree of valgus laxity by valgus stressing the opposite side
    - Grade I (stretch) – Tender with valgus stressing but does not open
    - Grade II (partial tear) – Tender with stressing and opens but with a definite endpoint
    - Grade III (complete tear) – Often less tender with stressing and no definite endpoint
- Pain and opening with valgus stressing at 0° (full extension) suggests that the MCL and one of the cruciate ligaments are also injured. This is difficult to pick up in the acutely injured knee
- A valgus stress to the knee opens the medial compartment and loads the lateral compartment
    - Patients in their 30s and 40s can have either or both

PEARL: Beware of lateral joint-line pain after a valgus strain – "red flag" for a lateral tibial plateau fracture.

Diagnostic testing

- Plain radiographs as indicated
- Rarely may see an avulsion fracture of the medial femoral condyle
- If concern for lateral tibial plateau fracture, then oblique views increase the sensitivity of plain radiographs
- Advanced imaging (CT, MRI) may be required to rule out definitively a tibial plateau fracture
- Chronic MCL injuries may develop calcification at the femoral insertion of the MCL

Treatment

- Isolated MCL injuries rarely require operative management
- May need 6–12 weeks to recover
- Grade III MCL tears more likely to be treated operatively when associated with ACL tears, PCL tears, and/or meniscal injuries
- Goals include: Reduce pain, reduce swelling, and maintain ROM and strength
- Compression, ice, and weight-bear as tolerated
- Crutches are often required acutely
- Knee immobilizer may be needed for patients to ambulate, but patients should be encouraged to remove the immobilizer, do ROM exercises, and weight-bear as tolerated; patients should be restricted from any running, twisting or jumping sports until reassessed
- Follow-up within a week is advisable to confirm the diagnosis, reassess other structures of the knee, and monitor progress
- Hinged knee braces are useful but rarely available in the ED

Prognosis

- Isolated MCL injuries do well with conservative treatment
- Instability is more often found with multi-ligament injuries,
- With chronic MCL injury, calcification can occur at the femoral insertion of the MCL, so called Pellegrini–Stieda disease; this is often painful and may require orthopedic referral

Lateral collateral ligament (LCL) injuries

Key facts

- Less commonly injured than the MCL but often more significantly
- The usual mechanism of injury is hyperextension and varus stress to the knee
- Usually requires higher forces to injure the LCL
- Since higher forces are often involved, more likely that associated structures are injured (see posterolateral corner injuries)

Clinical presentation

- Lateral knee pain after a varus force to the knee
- Occasionally varus forces to the knee can be seen with ankle inversions, as patients try to regain their balance
- Usually varus force is exerted with the knee hyperextended
- Typically, no significant effusion is noted in isolated lateral injuries – lateral knee pain is the predominant symptom
- LCL injuries can also be associated with posterolateral corner (PLC) injuries

Physical examination

- Varus stress the knee both at 30° of flexion and at 0° (full extension)

- Laxity at 30° tests the LCL
- Laxity at 0° (full extension) suggests that the LCL and either ACL or PCL are injured
- LCL injuries can also be associated with posterolateral corner (PLC) injuries

PEARL: Isolated LCL injuries are relatively rare – if LCL laxity is noted, an associated cruciate ligament injury is commonly present.

Diagnostic testing

- Plain radiographs to rule out associated fractures including the fibular head, lateral capsule avulsions, lateral tibial plateau, etc
- Oblique views are helpful to pick up subtle findings around the tibial plateau

Treatment

- Isolated LCL injuries are relatively rare
- Determining the full extent of ligamentous injuries in the ED can be challenging
- Therefore, it is prudent to suspect that ED patients with LCL findings are likely more significantly injured than they may appear
- Since a relatively high index of suspicion remains for a significant injury, then immobilization, crutches, minimal (or non-) weight-bearing, and close specialist follow-up are recommended

Prognosis

- Isolated LCL tears are generally treated non-operatively
- LCL + other injuries (PCL, PLC, ACL) are more likely to be treated operatively

Posterolateral corner (PLC) of the knee injury

Key facts

- Less common and less well-known knee-injury pattern
- Posterolateral corner complex of the knee includes many structures including the LCL, popliteus tendon, popliteus muscle, lateral capsule and iliotibial tract
- Typical mechanism of injury is hyperextension and varus stress
- Isolated PLC injuries are uncommon – they are commonly associated with injuries to either the PCL or ACL
- The patient is usually unable to bear weight and complains of lateral knee pain

PEARL: Posterolateral corner knee injuries are often unrecognized but can lead to significant instability of the knee if not treated early.

Physical examination

- A significant effusion may be seen (especially if there is an associated ACL tear or fracture)
- Assess peroneal nerve function (“drop foot”)
- Assessing for ligament laxity in the ED is compromised by muscle spasm secondary to acute pain and swelling
- Tests for PLC injuries include:
  - External rotation recurvatum test
    - Examiner lifts each leg by the great toe
    - A positive test is noted if the affected lower leg slips into external rotation and recurvatum at the knee
  - External rotation dial test
    - With the patient prone, test external rotation of the tibia at both 30° and 90° of knee flexion
    - A positive test is > 10° difference in external rotation compared to the opposite side
    - If a positive test is only found at 30°, this suggests an isolated PLC injury
    - If a positive test is found at both 30° and 90°, this suggests both PLC and PCL are injured

PEARL: A varus stress to the knee is uncommon, but a high-risk mechanism elicited on history should prompt a careful search for significant lateral knee pathology.

Diagnostic testing

- Plain radiographs may be normal or may show a small avulsion fracture around the fibular head or lateral knee
- Traumatic lateral knee pain can also be from a lateral tibial plateau fracture – carefully assess for joint-line tenderness and use oblique radiographs to look for subtle fractures

Treatment

- Initial treatment consists of:
  - Immobilization with knee brace
  - Crutches
  - Minimal (or non-) weight-bearing
- Close follow-up with specialist is recommended

Prognosis

- More significant PLC injuries (especially when involving other injuries) are more likely to be treated operatively
- Less significant injuries may be treated conservatively

Tibial plateau fractures

Key facts

- In younger adults, tibial plateau fractures are associated with relatively high-velocity mechanisms
- In older patients, tibial plateau fractures can occur after a low-velocity, valgus strain mechanism as osteoporosis contributes to the weaker bone
- For tibial plateau fractures: Approximately 66% are lateral, 25% are medial, and the rest are bicondylar
- Some tibial plateau fractures are radiographically occult
- Oblique views increase the sensitivity of plain radiographs, but are still not 100% sensitive
- Clinical suspicion for an occult tibial plateau fracture warrants either immobilization, non-weight-bearing status and close follow-up or, alternatively, advanced imaging in the ED

Clinical presentation

- Various mechanisms can result in a tibial plateau fracture; a valgus strain is far more common than varus but can occur from many mechanisms
- Hemarthrosis – swelling within an hour or two of the injury
- If there is an associated complete MCL tear, the hemarthrosis may not be contained and the knee may not appear as swollen
- Patients are generally not able to weight-bear

Physical examination

- Check distal neurovascular status
- Beware of signs of compartment syndrome
- Lateral joint-line pain after a valgus strain is a "red flag" for a lateral tibial plateau fracture
- May be associated with ligament injuries and/or meniscal injuries

PEARL: Lateral joint-line pain after a valgus strain is a "red flag" for a lateral tibial plateau fracture.

Diagnostic testing

- Plain radiographs – adding oblique views increases the sensitivity for tibial plateau fractures
- A lipohemarthrosis is highly specific for a fracture (since source of fat is bone marrow) but less than 50% sensitive
- On plain films, tibial plateau fractures can be radiographically occult; radiographically subtle; or clearly seen (Figure 4.9, Figure 4.10, Figure 4.11, Figure 4.12)

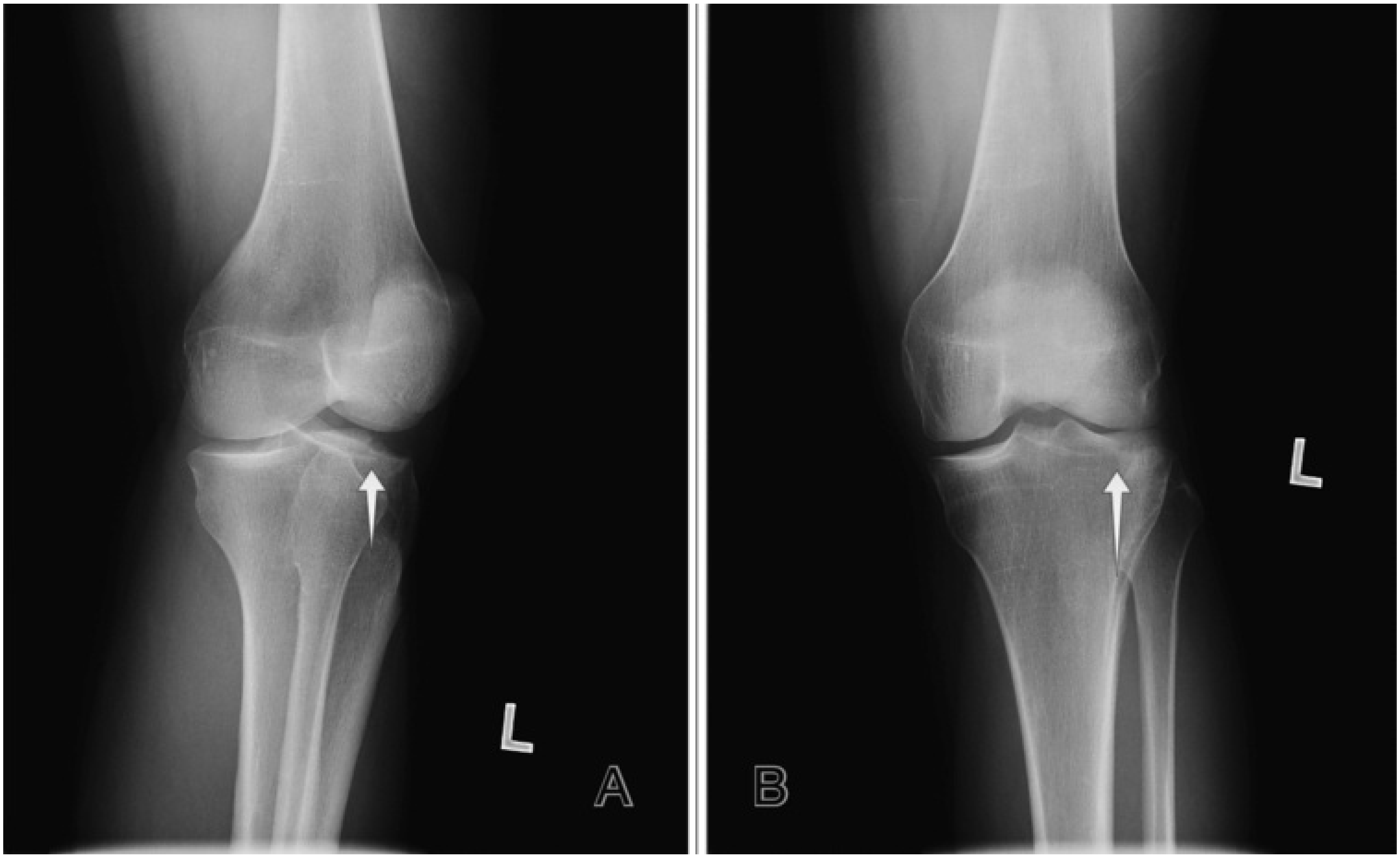


Figure 4.9 Subtle lateral tibial plateau fracture. Oblique (A) shows subtle depression. On the AP view (B) , the fracture is very subtle. (Images courtesy of Arun Sayal, MD.)

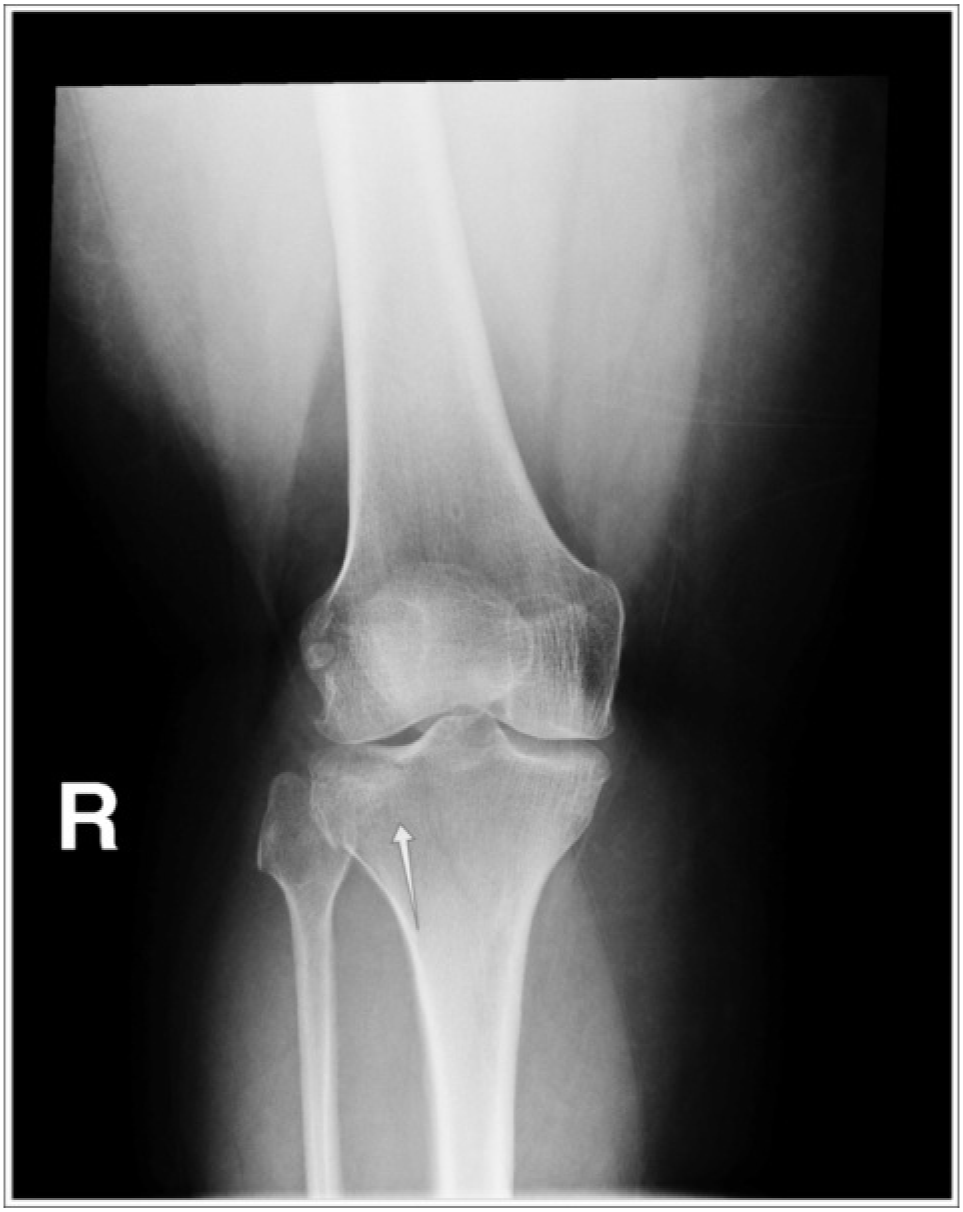


Figure 4.10 A larger, slightly depressed lateral tibial plateau fracture fragment (arrow). (Image courtesy of Arun Sayal, MD.)

Figure 4.11 AP (A) and lateral (B) views of young cyclist struck by a car. Note the effusion seen on the lateral view, the vertical proximal tibial fracture, and the possible depressed tibial plateau fracture. CT (C) of same knee demonstrating the tibial plateau fracture. (Images courtesy of Arun Sayal, MD.)

Figure 4.12 A comminuted tibial plateau fracture. (Image courtesy of Arun Sayal, MD.)

Treatment

- Most patients with depressed and/or comminuted tibial plateau fractures will be admitted for operative repair
- Suspected tibial plateau fractures should be treated with:
  - Immobilization – knee immobilizer or above-knee posterior slab
  - Crutches – non-weight-bearing status
- Depending on resources and practice pattern, some may CT the knee in the ED to make a definitive diagnosis
- Non-displaced and minimally depressed tibial plateau fractures are variably managed
  - High-velocity injuries are more significant, are more likely to have compartment syndrome and as such should be immobilized, elevated, and referred to orthopedics from the ED
- Low-velocity injuries are more typical in the elderly for whom the injuries may often be treated

non-operatively. However, a CT scan may be needed to clarify the details of the fracture (fragment location, comminuted, depression, etc.); crutches and the elderly may not be a safe combination; as such these should ideally be discussed with orthopedics before discharging from the ED
- Displaced fractures are typically treated operatively and need to be watched for compartment syndrome. Immobilization and referral to orthopedics from the ED is indicated. An above-knee posterior slab should be applied for comfort, to maintain alignment, and minimize swelling

Prognosis

- Non-operative management includes immobilization in 30–40°, crutches and non-weight-bearing status
- Close follow-up is needed and includes serial imaging to ensure that late displacement or depression does not occur
- Typically, non-weight-bearing status needs to be maintained for 6–8 weeks
- Patients can move to hinged braces during that time to allow for range of motion and strengthening exercises
- Operative management involves open reduction and internal fixation (ORIF) to reduce and stabilize the fracture
- Complications of operative treatment include:
  - Stiffness
  - Infection
  - Avascular necrosis of the fracture fragments
  - Post-traumatic osteoarthritis of the knee
  - Knee instability (if associated ligamentous injuries)
  - Delayed or non-union

Tibia and fibula fractures or dislocations

Key facts

- The extent of the soft-tissue injury often predicts the outcome of mid-tibia fractures
- High-energy fractures of the tibia are at risk of compartment syndrome
- High-energy fractures of the tibia are often open (compound) since the anterior aspect of the tibia has very little soft-tissue coverage
- High-velocity tibial fractures are typically transverse or comminuted with the fibular fracture found at the same level
- Low-velocity tibial fractures typically are oblique or spiral with the fibular fracture occurring at a different level
- The tibia carries about 90% of the load when walking; the fibula about 10% – as such fibular fractures tend to be more clinically occult
- Isolated fibular fractures (above the level of the ankle syndesmosis) that occur in the absence of direct trauma should alert the clinician to the possibility of a more significant injury at the joint “above or below” (i.e., the knee or ankle)

- Fibular head dislocations are rare – and commonly missed – and should be part of the differential diagnosis for traumatic lateral knee pain

Clinical presentation

- Fractures of the tibia can be associated with high- or low-energy mechanisms
- High-energy mechanisms cause significantly more soft-tissue damage and are associated with complications
- Compartment syndrome can be seen in up to 10% of these cases, especially if the fracture is closed
- Findings of a compartment syndrome may be delayed 12–24 hours after injury
- Pain out of proportion to what is expected and pain on passive stretching of the muscles are early signs of a compartment syndrome
- Passive toe flexion/ankle plantar-flexion tests the anterior compartment
- Passive toe extension/ankle dorsiflexion tests the posterior compartment
- Isolated fibular fractures can occur with direct trauma
- Common peroneal nerve palsies can accompany proximal fibular fractures – check for a “drop foot”
- All fibular fractures (especially spiral fractures) above the level of the syndesmosis should prompt assessment of the medial malleolus
- If tenderness or swelling is noted at the medial malleolus, then the injury may represent an external rotation, “Maisonneuve-type” fracture and the injury is often operative
- Proximal fibular fractures should also prompt careful assessment of the lateral knee structures including the LCL and the PCL
- Fibular head dislocations – mechanism of injury is usually a forceful twist with the knee flexed and the ankle internally rotated and plantar-flexed
- Fibular head usually dislocates anterolaterally
- Acutely the patients have pain, swelling, difficulty weight-bearing
- If missed and the patient develops a chronic subluxation/dislocation, then symptoms may be of lateral knee pain with clicking or locking
- Check for common peroneal nerve palsy

PEARL: Pain out of proportion to what is expected and pain with passive stretching of the ankle/toes are useful tests when considering compartment syndrome of the lower leg.

PEARL: All fibular fractures above the level of the syndesmosis should prompt assessment of the medial malleolus – looking for an occult Maisonneuve-type fracture.

Diagnostic testing

- Plain radiographs – usually two views of the tibia and fibula are sufficient. If there is concern specifically around the ankle or knee, then those joints should be imaged separately (Figures 4.13, 4.14, 4.15)

Figure 4.13 A high-energy fracture of the tibia: Comminuted, transverse, with a fibular fracture at the same level. (Image courtesy of Arun Sayal, MD.)

Figure 4.14 A low-energy fracture of the tibia: A spiral fracture with the fibular fracture at a level remote (proximal) from the tibial fracture. (Image courtesy of Arun Sayal, MD.)

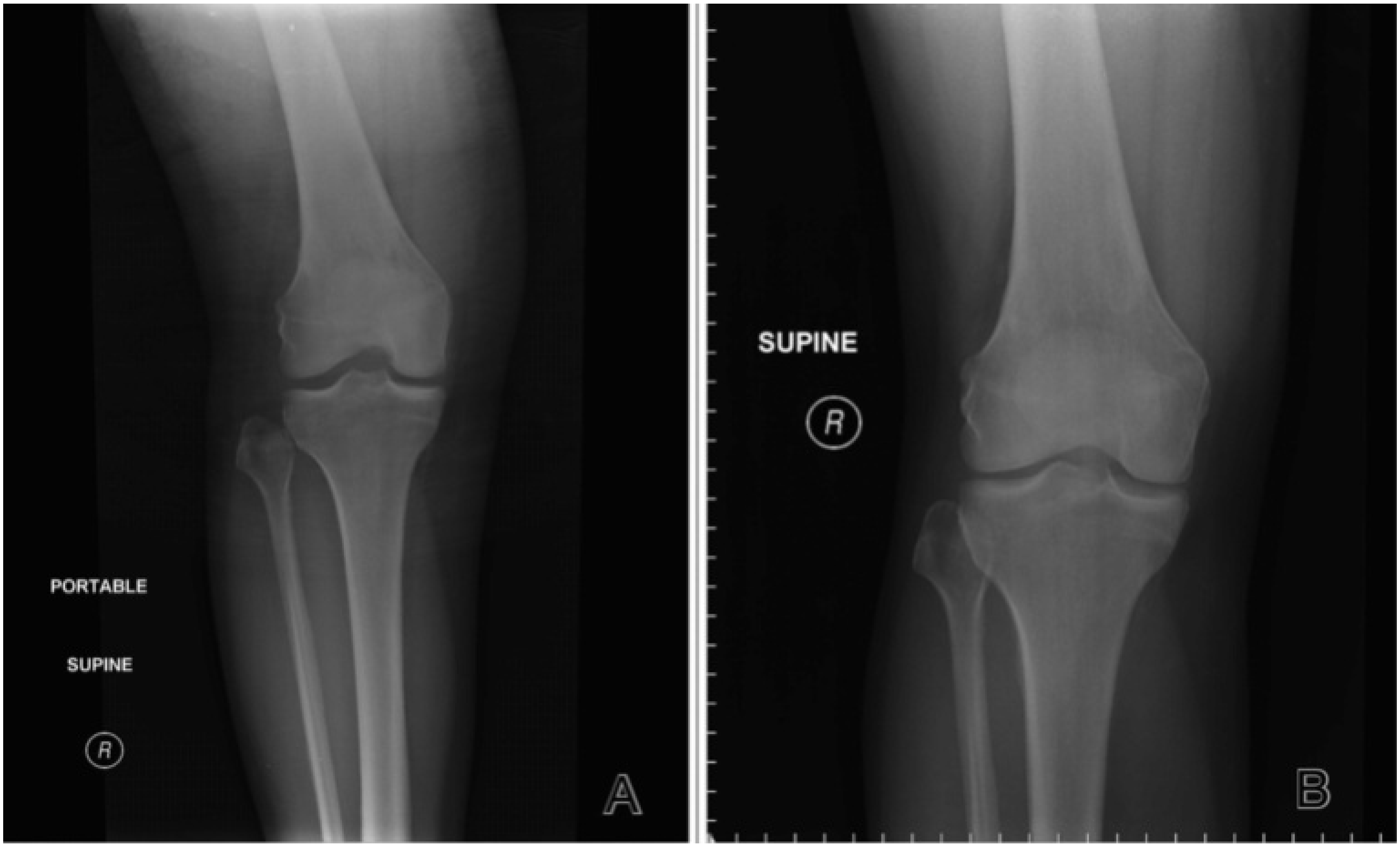


Figure 4.15 A: Lateral fibular head dislocation. B: Post-reduction showing the normal overlap of the fibular head and lateral aspect of the proximal tibia. (Images courtesy of Dr. Russel Segal.)

Treatment

- Fractures of the tibia often are treated operatively; the decision to treat non-operatively should be made by orthopedics
- If concern for compartment syndrome exists, then compartment pressures should be measured and if confirmed, immediate fasciotomies are indicated
- Significantly displaced fractures will swell significantly and can cause pain, secondary open fractures, and/or compartment syndrome
- Significantly displaced fractures of the tibia should, after appropriate sedation, be reduced in the ED with gentle in-line traction, repositioning, and immobilization
- ED immobilization for fractures that involve the proximal or middle third of the tibia requires a posterior slab splint

PEARL: Immobilizing a mid-tibia fracture in the ED can be challenging.

- Some helpful tips:
    - It is often easier to apply the above-knee splint in two stages
    - First stage – a standard posterior slab for the lower leg (with a supporting "U-slab" along the sides):
        - Second stage – once the splint begins to harden, the patient's heel can be placed on the bed with the knee flexed ~30°, and the splint can be extended above knee – (with supporting splints on the medial and lateral sides of the knee)

    - Use gravity to assist in obtaining and maintaining the alignment – have the patient with their knee at the edge of the bed, and lower leg hanging down during the first stage of the splint application. For patients who are sedated, they can be shifted toward the end of the bed to allow the lower leg to drop down
  - Isolated mid-fibular fractures from direct trauma (with no associated ankle or knee pathology) are usually stable since only 10% of the weight-bearing load is carried by the fibula; these patients can weight-bear as tolerated. Some may need immobilization and crutches
  - Follow-up should be arranged with orthopedics within a week
  - For fibular head dislocations, reduction may be attempted under sedation
  - With the knee flexed ~90°, reverse the mechanism that caused the dislocation – i.e., place the ankle in external rotation and dorsiflexion
  - Recheck imaging and neurovascular status post reduction; if reduced and no deficits, the joint can be immobilized and ensure close orthopedic follow-up

Prognosis

- Mid-tibial fractures can be complicated by: Infection, non-union (especially in smokers), malunion, DVT, and knee and ankle stiffness
- Operative treatment options include external fixation, intramedullary (IM) nails, and ORIF with plates
- Patients treated with operative management can weight-bear sooner and have better rates of union
- Isolated fibular fractures heal very well non-operatively. The clinician must ensure that no associated injury has occurred at the knee or ankle; if a significant knee or ankle injury is missed, then potential for long-term impairment exists
- Fibular head dislocations often heal with conservative treatment; if symptoms persist with conservative treatment, then operative management may be indicated

Quadriceps tendon rupture/patellar tendon rupture

Key facts

- Ruptures of the quadriceps tendon are two to three times more common than patellar tendon ruptures
- Both injuries are missed up to 20% of the time by the initial treatment provider
- Under the age of the 40, the problem tends to be under the patella (patellar tendon rupture)
- Over the age of 40, the problem tends to be over the patella (quadriceps tendon rupture)
- Delayed diagnosis (and delayed surgical repair) adversely affect long-term results
- An active straight leg raise is an important part of every knee examination to help rule out a rupture of the extensor mechanism – but it is not 100% sensitive

PEARL: A straight leg raise is an important assessment of the quadriceps tendon but it is not 100% sensitive in isolating a rupture of the tendon.

Clinical presentation

- Patellar tendon rupture
  - Typically under the age of 40
  - Often presents with sudden, anterior knee pain after a sudden quadriceps contraction with a flexed knee
  - Patients may report feeling a "'pop"
  - Most have difficulty with weight-bearing
  - Patients with rheumatic disease, chronic patellofemoral symptoms, or chronic steroid use (anabolic or corticosteroids) are at increased risk
  - A palpable defect may be felt just below the patella
  - Patients will often have anterior knee pain and swelling with or without bruising
  - Patella is often high-riding (patella alta) and hypermobile (Figure 4.16)
  - Inability to actively straight leg raise (i.e., lift the heel off the bed)
- Quadriceps tendon rupture
  - Typically over the age of 40
  - Often lower-velocity mechanism than seen with patellar tendon ruptures – a minor fall or feeling of knee giving way
  - There is often a variable amount of pain and gait disturbance
  - Increased risk of rupture if obese, systemic illness, or chronic steroid use
  - A palpable defect may be felt just above the patella, but this is less reliable in obese patients
  - The patella is often low-lying (patella baja) and hypermobile
  - Incomplete ruptures may be able to actively straight leg raise when lying, but not to extend the knee when sitting
- Patella *baja* and patella *alta* can be normal variants – important to compare clinically to the opposite side

PEARL: An active straight leg raise is an important part of every knee examination.

Figure 4.16 A: Patella alta in an 11- year-old male caused by a patellar tendon rupture; the ratio of patellar tendon length to length of patella should be < 1.2. B: In this case it is > 2. (Images courtesy of Arun Sayal, MD.)

Diagnostic testing

- Plain radiographs may show abnormal patellar positioning
- The Insall–Salvati index examines the ratio of patellar tendon length to length of patella
- Normal range is 0.8–1.2
    - A ratio of < 0.8 represents a low lying patella (patella baja) and can sometimes be seen with quadriceps tendon rupture
- A ratio of > 1.2 represents a high-lying patella (patella alta) and can sometimes be seen with patellar tendon rupture
- Occasionally avulsions of the patella poles can suggest extensor rupture (superior pole avulsion for quads rupture; inferior pole avulsion for patellar tendon ruptures)

Treatment

- Complete ruptures of the extensor mechanism require operative management
- Should be discussed with orthopedics while in the ED to plan early operative repair
- Incomplete tears are less common; should be immobilized and closely followed by orthopedics

Prognosis

- Operative cases are protected for about 6 weeks followed by more active rehabilitation
- Return to baseline activities is generally anticipated
- Delayed diagnosis (and delayed repair) are associated with adverse outcomes

- For missed injuries, pain may subside and patients may be left with vague anterior knee pain, difficulty with gait (the swing-through phase), and quadriceps atrophy

Patellar dislocations

Key facts

- First-time patellar dislocations involve more acute ligament damage than recurrent patellar dislocations
- Primary dislocations will have more pain and swelling on the medial side of the patella
- ~5% of primary patellar dislocations have an associated osteochondral fracture
- The osteochondral fragment can occur during the dislocation or the reduction; the source of the fracture can be the lateral femoral condyle or the undersurface of the patella
- Primary patellar dislocations are treated with immobilization and rehabilitation (unless an osteochondral lesion is present)

Clinical presentation

- More common in younger patients – teens to late 20s
- Mechanism is usually a non-contact knee twist – hyperextended knee with externally rotated foot
- When seen in the ED, patients may have dislocated (or subluxed) and spontaneously reduced
- Patients may state that their "knee slipped out" – but careful questioning can often confirm patellar shift and relocation
- If patella is dislocated, it almost always dislocates laterally
- If spontaneously reduced prior to arrival in the ED, the diagnosis is based on a combination of history (age, mechanism, sense of patella slipping, etc.) and physical (tender, swollen medial side patella, with a positive apprehension sign)
    - Apprehension sign
    - Examiner gently displaces the patella laterally and a positive sign is noted if there is a quadriceps contraction or facial grimace noted
- Primary dislocations involve an acute injury to the medial patellofemoral ligament. Therefore, first time dislocations are more likely to have medial patellar pain and swelling, along with a positive apprehension sign
- With recurrent dislocations, a positive apprehension sign is noted, and often there is less pain and swelling medially since there is less acute ligament damage
- If a hemarthrosis is found (large effusion within an hour or two of injury), diagnostic consideration should be given to an associated osteochondral fracture or, less commonly, a concomitant ACL tear

Diagnostic testing (Figure 4.17 A, B)

- Plain radiographs – will show lateral displacement of the patella, but usually the diagnosis is clinically apparent and pre-reduction films are typically not necessary
- Successful anatomic reduction is also clinically apparent

- Post-reduction films (including obliques and "sunrise" views) may reveal an osteochondral fragment
- Some osteochondral fragments can be radiographically occult
- Purely chondral lesions (e.g., cartilage only with no bony fragment) will not be seen on plain radiographs but will present as a loose body in the future as the patient ambulates (intermittent sharp pain and locking)

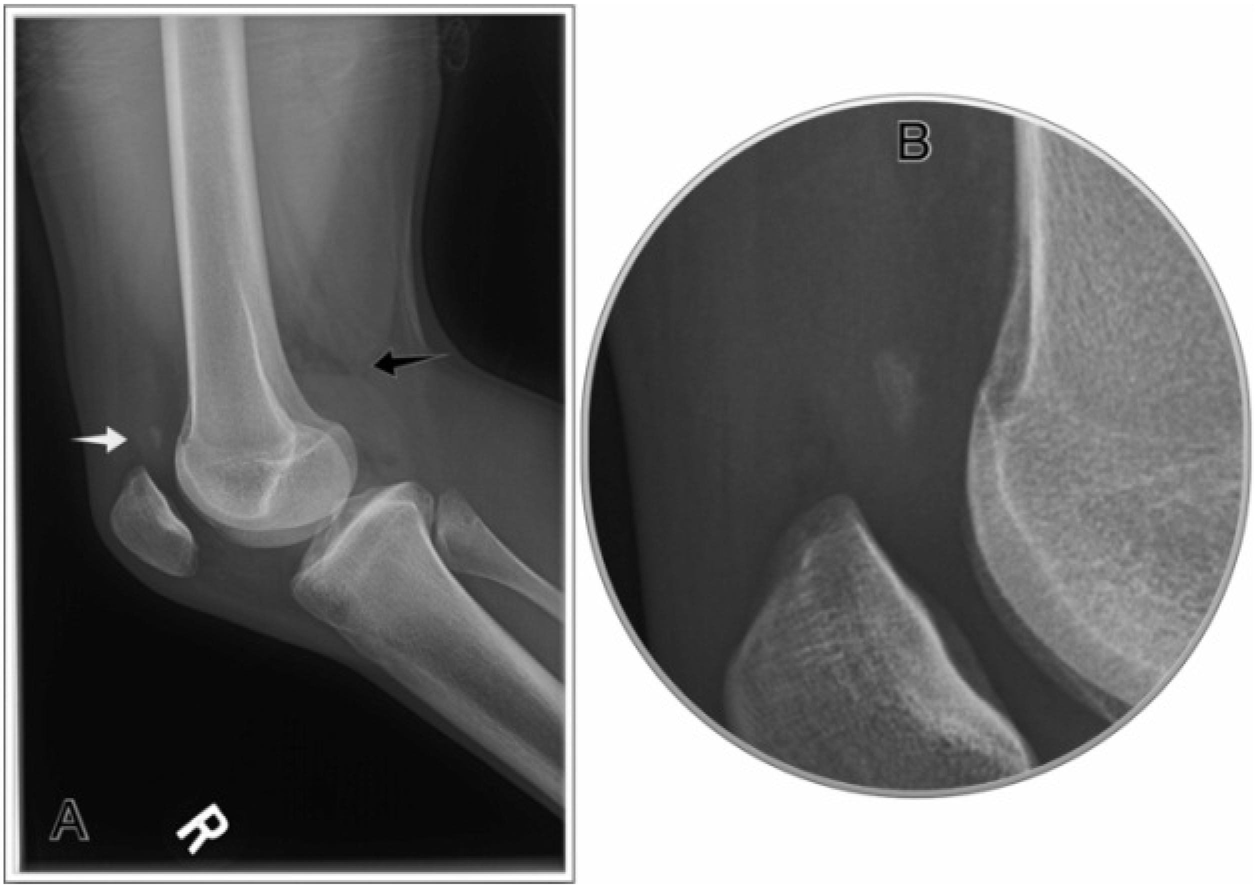


Figure 4.17 A: Patellar dislocation post-reduction shows an osteochondral fragment (white arrow) seen just above and posterior to the patella. Enlarged in B. Also seen is a lipohemarthrosis (black arrow) behind the femur, indicating the presence of a fracture. (Image courtesy of Arun Sayal, MD.)

Treatment

PEARL: Quadriceps relaxation is one of the keys to reducing a patellar dislocation. Encourage quadriceps relaxation by flexing the hip and slowly extending the knee. (Rectus femoris originates above the hip, so hip flexion helps with quadriceps relaxation.) Then apply posterior-directed pressure on the lateral aspect of the patella (to tilt the medial side of the patella over the lateral femoral condyle), followed by gentle medial-directed pressure to reduce.

- Whether reduced spontaneously or actively, primary patellar dislocations should be immobilized in extension and close follow-up should be arranged
- Ideally, patients can be placed in a patellar stabilizing brace that allows knee flexion and maintains patellar alignment (such braces are not available in most EDs)
- Recurrent patellar dislocations are less in need of immobilization (since there is little acute ligament injury to heal); such patients should be referred to orthopedics as out-patients for assessment of possible operative correction

Prognosis

- Most patients with patellar dislocations can be managed non-operatively with a focus on rehabilitation (particularly strengthening vastus medialis to help the patella track more medially)
- If an osteochondral injury occurs, these patients need orthopedic referral for arthroscopy – either removal or reduction/fixation depending on the size and donor site of the fragment
- Recurrent patellar dislocations are seen in ~25% of cases

Patellar fractures

Key facts

- Usually from a direct force to the front of the knee (e.g., fall or dashboard injury)
- Integrity of the extensor mechanism is of paramount importance in deciding operative versus non-operative management
- The patella is the largest sesamoid bone in the body
- A bipartite patella can mimic a fracture, but is a normal variant

Clinical presentation

- Usual mechanism of injury is a direct blow to patella – fall directly on to anterior knee or dashboard injury
- Indirect trauma from a forceful contraction can cause avulsions of the proximal pole (at the quads tendon insertion) or the distal pole (at the patellar tendon origin) – these injuries are covered under quadriceps/patella tendon rupture)
- Pain and swelling localized to the anterior aspect of the knee
- Difficulty weight-bearing
- Active straight leg raise is required to assess integrity of the extensor mechanism
- Pain may inhibit ability to lift heel off bed – patients often need to be encouraged to push through the pain to assess properly the quadriceps tendon function

PEARL: An active straight leg raise is required to assess integrity of the extensor mechanism – encourage the patient to push past the pain as it may save an operation!

Diagnostic testing

- Plain radiographs (Figures 4.18, 4.19, 4.20 A,B, C) – will often demonstrate the fracture. Consider adding a "skyline" or "sunrise" patellar view to better assess for alignment and subtle vertical fractures. Various fracture patterns are possible – vertical, horizontal, stellate
- Bipartite patella is a variation of normal (incidence ~2–5%); when present, it is usually on the superolateral quadrant of the patella – a curved lucency that can be mistaken for a fracture (should clinically correlate to rule out a fracture)

Figure 4.18 A bipartite patella; if present it is usually found in the superolateral quadrant of the patella – this is a normal variation. (Image courtesy of Arun Sayal, MD.)

Figure 4.19 Non-displaced transverse patellar fracture (with a fabella noted posteriorly, a variation of normal). (Image courtesy of Arun Sayal, MD.)

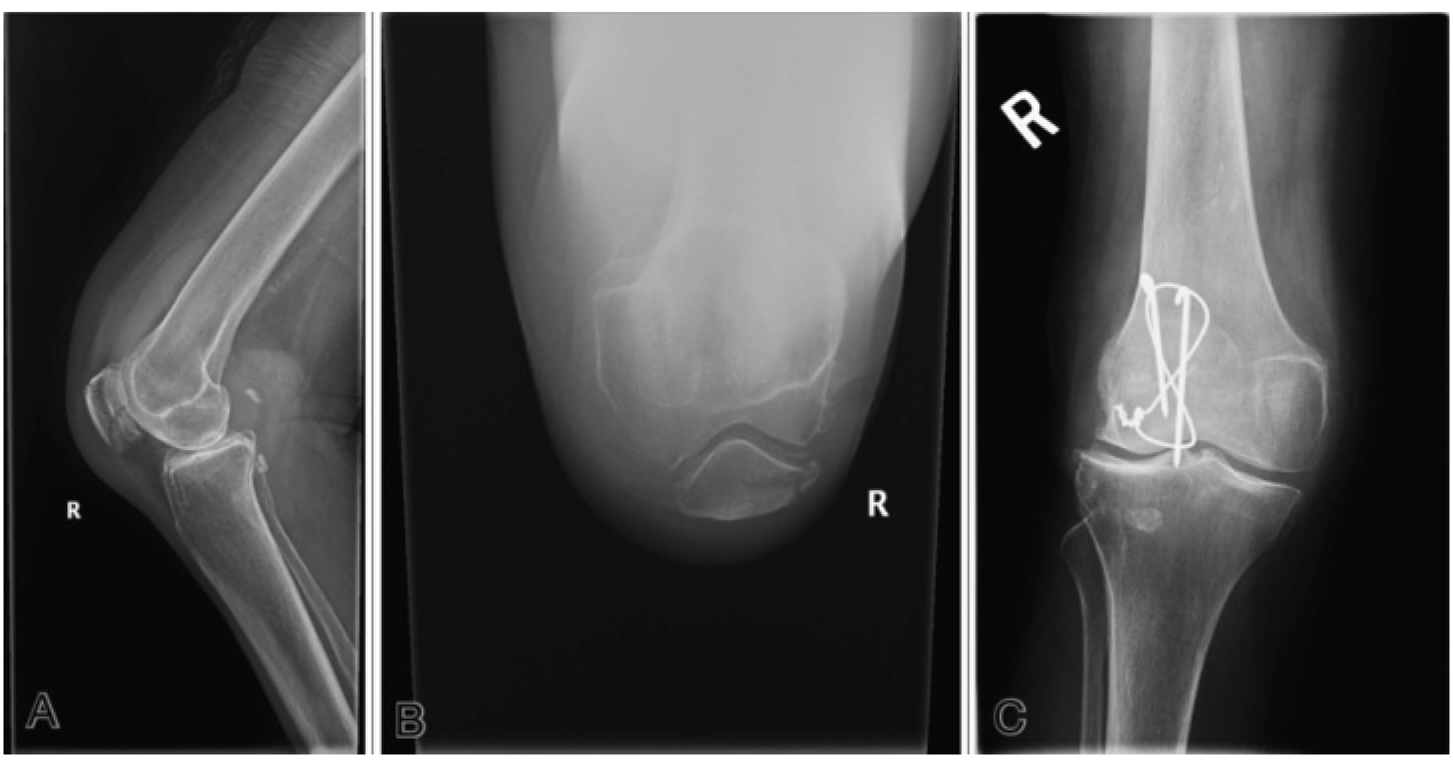


Figure 4.20 A: A comminuted fracture of the patella. B: A "sunrise" or "skyline" view of the same fracture – shows comminution. C: The patient did not have an intact extensor mechanism, so was treated operatively with internal fixation by tension band wiring. (Images courtesy of Arun Sayal, MD.)

Treatment

- If the extensor mechanism is intact, then non-operative treatment with immobilization in extension and orthopedic follow-up within a few days is appropriate
- Immobilization can either be a well-fitted commercial knee immobilizer or a Jones bandage (posterior splint from malleoli to upper third of the femur, which keeps the knee extended)
- Weight-bearing is allowed for cases to be managed non-operatively
- If the extensor mechanism is disrupted, then early operative management is indicated and these patients should be discussed with orthopedics while in the ED

Prognosis

- Non-operative cases are followed closely and gentle ROM exercises can usually begin at 3 weeks
- Both operative and non-operative cases can develop stiffness and quadriceps weakness that often require rehabilitation
- Operative cases can also develop infection, irritation from the hardware, and avascular necrosis of fracture fragments
- If the fracture fragments are not anatomically aligned, then premature osteoarthritis can develop in the patellofemoral compartment over subsequent years

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www.orthobullets.com. Similar to below in that it is by orthopedic surgeons for orthopedic surgeons. It is more succinct but has fewer references.

www.WheelessOnline.com. From Duke University Medical Center's Division of Orthopedic Surgery, a comprehensive review for orthopedic surgeons. A little light on the actual ED treatment (it is intended for orthopedic surgeons), but reasonably good imaging examples, and explanations of operative indications are well covered.

Chapter 5 Foot and ankle emergencies

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Achilles tendon injuries

Presentation

- Achilles injuries often present as a sudden onset of pain in the posterior aspect of the ankle, without direct trauma
- The typical patient is male, 30–40 years old who has begun new activities such as jumping sports, known colloquially as a "Weekend Warrior"
- Often patients can ambulate, but with poor balance and with pain

Physiology

- The rupture typically occurs 2 to 5 cm proximal to the insertion of the Achilles within the calcaneus. This is the "watershed zone" of diminished vascularity
- These injuries have been associated with recent fluoroquinolone use

PEARL: Have a high index of suspicion for an Achilles tendon injury in patients complaining of ankle pain without direct or commensurate trauma.

Diagnostic work-up

- The physical examination is the key to diagnosis
- The patient will often maintain the ability to plantar flex their ankle because of the continuity of the flexor hallux longus and the flexor digitorum longus
- There will often be weakness of plantar-flexion and tenderness with resisted plantar-flexion
- Palpation in the posterior aspect of the ankle and Achilles may reveal a palpable gap
- Ecchymosis and swelling in this area is common
- Positive Thompson test
  - Lie the patient prone on the examination table with shoes and socks removed from both feet
  - With the knee bent to 90° on the uninvolved extremity, the ankle should have a resting plantar-flexion posture
  - When the calf is squeezed, the ankle will plantar flex
  - On the side with an Achilles tendon rupture, the ankle will stay bent essentially to 90° when the knee is bent. In addition, when the calf is squeezed, the ankle will not move
  - This failure of the ankle to move when the calf is squeezed is what constitutes a positive Thompson test

- Plain radiographs of the foot or ankle are necessary to ensure there is not an avulsion fracture of the calcaneus

PEARL: Diagnosis of an Achilles tendon injury is best made by physical examination, and the gold standard test for confirmation is the Thompson test.

Treatment

- Place the patient in a posterior slab splint with the ankle in resting plantar-flexion
- A “CAM” boot with 15° of plantar-flexion can also be used if available
- Crutches and non-weight-bearing status are required

Prognosis

- The long-term outcome of Achilles ruptures is quite good
- Historically, patients were operatively repaired within 1 to 2 weeks. However, newer literature indicates equally good outcomes in eligible patients who undergo non-operative treatment with progressive casting and functional rehabilitation
- In general, patients are able to return to sporting activities in 4–6 months after an Achilles rupture

Ankle fractures and dislocations

Presentation

- Ankle fractures can have a variety of histories, from a simple twist and fall to a violent motor vehicle collision
- For most ankle fractures, patients present with the inability to weight-bear
- They will often complain of pain over the medial or lateral malleolus

Physiology

- Ankle fractures can be the result of rotational injuries or of axial loads
- In a rotational injury, often the injury will be the result of an inversion or eversion stress to the ankle
- During an inversion event, the injury will often start over the distal tip of the fibula (the lateral malleolus), and progress in a circular fashion to the posterior aspect of the ankle (posterior malleolus) and then to the medial distal portion of the ankle (medial malleolus) or deltoid ligament (Figure 5.1 A, B, C)
- Similarly, an eversion event will often start with an injury over the medial malleolus or deltoid ligament, then progress to the posterior malleolus and then the lateral malleolus
- Conversely, a pilon fracture results from an axial load being placed upon the foot. This can occur either from a sudden deceleration (fall from height) or from a direct impact (head on motor vehicle collison). The talus is essentially forced into the distal tibial plafond, resulting in

a fracture of the entire distal tibia

Figure 5.1 PA (A), oblique (B), and lateral (C) views of a trimalleolar fracture This is a very unstable injury that will require operative repair. The fibula has a Weber C fracture. (Image courtesy of Michael Abraham, MD.)

Diagnostic evaluation (Figures 5.2A, B and 5.3)

- Obtain plain radiographs of the joint
  - These should include PA, lateral, and mortise views
    - The mortise view is an AP view with the ankle internally rotated approximately 20° such that the medial and lateral malleolus are in the same frontal plane
- Especially in cases of fractures with dislocation, the diagnosis is often immediately evident
- The physical examination should focus on skin breaks, motor function, and vascular status
- The vascular examination is important on the initial evaluation but even more important after reduction of any dislocation or manipulation
- Similarly, sensation to light touch often can improve after the reduction of a fracture

PEARL: Beware of isolated fractures of the medial malleolus. This may indicate a rotational-type injury where the energy of the fracture travels up the syndesmosis (before exiting the proximal fibula); a Maisonneuve fracture. Isolated fractures of the medial malleolus should also be evaluated with plain radiographs of the tibia/fibula to exclude this injury.

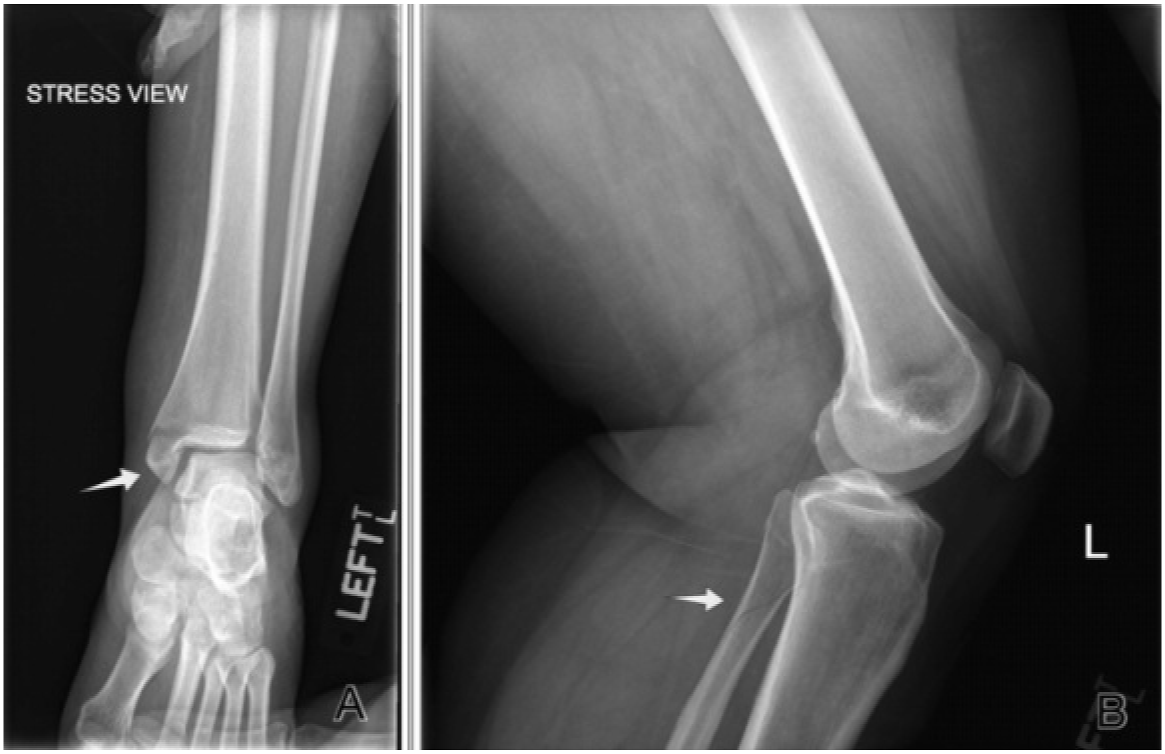

Figure 5.2 Images show a Maisonneuve fracture pattern of a distal tibial fracture (A) and a proximal fibular fracture (B). Distal tibial injuries always require evaluation of the fibular head to rule out this type of injury. (Images courtesy of Michael Abraham, MD.)

Figure 5.3 Fracture and dislocation of the ankle. Notice the lateral dislocation of the tibia on the talus and the complete disruption of the ankle mortise. (Image courtesy of Michael Abraham, MD.)

Treatment

- In cases of open fractures, an orthopedic consult is emergent
    - The wound should be irrigated and dressed by the ED provider to help reduce the risk of infection
    - Consider starting antibiotics (i.e., cefazolin) to reduce the risk of infection
- Dislocation of an ankle fracture should be promptly managed. Often the talus will sublux or dislocate laterally, which compromises the integrity of the skin medially. The goal of the reduction is to get the talus to sit under the distal tibia (ankle mortise) and to relieve pressure over the skin
- Reduction can be accomplished with procedural sedation, intra-articular injection of a local anesthetic (without epinephrine), or with a forceful and longitudinal traction of quick duration
- In cases of intra-articular injection, there is often a large space just medial to the talus, assuming a lateral dislocation of the talus within the ankle mortise
    - The surface landmark is the tibialis anterior tendon

    - The injection can be done just medial to this landmark
    - A soft spot is often palpable to help guide the proper area to start
- To reduce the fracture:
    - Over-exaggerate the fracture
        - In cases of a lateral dislocation, this would involve tipping the ankle into greater valgus after shifting the ankle laterally
        - Having the knee flexed is often helpful as this will help relax the gastrocnemius muscle
    - Apply longitudinal traction and restore the bone to its normal position
    - An assistant can hold counter-traction to the proximal tibia or distal femur
- Post reduction, immobilize the joint
    - A fracture–dislocation should be placed in a **posterior split** plus a **stirrup splint** for medial and lateral stability
        - This combination prevents dorsiflexion, plantar flexion, inversion, and eversion
    - A **stable fracture** should be placed in a simple **posterior splint**
    - Distal fibular fractures (Weber A) can be immobilized with a posterior splint or CAM walking boot and most are immediately weight-bearing as tolerated by the patient
- Post-reduction radiographs are a necessity to ensure the ankle is reduced and aligned properly
- Fibular fractures above the malleolus (Weber B and C) will require operative repair
- Discharge instructions should include elevation, ice, and non-weight-bearing status

Prognosis

- The outcome of ankle fractures is as varied as the presentations, and depends on both the amount of energy involved and the presence of any associated soft-tissue injuries
- Some fractures require surgical intervention with open reduction and internal fixation, while other fractures are treated conservatively with splinting and casting
- In general, ankle fractures that require surgical intervention require 6–12 weeks of non-weight-bearing

Hind foot and mid-foot injuries

Presentation

- Injuries in this group entail a variety of injuries, including:
    - Calcaneus fractures
        - Result from axial load injuries, similar to ankle pilon fractures
        - With any axial load injury, it is important to evaluate for injuries at the knee, hip, pelvis, and lumbar spine
        - Patients will be unable to bear weight on the heel
    - Talus fractures (Figure 5.4)
        - Result from an axial load with forced dorsiflexion of the ankle
        - These are often the result of high-energy trauma and must be recognized promptly for optimal management because of the tenuous blood supply of the talar neck

            - Avascular necrosis of the talus is a common long-term complication even if properly managed
    - Lisfranc injuries
        - The result of an axial load placed on to the heel of a foot that is plantar flexed
        - A common example is a football player whose toes are planted into the ground but whose heel is off the ground. Often another player rolls on to the heel, causing an injury to the Lisfranc joint
        - The Lisfranc joint is located between the cuneiforms and the first and second metatarsal bases
            - The Lisfranc ligament connects the medial cuneiform with the base of the second metatarsal
        - This injury is often missed in the ED and failure to diagnose is one of the most common reasons for litigation later
    - Metatarsal injuries (Figure 5.5 A, B)
        - Commonly caused by inversion/eversion injuries or direct trauma
        - Fifth metatarsal fractures are the most common
            - Can be divided into avulsion or "pseudo Jones" and distal or "Jones" fractures
            - Jones fractures require more aggressive follow-up and management because of the increased risk of malunion, non-union, and avascular necrosis

PEARL: Prior to making the diagnosis of a "foot sprain" consider the diagnosis of a Lisfranc injury and disposition the patient accordingly. This injury is often missed in the ED and failure to diagnose is one of the most common reasons for litigation later.

Figure 5.4 Plain radiograph with arrow indicating a medial talus fracture. These injuries have a high rate of non-union and will need operative repair. (Image courtesy of Michael Abraham, MD.)

Figure 5.5 A: Image of a fifth metatarsal fracture in an 11-year- old. White arrow highlights the fracture. B: Same patient 1 month later after conservative treatment. (Images courtesy of Michael Abraham, MD.)

Diagnostic work-up

- Physical examination should include a neurovascular assessment as well as documentation of any breaks in the skin
- Any injury which involves an axial load pattern of injury should prompt evaluation of the ipsilateral knee, hip, pelvis, and lumbar spine
- Obtain plain radiographs of the foot. AP, oblique, and lateral films are standard
  - In cases of a calcaneus fracture, a Harris axial view should also be obtained
  - When evaluating for a Lisfranc injury, a fleck sign can be seen at the medial base of the second metatarsal
    - This is a small piece of bone pulled off by the stout Lisfranc ligament and should alert the practitioner to the possibility of a more serious injury
  - Weight-bearing radiographs are helpful in suspected Lisfranc injuries
    - However, they may be hard to obtain in the acute setting because of patient discomfort
  - A CT is useful to further delineate the extent of talus and calcaneus fractures, and in cases where the plain films may not be diagnostic but the index of suspicion is high

Treatment

- Immobilization and non-weight-bearing with a prompt referral to orthopedics is the mainstay of treatment
- Calcaneus fractures

  - Require a soft bulky dressing with or without a posterior slab splint
  - Traditionally, surgery was delayed 10–20 days to allow for swelling to resolve. However, surgeons are often now choosing to treat these fractures within 24–48 hours, before the swelling reaches maximum
  - Urgent orthopedic consultation or follow-up
- Talus fractures
  - Displaced fractures of the talar neck require urgent fixation, usually within 24 hours
  - Posterior splinting with ice and elevation are necessary to stabilize the joint prior to surgery
  - Emergent orthopedic consultation in the ED
- Lisfranc injury
  - Recognition of the Lisfranc injury and distinguishing it from a simple "foot sprain" is the key to treatment
  - Immobilize in a posterior splint
  - Urgent orthopedic consultation or follow-up
- Metatarsal fractures
  - Proximal avulsion injuries of the fifth metatarsal can be treated with a hard-soled shoe and weight-bearing as tolerated
- Jones fractures
  - Place in a posterior splint with strict non-weight-bearing
  - Urgent orthopedic consultation or follow-up as these patients often require ORIF

PEARL: Talar fractures will often require operative repair in 24 hours. Admission and frequent neurovascular checks are warranted.

Prognosis

- The prognosis for fractures of the talus and calcaneus is more guarded than for ankle fractures. Often patients require surgical intervention to restore the normal anatomy, but this often will only delay the onset of post-traumatic arthritis
- Non-weight-bearing status for 4–12 weeks can be expected
- Patients should be informed that a complete return to pre-injury function is not expected with calcaneus and talus injuries
- Lisfranc injuries are the exception. With prompt recognition and anatomic restoration of the tarsometatarsal complex, return to pre-injury status and sports can often be accomplished

Foreign bodies

Presentation

- A common complaint
- Often patients are barefoot at the time of injury, though it is common for foreign bodies to puncture through a shoe
- Patients often make attempts at removal, but are unable to remove all of the foreign body

Diagnostic evaluation

- Obtain a thorough history
    - Ask what the foreign body is (e.g., glass, wood, metal)
    - Document whether the patient was wearing footwear and what type
    - Document the patient's tetanus immunization status
- Complete a physical examination of the area
    - Document the entrance wound, including its size, color, any odor, and whether a foreign body can be visualized
    - Note the location of any loss of sensation or range of motion
- Plain radiographs are helpful if the foreign body is radiopaque (e.g., metal, some plastics, and glass), but should be ordered on all patients
    - This helps exclude radiopaque foreign bodies as well as evaluate for any subcutaneous air
    - It is helpful to place two or three radiographic markers, or pellets, on the surface of the skin prior to obtaining the radiographs. By noting the location of the pellets on two orthogonal radiographs, the radiographs can then help to triangulate the foreign body removal
- Ultrasound is also helpful in confirming the presence of radiolucent foreign bodies
    - Ultrasound can document the location and depth of the body
    - When possible, a marker should be on the skin after the ultrasound is complete to note the location and depth of the retained foreign body

PEARL: Ultrasound is helpful for identifying a foreign body but also for removal using real-time visualization.

Treatment

- Irrigation of the wound
    - This is often sufficient for foreign-body removal
    - Consider using a local anesthetic to improve patient comfort
- In cases of fresh wounds and foreign bodies, the tract made by the foreign body is the only one present
    - After irrigation with a blunt-tipped needle, exploration with a hemostat may be all that is necessary
- In cases where the wound is several days old, the tract may already have partially healed, and "blind removal" is more difficult
    - After irrigation, a referral to orthopedics for removal with the aid of fluoroscopy is often necessary
- Tetanus status should always be verified, and updated as needed
- Antibiotics are given as needed
- Diabetic patients and patients where the injury occurred through a rubber-soled shoe should be treated prophylactically with a fluoroquinolone

Prognosis

- The prognosis for foreign bodies is usually good, but can depend on what other structures are

injured
- In diabetic patients, especially those with peripheral neuropathy, a foreign body can lead to osteomyelitis and chronic infections that may ultimately result in an amputation

Infections

Presentation

- Foot and ankle infections can vary widely in their presentation and clinical significance
- Onychocryptosis, ingrown toenails, tinea pedis, and athlete's foot sit at one end of the clinical spectrum whose course is benign, while abscess and diabetic foot infection represent more serious infectious processes

Diagnostic work-up

- The evaluation of a foot infection will vary based upon the suspected underlying clinical diagnosis
- Inquire and document any chronic medical conditions. Diabetes should be specifically asked about
    - Elevated blood sugars without any other change in a patient's routine could indicate an indolent infection
- Examination should note:
    - The overall appearance and warmth of the foot as well as any areas of fluctuance
    - Distal pulses and light touch sensation is important
    - Erythema should be outlined with a marking pen
- Notation should also be made of any breaks in the skin, especially between the toes

PEARL: Diabetics presenting to the ED with a red hot swollen foot but without any breaks in the skin may represent an acute Charcot arthropathy not an infection. To help differentiate the two, elevate the affected extremity while the patient is lying on their back. If the patient has cellulitis or an infectious process, the erythema will be unchanged. However, if the redness improves, this may represent a Charcot arthropathy.

- For patients with more severe presentations obtain laboratory studies
    - CBC, ESR, CRP, HgbA1c, and blood cultures
- Plain radiographs of the foot and ankle will help evaluate for osteomyelitis, fractures, foreign bodies, and Charcot arthropathy
- CT or MRI are both helpful in the evaluation of abscess
- MRI is more specific for osteomyelitis, but rarely required in the ED evaluation

Treatment

- Ingrown toenails:
    - Placement of a cotton wisp under the painful edge of the nail allows the nail to continue to

grow without piercing the dermal edge
    - If the nail is recalcitrant to conservative therapy, a referral to a podiatrist for digital block and partial nail excision is needed
- Tinea pedis:
    - Treated with over-the-counter anti-fungals
    - These medications should be used for 2–4 weeks, well past the resolution of symptoms
    - Coverage for *staph* and *strep* species may be necessary in chronic cases
- Abscesses:
    - Should be incised when superficial
    - Cultures of the purulent material will help guide future antibiotic treatment
    - Superficial swabs and cultures of chronic wounds are not helpful and should not be done
- Diabetic foot infections and acute osteomyelitis:
    - Often require a hospital admission for IV broad-spectrum antibiotics
    - Consult podiatry, orthopedics or your soft-tissue surgical service if there are areas that you feel would benefit from debridement

Prognosis

- Prognosis varies dependent upon the underlying diagnosis
    - Diabetic foot infections are the most common cause of below-knee amputations. Prompt diagnosis and treatment can help avoid this complication
    - Most infections heal well without long-term sequelae
    - Tinea infections are often chronic and frequently relapse

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Chapter 6 Spine emergencies

Kelley Banagan

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Acute spine injuries: Cervical, thoracic, and lumbar spine fractures and the spine-injured patient

Key facts

- The initial evaluation of spine injuries in a trauma patient is of obvious importance, as a missed injury can cause permanent and devastating neurologic injuries
- Spinal cord and spinal column injuries are typically seen in two age groups and with two different mechanisms. High-energy mechanisms in the younger patient population, and lower-energy mechanisms in older patients with ankylosed spines, or those at risk of fragility fractures
- Closed head injuries and facial trauma should prompt a work-up for a cervical spine injury, as it implies that the cervical spine was also subjected to a great deal of force
- If a single spinal fracture is identified, potential spinal injuries at other levels should be evaluated

Evaluation and management

- Protocols and systems to immobilize patients at the scene, protect the spine, and provide safe extrication and transport to the emergency department have increased survival in the spine-injured patient, and reduced the number of neurologic injuries
- Poor immobilization and handling of patients have been shown to result in further neurologic injury after the initial accident or insult
- Patient immobilization during transport should consist of a rigid cervical collar, lateral supports, and securing the patient to a backboard with tape and body supports
- Young children are the exception, owing to the fact that their heads are disproportionately larger than their bodies. They should not be positioned flat on a backboard as this can cause anterior translation and flexion of a cervical injury. In order to accommodate this anatomic variation the backboard needs to be equipped with an occipital recess or a mattress placed beneath the torso and backboard
- Patients with ankylosing spondylitis also require special attention be paid to positioning during transport. These patients often have a fixed kyphotic deformity of the spine. This posture should be respected and maintained during transport. The patient's head may need to be supported with several pillows
- Prolonged unnecessary immobilization can lead to increased morbidity in the form of pressure sores and other ailments; patients should be removed from the backboard in a timely fashion, and cervical collars should be removed as soon as a cervical injury is ruled out

Emergency evaluation: ABCDE

- **Airway**: The cervical spine must be maintained in a stable position while managing the airway in a trauma patient. In-line immobilization with the cervical spine in a neutral position during direct laryngoscopy and orotracheal intubation is the preferred method

PEARL: Manual in-line traction has fallen out of favor because of the potential of distracting a cervical spine injury, especially one at the occipitocervical junction. In-line immobilization is preferred, and should not consist of any traction being applied to the cervical spine.

- **Breathing**: Patients who experience a spinal cord injury at or above C3 typically require emergent intubation at the scene secondary to respiratory distress. Patients with signs of impeding respiratory failure should be pre-emptively intubated
- **Circulation**: Hypotension, if present, should be assumed to be a result of hemorrhagic shock, and a search for the source of bleeding should follow. Initial treatment involves aggressive fluid resuscitation and vasopressors, as needed

PEARL: Seat-belted patients who present with a thoracolumbar flexion distraction injury should be evaluated for intra-abdominal trauma, including a blunt aortic injury.

- **Neurogenic shock**: Classically presents with hypotension in the setting of bradycardia. It occurs in roughly 20% of patients with cervical spine trauma, and is the result of disruption of the sympathetic tone of the peripheral vasculature and the heart

PEARL: Neurogenic shock is classically seen in patients with spinal cord injury above T4.

- **Disability and exposure**: A log roll should be performed during the secondary survey. Tenderness, swelling, bruising or a step-off deformity may be signs of a spine injury. A digital rectal exam and assessment of the patients rectal tone is an essential part of the neurologic assessment and the general trauma evaluation

PEARL: Lower-extremity injuries such as calcaneal, pilon, or tibial plateau fractures that result from axial loading should prompt the physician to evaluate the spine for a thoracolumbar burst fracture.

Neurologic evaluation (Tables 6.1, 6.2, 6.3)

- In the acute setting the neurologic assessment is performed in accordance with the international standards for the Neurologic Classification of Spinal Cord Injury, formerly the ASIA (American Spinal Injury Association) standards
- Motor examination: Measures the strength of five upper and five lower-extremity myotomes on a grading scale of 0–5, established by the Medical Research Council
- Sensory examination: Performed by evaluating light touch and pinprick sensation in 28 dermatomes. Sensation is either absent, impaired or normal and scored 0, 1, 2 respectively
- Reflexes: in patients with spinal cord injuries reflexes are usually absent initially and the limbs are flaccid. Reflexes will become hyperreflexic later in the course of spinal cord injury

- A Babinski response, when pathologic, is associated with upper motor neuron dysfunction. The reflex is elicited by stroking the lateral plantar surface of the foot with a semi-sharp object. A pathologic response will be noted by extension of the great toe with flexion and spreading of the lateral toes
- A bulbocavernosus reflex is performed by tugging on the bladder catheter or stimulating the glans or clitoris and evaluating whether reflex anal contraction occurs
- Spinal shock: A temporary state of the acutely injured spinal cord marked by loss of reflex function below the level of the injury. This typically lasts from 24 to 48 hours, and the end is marked by the return of reflexes, including the bulbocavernosus reflex. Technically speaking the diagnosis of a complete spinal injury can not be made until spinal shock resolves

PEARL: If light touch or pinprick sensation is present in any form at S4–5, or if any anal sensation or contraction is present, the patient has an incomplete spinal cord injury.

- Sensory level: The most distal level with normal sensation to pinprick and light touch
- Motor level: The most distal level with intact innervation; below this level there are motor deficits

PEARL: The most distal muscle to have grade-3 strength or higher is considered to be fully innervated because of muscle polyinnervation.

Table 6.1 ***Universal terminology of a spinal cord injury: ASIA Impairment Scale (AIS).***

AIS level	Description
A	No motor or sensory function in the lowest sacral segments
B	Sensory sparing in the lowest sacral segments with no motor function
C	Preserved motor function below the neurologic level, with the majority of muscle groups a grade 2 or less
D	As above but with a muscle grade 3 or more
E	Normal motor and sensory function

ASIA impairment scale (AIS): The most widely accepted system for categorizing spinal cord injury patients.

Table 6.2 ***Muscle strength scoring system.***

Grade	Description
5	Muscle contracts normally against full resistance
4	Muscle strength is reduced, but muscle contraction can still move joint across resistance
3	Muscle strength is reduced so that the joint can only be moved against gravity with the examiner's resistance removed
2	Muscle can move only if the resistance of gravity is removed
1	Only a trace or flicker of movement is seen or felt in the muscle, or fasiculations are observed in the muscle
0	No movement is observed

Table 6.3 ***Vertebral level and muscle-group controlled.***

Vertebral level	Muscle-group controlled
C5	Elbow flexion
C6	Wrist extension
C7	Elbow extension
C8	Long-finger flexion
T1	Finger abductors
L2	Hip flexion
L3	Knee extension
L4	Ankle dorsiflexion
L5	Great- toe extension
S1	Ankle plantar flexion, voluntary anal contraction: present or absent

Initial radiographic evaluation in the spine trauma patient

- The NEXUS and Canadian C-spine rules are utilized to help the practitioner exclude a C-spine injury without the use of radiographs
- Asymptomatic patients with the following criteria do not require radiographs:
  - Fully awake, alert and co-operative
  - Involved in a low-energy trauma
  - Neurologically intact
  - No mid-line tenderness
  - Can actively rotate his/her head 45°
  - No distracting injuries

PEARL: Patients with neck pain, tenderness to palpation, and obtunded patients require radiographic evaluation. Patients with distracting injuries should be placed on spine precautions until their other injuries are addressed.

- At most institutions CT has replaced conventional radiographs as the imaging modality of choice for evaluating potential spine injuries
- MRI is the study of choice for evaluating ligamentous injuries, neural element trauma and compression, and disc herniations

PEARL: Not all abnormal findings on MRI are clinically significant; MRI has the tendency to "over-read" injury to the posterior ligamentous structures in the cervical and thoracolumbar spine.

- Both CT and MRI may be needed to clear the cervical spine in an obtunded patient

Special patient population: Ankylosing spondylitis and diffuse idiopathic skeletal hyperostosis (DISH)

- Recognizing patients with ankylosing spondylitis and DISH is of paramount importance when evaluating for a potential spine injury
- These patients can suffer fractures and devastating neurologic injuries as a result of even low-energy trauma
- This patient population can experience rapid neurologic deterioration if their fracture is not identified or if treatment of their fracture is delayed
- Typical guidelines for determination of spinal stability do not apply to this patient population, and deeming a fracture stable because there is no displacement is a grave error

PEARL: In patients with ankylosing spondylitis or DISH who present with neck or back pain the assumption should be made that they have suffered a fracture. Advanced imaging such as a CT or MRI is mandatory.

Emergency management of the spine-injured patient

- If an injury is identified, the spine must be protected until definitive management is provided (e.g., rigid cervical orthosis for patients with a cervical spine fracture and maintenance of spine precautions)
- If a patient has an occipitocervical dissociation, immediate application of a halo is recommended given the highly unstable nature of the injury
- The administration of high-dose steroids in patients with an acute spinal cord injury is controversial and is not the standard of care
- Management of blood pressure has been recognized as a neuroprotective strategy, and protocols that aim to keep mean arterial blood pressure above 85 to 90 mm Hg for 5–7 days with aggressive volume resuscitation and vasopressors have shown improved neurologic outcomes

PEARL: Hypotension should be avoided in the patient with an acute spinal cord injury.

Cauda equina syndrome

Key facts

- Cauda equina syndrome is most often caused by a central disc herniation
- Usually presents as perineal sensory loss with urologic dysfunction in the setting of back pain and bilateral sciatica
- Younger patients are typically affected
- Emergency decompression is typically regarded as the treatment of choice

Symptoms

- Urinary retention followed by overflow incontinence, that is generally painless
- Decreased anal sphincter tone or fecal incontinence
- Saddle anesthesia, including the inability to feel urethral or vaginal sensation
- Bilateral lower-extremity weakness or numbness
- Progressive neurologic deficit

Physical examination findings

- Patients may have back pain, spasm of the paraspinal musculature, and sciatica-type symptoms
- Perineal numbness or decreased sensation to pinprick
- Laxity of bladder or anal sphincter, or decreased rectal tone
- Motor weakness on manual motor testing of major muscle groups

Treatment

- Patients should undergo emergent MRI if there is suspicion of cauda equina syndrome
- A foley catheter should be placed to avoid bladder injury from overdistension. A post-void residual or a bladder scan may aid in the diagnosis
- Consult with the neurosurgical or orthopedic spine service as soon as the diagnosis is suspected

Spinal epidural abscess (SEA)

Key facts

- Spinal epidural abscess (SEA) is a rare condition, but suspicion should be raised in high-risk patient populations
- Prompt diagnosis and treatment improve prognosis and minimize neurologic complications
- Antibiotic therapy and operative intervention is the treatment of choice, although medical management alone is warranted and successful in some cases

Incidence and microbiology

- SEA accounts for 7% of all spinal infections
- There has been an increase in the frequency of SEA secondary to:
    - Aging population
    - Increased prevalence of co-morbidities such as diabetes mellitus
    - Increased number of invasive spinal procedures
    - Intravenous drug use
- Most infections occur in the thoracic spine, followed by the lumbar spine
- SEAs often involve several contiguous vertebral levels, and generally arise as a result of adjacent vertebral discitis or osteomyelitis
- Hematogenous spread is the most common route of infection
- *Staphylococcus aureus* is the most common organism cultured

Risk factors for spinal epidural abscess

- Diabetes
- Intravenous drug abuse
- Bacteremia
- Alcoholism
- Trauma
- Immune suppression
- HIV infection
- Chronic steroid use
- Chronic renal insufficiency
- Malignancy
- Indwelling central venous catheters
- Previous spinal procedures

Clinical presentation and diagnosis

- Localized back pain, fever, and neurologic deficits are the most common presenting symptoms
- Direct compression of the neural elements by the abscess can cause neurologic deficits
- Lab studies include:

- WBC
- ESR
- CRP
- Blood cultures
- Urinalysis

PEARL: Plain radiographs and CT scan may be unremarkable unless there is also an ongoing vertebral discitis or osteomyelitis.

PEARL: MRI with gadolinium is the most sensitive and specific test for evaluating and detecting an epidural abscess. If the patient is unable to receive an MRI because of contraindications a CT myelogram should be arranged emergently.

PEARL: Empiric antibiotics should be witheld until a tissue sample/culture can be obtained.

Treatment

- Prompt diagnosis and treatment is essential to prevent neurologic deterioration and maximize recovery
- Once diagnosed a consultation to the neurosurgical or orthopedic spine service should be made so that, if warranted, operative intervention can be planned. This usually consists of surgical decompression of the affected levels, followed by targeted long-term antibiotic therapy
- The primary goals of treatment are eradication of infection, preservation or improvement of neurologic function, relief of pain, and maintaining spine stability

Vertebral compression fractures

Key facts

- The most common site for osteoporotic compression fractures is the spine
- A quarter of patients with vertebral compression fractures become sufficiently symptomatic to seek medical attention
- Pain is usually localized to the fracture level
- Neurologic symptoms are rare
- Patients with compression fractures need treatment for their osteoporosis
- Non-surgical and surgical treatment options exist, and both are effective

Clinical evaluation and imaging

- A comprehensive history and physical is essential, because these patients often have many co-morbidities
- There is usually pain with palpation at the fracture site
- Pain is usually mechanical in nature (e.g., worse with load-bearing positions)
- Lab work should include CBC, BMP, and ESR, as well as serum and urine electrophoresis

PEARL: Underlying infectious or malignant causes for the fracture should be ruled out.

- Plain radiographs are the initial study of choice for compression fractures (Figures 6.1 and 6.2)

PEARL: A vertebral compression fracture is defined as radiographic loss of vertebral body height of 20% or more.

- MRI may be useful to determine whether the fracture is acute or chronic, based on the presence of bony edema

Figure 6.1 A T12 compression fracture. (Image courtesy of Michael C. Bond, MD.)

Figure 6.2 An L1 compression fracture. (Image courtesy of Michael C. Bond, MD.)

Treatment

- Most compression fractures are successfully managed with rest, activity modification, analgesics and bracing. Two-thirds of patients respond to non-operative care

PEARL: Braces are used to reduce pain by decreasing load on the fractured vertebra, reducing movement through the fracture site, and decreasing muscle spasm.

- Overall bone health in patients with compression fractures should be evaluated. In the long term this may require the assistance of a rheumatologist or endocrinologist
- Pharmacotherapy for osteoporosis can reduce fracture incidence by 50%
- Progressive loss of vertebral body height and progressive kyphosis may necessitate operative intervention

Lumbar disc herniation

Key facts

- Peak incidence is in the fourth and fifth decades of life

- Only 4–6% of lumbar disc herniations become symptomatic, and only 2–4% are surgical candidates
- Distal lumbar levels are most commonly affected, L5/S1, L4/L5
- Within 3 months of symptom onset, 90% of patients will experience improvement without surgical intervention

Clinical presentation and physical examination

- Patients typically present with back and leg pain, with or without an inciting event
- Leg pain will typically follow the dermatomal pattern of the nerve root that is affected by the herniation

PEARL: Presence of sciatica is the most sensitive and specific finding for lumbar disc herniation.

- Patients may present with the hip and knee of the involved extremity flexed and externally rotated in order to take tension off the involved nerve root
- A positive straight leg raise test results from increased tension on the nerve root

PEARL: A positive contralateral straight leg raise has a higher specificity than a positive ipsilateral straight leg raise.

- The level of the herniation will determine the nerve root affected and the resultant radicular symptoms; sensory, motor or reflex deficits may result
- The ability to perform a thorough and accurate neurologic evaluation is essential in determining normal from abnormal and assessing whether the findings are attributable to a disc herniation

Treatment

- Surgery is rarely indicated at the time of symptom onset

PEARL: Absolute indications for surgery include cauda equina syndrome or a progressive neurologic deficit.

- Conservative treatment consists of:
  - Physical therapy
  - NSAIDs
  - Muscle relaxants
  - Epidural steroid injections
  - Oral steroids
  - Acupuncture
  - Manipulation
  - Traction

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Chapter 7 Pediatric orthopedic emergencies

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Key facts

- Pediatric bones are more flexible than adults, leading to unique fracture patterns such as:
  - Buckle fractures
  - Greenstick fractures
  - Plastic deformation
- Because of the high metabolic turnover for pediatric bones, closed reduction and casting is the treatment of choice for most pediatric fractures
- Transient synovitis is an inflammation of the hip joint that typically follows a viral upper respiratory infection (URI) and is characterized by hip pain and a limp
- Transient synovitis is typically self-limited and treated with non-steroidal anti-inflammatory medication (NSAIDs), though excluding a bacterial infection is critical to avoid significant morbidity
- Slipped capital femoral epiphysis (SCFE) occurs in obese pre-pubescent children. Pain may be indolent in cases of chronic SCFE, though acute worsening of pain is seen after relatively minor trauma in some cases
- SCFE presents bilaterally in a significant proportion of cases, even if only one side is symptomatic

Unique features of pediatric fractures

General principles

- Bones in children remodel at a more rapid rate than adults, making closed reduction a viable treatment modality for many fractures that would require operative repair in adults
- Bones in children are more flexible, leading to unique fracture patterns such as buckle and greenstick fractures that are not seen in adults
- Injury to growth plates can result in significant morbidity

Buckle fractures

- Buckle or torus fractures typically occur at the metaphyseal diaphyseal junction and result from a "crumpling" of the more porous metaphysis (see Figure 7.1)
- Typical locations for buckle fractures include the distal radius, distal tibia, distal fibula and distal femur

- A fall on to an outstretched arm or leg is a common mechanism of injury
- Treatment involves splinting or casting for 4 weeks and outpatient orthopedic follow-up. Some centers will immobilize for even shorter periods with similar results
- Prognosis is excellent

Pearl: Buckle fractures can be adequately treated with splinting or casting for 4 weeks with excellent prognosis.

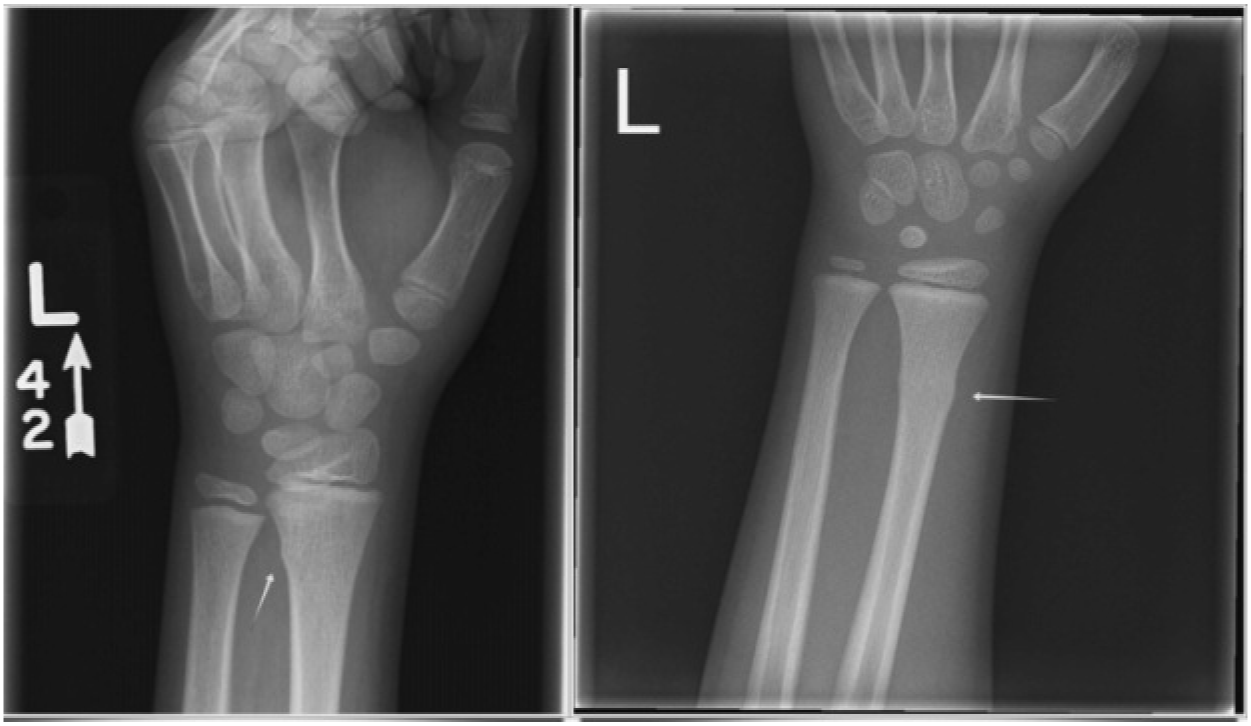

Figure 7.1 Buckle fracture of the distal radius (arrows).

Greenstick fractures

- Greenstick fractures commonly occur after a fall on to an outstretched arm or jumping on to a leg (see Figure 7.2)
- Because of the flexibility of pediatric bones, one cortex breaks while the other remains intact, similar to trying to break a piece of green wood
- Treatment of greenstick fractures involves closed reduction and splinting or casting
- Prognosis is excellent, provided acceptable closed reduction is achieved

Figure 7.2 A: shows the Greenstick fracture of the forearm (arrow). B: shows the impressive bowing that can occur (arrow).

Plastic deformation

- Occurs after a longitudinal force is applied to growing bone, such as the force that occurs with a fall onto an outstretched arm
- The bone bends and microscopic fractures occur which result in a bend but no visible fracture line on plain radiographs
- Typically occurs in the radius, ulna or fibula
- If the deformity is less than 20°, the bone often remodels and closed reduction is not needed
- Greater degrees of deformity require attempts at closed reduction
- Casting is the treatment of choice and these injuries rarely need operative repair

Growth plate injury

Key facts

- The Salter–Harris classification system is used to describe fractures involving the growth plate. The higher the classification, the higher the likelihood that the patient will have growth

abnormalities such as growth arrest, malunion, growth disturbance with angulation, or growth acceleration
- Growth plate injuries account for 20% of all pediatric fractures

Pearl: Salter–Harris Type I and V injuries can appear the same on plain radiographs. Comparison views of the contralateral leg can help distinguish the two, though the provider should always assume it is the more serious (Type V) injury.

Description

- Injury to the growth physis or physeal plate
- The most commonly affected bones are the long bones of growing children specifically distal radius, distal tibia, phalanges, and proximal humerus
- Sites which show the most growth disturbance when injured are the distal femur and distal tibia

Epidemiology

- Younger children have a higher risk of serious sequela from a physeal injury because they have more potential growth remaining

Incidence

- Males are affected twice as often as females
- Accounts for 20% of all pediatric fractures

Prevalence

- Occurs most frequently in girls aged 11–12 years and boys aged 12–14 years, when growth is most rapid

Etiology

- Trauma, infection, tumors, drugs (steroids, testosterone, estrogen)

Salter–Harris classification

- Five total patterns of physis fractures. Types III to V are at highest risk for growth plate damage
  - Type I: Split parallel through the physis
  - Type II: Split through physis and exits through the metaphysis
  - Type III: Intra-articular fracture through the epiphysis and exits through physis
  - Type IV: Intra-articular fracture through the epiphysis that exits through metaphysis and physis
  - Type V: Crush injury to the physis

Physical examination

- Evaluate the limb for open wounds, swelling, crepitus, and neurovascular status

Tests

- Plain radiographs: AP, lateral, and oblique
- CT scan: May be necessary to evaluate complicated fracture patterns
- MRI: Best method to establish injury to the growth plate since it can visualize the cartilage of the growth plate as separate and distinct from bone

Treatment

- Ice, immobilization
- Pain medication
- Monitor for compartment syndrome as appropriate
- Splint non-displaced fractures
- Displaced fractures should be reduced under procedural sedation, hematoma block, or general anesthesia. The fracture is then splinted and alignment is rechecked with repeat plain radiographs

Follow-up

- Patients should be seen by orthopedics in 3 to 5 days, and the splint is usually maintained for 1–2 weeks, until swelling has resolved

Surgery

- If closed reduction is not possible or fractures become unstable, the fracture will need to be reduced in the operating room and stabilized by percutaneous pins or internal hardware

Prognosis

- The higher Salter–Harris classification correlates with higher incidence of growth abnormality such as growth arrest, malunion, growth disturbance with angulation, or growth acceleration. The closer the child is to skeletal maturity, the less likely growth abnormality will result
- A bony bar can be resected or a corrective osteotomy done surgically to restore angulation or length deformity. Another simple option is to stop the growth in the contralateral growth plate to maintain symmetry

Monitoring

- Monitored for 6 to 12 months after injury to ensure normal growth

Osgood–Schlatter disease

Key facts

- A traction apophysitis of the tibial tuberosity
- Treatment is supportive with rest, ice, pain control, and patellar strap

Description

- Osgood–Schlatter disease is a traction apophysitis of the tibial tuberosity caused by repetitive strain by the quadriceps tendon.

Epidemiology

Incidence

- Males are affected twice as often as females
- Bilateral presentations are seen in 25–50% of patients
- Commonly seen in patients who participate in running, jumping, and squatting activities

Prevalence

- Frequent in girls aged 8–12 years and boys aged 10–15 years when growth is most rapid

Etiology

- Repetitive traction of the patellar tendon from the tibia tubercle from running, jumping, rapid growth, and overuse

Intrinsic risk factors

- Tight rectus femoris, tight hamstrings, patella alta, and external tibial rotation

Physical examination

- May note tenderness to palpation directly over the tibial tuberosity with no or trace swelling at the insertion site
- Testing of the quadriceps muscle will elicit full strength but will cause pain at the site. If strength of resisted leg extension is weak and there is swelling at the tibial tuberosity, consider that there may be a tibial tubercle avulsion fracture
- Deep squats will elicit pain
- Evaluate foot alignment for pathology which may stress the knee such as over-pronation or pes planus

Tests

- Radiographs are not required. If radiographs are done, the lateral knee view may demonstrate sclerosis at the tubercle

Treatment

- Rest or activity modification
- Ice
- Possible short course of anti-inflammatory medication
- Eccentric stretching and strengthening the quadriceps and hamstrings
- Patellar strap bracing
- Foot inserts if indicated by clinical examination

Follow-up

- Follow-up with primary care physician if pain progresses, limp, swelling develops or inability to walk

Prognosis

- Favorable, but will be exacerbated during times of rapid growth or activity
- Many will have prominence of the tibial tuberosity into adulthood. May have persistent pain with kneeling as an adult, which may represent presence of residual ossicles and warrant surgical removal

Pearl: If initial presentation includes swelling, inability to actively extend the knee, decreased strength with knee extension, inability to walk, obtain radiograph to evaluate for avulsion fraction of the tibial epiphysis.

Child abuse/non-accidental trauma

Epidemiology

- Infants and children with disabilities are at higher risk
- In more than 80% of cases the parent or primary guardian is the abuser
- History given is inconsistent with the mechanism of injury

Risk factors

- Domestic violence
- Maternal depression
- Drug and alcohol abuse
- Premature birth
- Unrealistic expectations for the child

Signs and symptoms

- Description of the mechanism does not match the injury
- Child is developmentally unable to sustain such an injury
- Soft-tissue injuries are common and consider abuse if bruises, ecchymosis, and soft-tissue injuries are on the face, cheeks, back, neck or if the child is not cruising yet. The child might also have bruises in clusters or patterned marks

Fractures highly suspicious of abuse

- Rib fractures, especially posterior
- Metaphyseal or "bucket handle" fractures
- Scapular fractures
- Spinous process fractures
- Sternal fractures

Fractures moderately suspicious of abuse

- Long-bone transverse or spiral fractures of the diaphysis of the femur, humerus, tibia
- Multiple bilateral fractures
- Different stages of healing with multiple fractures
- Epiphyseal separations
- Vertebral body separation
- Complex skull fractures
- Pelvis fractures

Diagnosis

- Maintain high index of suspicion when history does not explain injury
- Conduct careful examination of the skin

Tests

- Skeletal survey for all children less than 2 years of age

    1. Skull AP and lateral view
    2. Chest AP including clavicles
    3. Right and left oblique of the chest
    4. AP of abdomen to include pelvis and hips
    5. Lateral spine to include cervical, thoracic, and lumbar vertebrae
    6. AP spine to include cervical, thoracic, and lumbar vertebrae
    7. AP bilateral humerus
    8. AP bilateral forearms
    9. AP bilateral femurs
    10. AP bilateral tibia and fibula
    11. Posterior view of the hands

12. Dorsoplantar view of the feet

- Head computed tomography for any child less than 1 year with suspicion of abuse or greater than 1 year with concerning signs of head trauma

Treatment

- Treat each fracture as clinically indicated
- Report abuse to the appropriate state child protection authority

Prognosis

- Children who are victims of abuse without proper intervention are likely to sustain more repeated episodes.
- Twenty percent of the fatalities related to abuse had contact with the health care community within one month of death

Spinal cord injury without radiographic abnormality (SCIWORA)

Key facts

- A traumatic injury to the spinal cord that is not evident on plain radiographs or CT
- Most often occurs in children less than 8 years old

Description

- A traumatic injury to the spinal cord that causes neural damage without evidence of radiographic injury on plain radiographs or CT. The increasing elasticity of the spine, shape of the vertebral bodies, facet alignment, and level of maximum flexion in the cervical spine place the pediatric spine at risk because of its hypermobility and malleability. This term was coined before the widespread availability of MRI. With this imaging modality, these patients will have abnormalities that can be visualized

Epidemiology

- Most often presents in children less than 8 years of age
- Responsible for approximately 5% of all spinal cord injuries in children
- Three critical features:

1. May have a delay in diagnosis because of transient paresthesia
2. Progressive latent paralysis can present up to 4 days after the injury
3. Recurrent episodes may occur without proper immobilization

Initial evaluation

- Immobilize in hard collar and place on spine board
- Document neurologic defects on examination
- Obtain AP, lateral, and odontoid plain radiographs or CT of cervical spine to exclude fracture or dislocation

Test

- If CT of the cervical spine is normal yet neurologic deficits persist, the patient should have an MRI of the cervical spine

Treatment

- Immediate consultation with neurosurgery
- Cervical stabilization in hard collar
- Strict bed rest with logroll as necessary
- Methylprednisone load within 8 hours of injury if advised by your local neurosurgical consultant

Transient synovitis

Clinical presentation

- Inflammatory condition of the hip typically following a viral upper respiratory illness
- Occurs most commonly in children ages 3–8 years and presents with hip pain and a limp with varying degrees of limitation of range of motion at the hip
- Low-grade fevers may occur though high fever should raise concern for a bacterial infection of the hip
- Affected individuals are typically non-toxic in appearance
- May be bilateral in up to 5% of cases

Diagnostic testing

- Diagnosis is clinical
- It is important to differentiate transient synovitis from septic arthritis or Lyme arthritis
- Afebrile children who can bear weight, even if limping, can be managed expectantly
- If the child is febrile, further testing is indicated including CBC, ESR, CRP and blood cultures
- Fever > 38.5° C in the past week, ESR > 40 mm/hr, a WBC count > 12,000 cells/mm^3 and a CRP > 2 mg/dL are all risk factors for bacterial illness
- Lyme titers may be useful in endemic areas
- Ultrasound should be used to evaluate for an effusion if there is a clinical concern for bacterial infection. The presence of an effusion does not rule in or rule out transient synovitis, but can predict whether you will be able to obtain fluid for analysis
- A bone scan can be used for evaluation if there is concern about osteomyelitis

Pearl: Ultrasound may reveal fluid in cases of transient synovitis and up to a quarter of patients will have bilateral effusions, even if only one side is symptomatic.

Treatment

- Non-steroidal anti-inflammatory medications such as ibuprofen are the mainstay of therapy
- Affected children can weight-bear as tolerated

Prognosis

- Recovery without sequelae is the typical course
- Pain usually resolves within days
- Persistent pain despite NSAIDs should raise suspicion for Legg–Calves–Perthes disease or occult infection

Slipped capital femoral epiphysis (SCFE)

Clinical presentation

- Typically occurs in obese, pre-pubescent patients
- Presents with hip pain and gait disturbance with no history of discrete trauma
- Pain may be acute or indolent over the course of weeks to months
- SCFE is bilateral in up to 40% of cases and often the other side is asymptomatic
- Obesity is the chief risk factor for SCFE although there are other predisposing conditions including:
  - Renal failure
  - Hypothyroidism
  - Growth hormone deficiency
  - Radiation therapy

Pearl: Patients with SCFE may present with knee or thigh pain and not hip pain and this may lead to delay in diagnosis.

Diagnostic testing

- Plain radiographs are the initial diagnostic modality of choice and should include the following views:
  - Anteroposterior (AP) view of the pelvis
  - Frog-leg lateral view of the affected hip
  - Obtaining radiographs of the opposite hip should be strongly considered given the incidence of bilateral disease
- Radiographic findings include widening of the femoral head physis, irregularity or blurring of the physis, or slippage of the epiphysis (the so-called ice cream falling off the cone) (see Figure

7.3)

Pearl: On the AP radiograph, a line drawn along the superior aspect of the femoral neck should intersect the femoral head (Klein's line, see Figure 7.4). In cases of SCFE, the line will pass superior to the femoral head, indicating slippage.

- Plain radiographs are the screening test of choice for SCFE. An MRI may be used for patients whose initial radiographs are inconclusive and there is a high degree of suspicion. An MRI is particularly useful early on in the course of the illness

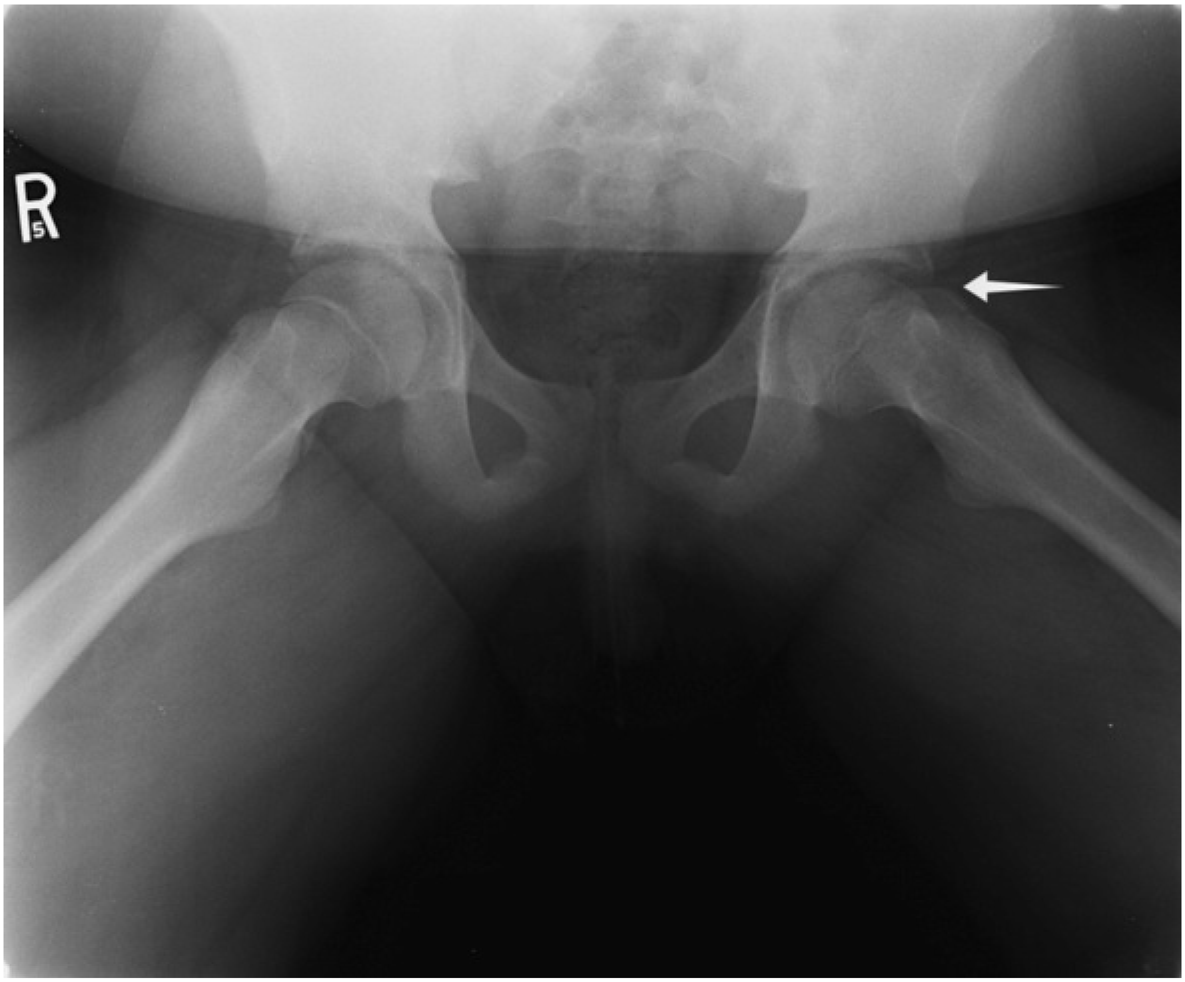

Figure 7.3 Slipped capital femoral epiphysis of the left hip revealing the so-called "ice cream falling off the cone" (arrow).

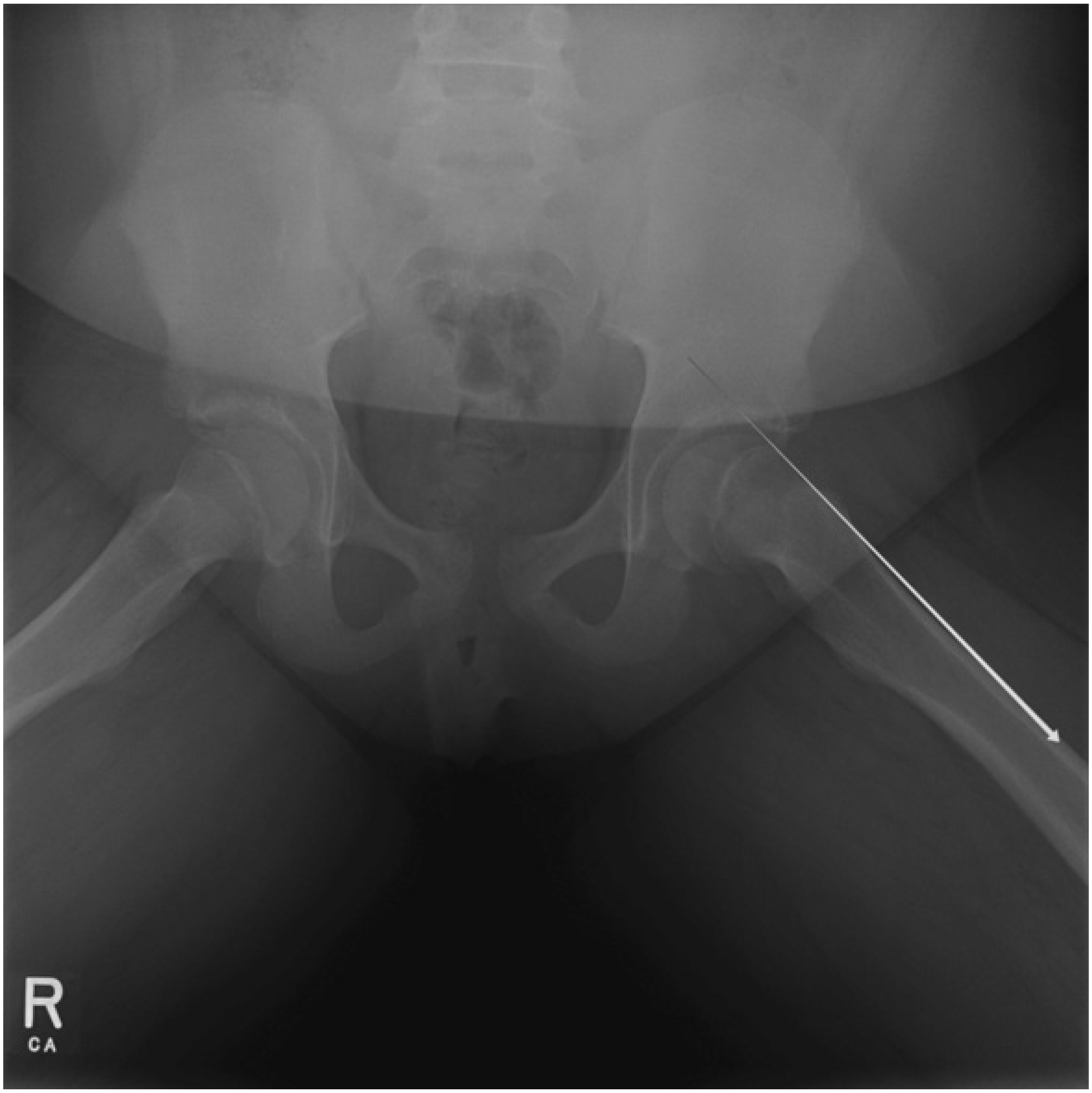

Figure 7.4 Slipped capital femoral epiphysis showing Klein's line. A line drawn along the superior aspect of the femoral neck should intersect the epiphysis.

Treatment

- Patients diagnosed with SCFE should be non-weight-bearing
- Refer to an orthopedic surgeon
- Admission to the hospital is generally indicated, particularly in cases of acute slippage or cases of bilateral SCFE
- Treatment is operative and involves reduction of the slip and pinning (see Figure 7.5)

Figure 7.5 Operative fixation with pinning of a slipped capital femoral epiphysis on the right hip.

Prognosis

- Up to 50% of patients with unilateral SCFE will eventually slip on the other side so careful follow-up is indicated
- Most contralateral cases will occur within 1–2 years after initial slip
- Complications include avascular necrosis of the femoral head and is more common in acute slips and those that are unstable
- Chronic gait abnormality and leg-length discrepancy are rare but can occur

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Chapter 8 Orthopedic infections and other complications

Stephen Y. Liang, Michael C. Bond and Michael K. Abraham

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Septic arthritis

Key facts

- Infection occurs primarily through hematogenous seeding of the joint (bacteremia)
- Contiguous soft-tissue infection or direct inoculation of the joint (e.g., penetrating trauma, recent arthrocentesis or intra-articular injection) may also play a part, albeit to a lesser extent
- Risk factors include age, diabetes mellitus, rheumatoid arthritis, joint surgery, prosthetic joint (hip or knee), skin infection, intravenous drug use, and alcoholism
- *Staphylococcus aureus* and streptococcus are the primary infecting organisms seen in adults, although immunocompromised patients may also be at risk for Gram-negative infection
- Disseminated *Neisseria gonorrhoeae* infection can present as septic arthritis and should be considered in sexually active adults

Clinical presentation

- Joint pain that is worse with range of motion is a primary complaint, most commonly involving the knee or hip
- Fever is often present
- Examination of the affected joint may reveal:
  - Joint effusion with erythema, warmth, and tenderness
  - Painful or limited range of motion
  - Overlying cellulitis or pustules (seen with disseminated *Neisseria gonorrhoeae* infection[DGI])
  - Multiple joint involvement is occasionally seen, particularly with DGI or sepsis
- Symptoms and examination findings may be minimal in the setting of immunosuppression

Diagnostic testing

- Definitive diagnosis rests upon arthrocentesis of the affected joint, preferably before antibiotics are given
  - If the affected joint is a prosthetic joint, the arthocentesis should be done by an orthopedic surgeon, preferably under sterile conditions in order to prevent potential seeding of the joint
  - Synovial fluid should be sent for white blood cell (WBC) count with differential, Gram stain, and aerobic culture

    - Synovial WBC > 50,000 cells/mm^3 is generally indicative of septic arthritis, but is not sensitive enough to rule it out
    - A differential with > 90% polymorphonuclear cells increases the likelihood of infection
    - Gram stain is only 50–60% sensitive for detection of bacteria in synovial fluid
    - If minimal synovial fluid is recovered, culture should take precedence over all other tests
- Obtain blood cultures prior to administering antibiotics
- Check CBC, erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP)
    - Not helpful acutely but can be followed to ensure resolution of the disease
- Consider plain radiographs of the affected joint to exclude joint destruction or associated osteomyelitis
- Bedside ultrasound may aid in detecting a joint effusion and facilitating arthrocentesis

Treatment

- Antibiotic therapy
    - Empiric coverage of Gram-positive organisms, including methicillin-resistant *S. aureus* (MRSA) is recommended pending culture and sensitivity
        - Vancomycin 15 mg/kg IV (based on actual body weight and normal renal function) every 12 hours
    - In immunocompromised patients, the addition of a third-generation cephalosporin should afford adequate empiric coverage of most Gram-negative bacteria
        - Ceftriaxone 2 g IV once daily
        - Ceftazidime 1–2 g IV every 8 hours
        - Cefotaxime 2 g IV every 8 hours
    - Coverage should always be narrowed once antibiotic sensitivities are known for any organisms cultured
- Surgery
    - Orthopedic surgery consultation is advised as irrigation and operative debridement versus serial arthrocentesis of the infected joint may be necessary
    - Infections involving prosthetic joints often require hardware removal
- Admit to the hospital

Prognosis

- Timely diagnosis and treatment are the keys to reducing mortality and preventing poor functional outcomes
- Complications of untreated septic arthritis can include joint destruction, osteomyelitis, suppurative disease, and sepsis

PEARL: Septic arthritis must be considered in the patient presenting with a swollen, painful joint, particularly in the absence of a preceding injury.

PEARL: An arthrocentesis for synovial fluid analysis and culture should always be performed if septic arthritis is suspected.

PEARL: Infected joints require orthopedic surgery consultation for consideration of irrigation and debridement in the operating room.

Infectious tenosynovitis

Key facts

- Infection of the tendon sheath, often involving the flexor tendons of the hand and wrist
- Typically associated with penetrating trauma (e.g., lacerations, bites, punctures, intravenous drug use)
- May also result from contiguous spread of an adjacent soft-tissue infection or hematogenous spread (DG mycobacteria)
- *Staphylococcus aureus* and streptococcal infections are the most common infecting organisms although Gram-negative bacilli may be seen with bites and in diabetics

PEARL: Infectious tenosynovitis is an orthopedic emergency that requires early consultation with a hand surgeon.

Clinical presentation

- Kanavel's four cardinal signs of flexor tenosynovitis include:
  - Pain with passive extension of the finger
  - Semi-flexed position of the finger at rest
  - Symmetric swelling of the finger (sausage digit)
  - Tenderness to percussion over the tendon sheath
- Localized erythema, lymphangitic streaking, and fever may be present
- Subcutaneous purulence (secondary to tendon sheath rupture) and digital ischemia signal advanced infection
- Vesiculopustular lesions and polyarthralgias may accompany gonococcal tenosynovitis

PEARL: Pain with passive extension of the finger is often the earliest of Kanavel's cardinal signs to appear.

Diagnostic testing

- Check CBC
- Definitive diagnosis requires Gram stain and culture of tendon sheath fluid by aspiration or during surgical intervention by a hand surgeon
- Plain radiographs may be helpful in identifying associated fractures and foreign bodies

Treatment

- Antibiotic therapy
  - Empiric coverage of *Staphylococcus aureus* (including MRSA), streptococcus, and Gram-

negative bacilli can be achieved with:
        - Vancomycin 15 mg/kg IV (based on actual body weight and normal renal function) every 12 hours
    - In combination with one of the following:
        - Ciprofloxacin 500 mg PO twice daily
        - Ceftriaxone 2 g IV once daily
    - If a human or animal bite is involved and MRSA is not a primary concern, consider:
        - Ampicillin–sulbactam 3 g IV every 6 hours
    - Coverage should always be narrowed once antibiotic sensitivities are known for any organisms cultured
    - Early and mild cases may occasionally be managed with antibiotics, splinting, elevation, and close observation
- Surgery
    - Hand surgery consultation should always be sought to determine if operative drainage and debridement is warranted
    - In severe cases, amputation may be required
- Administer tetanus prophylaxis if indicated
- Admit to hospital

Prognosis

- Complications of untreated disease can include tendon scarring and necrosis, loss of function, proximal spread of infection, and even compartment syndrome

PEARL: Tenosynovitis in the absence of penetrating trauma, should raise suspicion for DGI.

Clenched fist injuries

Key facts

- Commonly referred to as a “fight bite”
- Associated with wounds over the dorsum of a metacarpophalangeal (MCP) or proximal interphalangeal (PIP) joint sustained after striking an opponent’s teeth with a clenched fist
    - Classically involves the third or fourth MCP joint of the dominant hand
    - May result in damage to and contamination of the extensor tendon, tendon sheath, and/or joint capsule with human oral flora
    - Bacteria inoculated into the wound may travel proximally into the dorsal hand upon relaxation of the extensor tendon and unclenching of the fist
- Infection can range from cellulitis to septic arthritis and soft tissue infections involving the deep spaces of the hand
- Common infecting organisms include *Staphylococcus aureus*, streptococcus, corynebacterium, *Eikenella corrodens*, and anaerobic bacteria

Clinical presentation

- Examination of the affected MCP or PIP joint shortly after the injury may reveal deceivingly small lacerations
- Erythema, swelling, purulent wound discharge, and decreased range of motion developing several days after a clenched fist injury signal infection

PEARL: A clenched fist injury should be suspected in any patient presenting with lacerations over the dorsal aspect of the MCP joint.

Diagnostic testing

- Gram stain and culture (aerobic and anaerobic) should be obtained from infected wounds along with blood cultures prior to administering antibiotics
- Plain radiographs of the hand may reveal concomitant fractures or foreign bodies (e.g., tooth fragments) after the initial injury, or osteomyelitis in delayed presentations with infection

Treatment

- Initial care of the uninfected fight bite
    - Extensor tendon injury and joint capsule involvement may require hand surgery consultation and should be carefully investigated by examining the wound with fingers flexed in a closed fist
    - If surgical consultation is not indicated, the wound should be thoroughly irrigated and allowed to heal by secondary intention
    - Antibiotic prophylaxis should consist of amoxicillin–clavulanate for 3 to 5 days
    - Administer tetanus prophylaxis if indicated
    - The wound should be re-evaluated by a healthcare provider within 24–48 hours

PEARL: Antibiotic prophylaxis is always indicated after a clenched fist injury given the high risk of infection.

- Management of the infected fight bite
    - Antibiotic therapy
        - Empiric regimens include:
            - Ampicillin–sulbactam 3 g IV every 6 hours
            - Ceftriaxone 2 g IV once daily + metronidazole 500 mg IV/PO every 8 hours
        - Coverage should always be narrowed once antibiotic sensitivities are known for any organisms cultured
    - Surgery
        - Hand surgery consultation is advised as irrigation and operative debridement are often required
    - Administer tetanus prophylaxis if indicated
    - Admit to the hospital

PEARL: Infected fight bites should be evaluated by a hand surgeon for irrigation and debridement in the operating room.

Prognosis

- Delayed presentation and inadequate debridement of infected wounds can lead to poor outcomes including septic arthritis, joint destruction, and loss of function

Osteomyelitis

Key facts

- Infection of bone can result from hematogenous seeding (bacteremia), contiguous spread of an adjacent infection (e.g., cellulitis, abscess, infected ulcer), or direct inoculation (e.g., open fracture, orthopedic surgery)
- Risk factors include diabetes mellitus, peripheral vascular disease, sickle cell disease, chronic corticosteroid use, immunosuppressed states (including HIV), joint disease, history of open fracture or orthopedic hardware, intravenous drug use, and alcoholism
- *Staphylococcus aureus*, coagulase-negative staphylococci, and Gram-negative bacilli (including *Pseudomonas aeruginosa*) are commonly implicated organisms

Clinical presentation

- Acute osteomyelitis is marked by localized pain, erythema, and swelling for several days with or without fever or malaise
- Chronic osteomyelitis develops over a longer period of time and is more likely to present solely with non-specific symptoms
- Examination of the affected site may reveal:
    - Erythema, warmth, swelling, and tenderness to palpation
    - Limited or painful range of motion of an adjacent joint
    - Draining sinus tract (chronic osteomyelitis)
    - Non-healing ulcer (chronic osteomyelitis)
        - Ulcer area > 2 cm^2 and probing to bone within a diabetic foot ulcer are highly predictive of osteomyelitis

PEARL: Normal plain radiographs do not rule out osteomyelitis.

Diagnostic testing

- Check CBC, ESR, and C-reactive protein
- Obtain blood cultures prior to administering antibiotics
- Superficial wound or sinus tract cultures are of limited use as they may not accurately reflect the organisms responsible for infection of the bone
- Definitive diagnosis rests upon bone biopsy and culture
    - Consider discussing with orthopedics or admitting service on holding off on antibiotics until a bone biopsy or culture can be obtained
    - If septic, antibiotics should be started immediately after blood cultures are obtained

- Plain radiography of the affected bone may reveal periosteal elevation or cortical bone destruction
    - Radiographic changes may not be evident within the first few days to weeks after onset of symptoms
- MRI is highly sensitive and specific for detecting bone marrow edema, cortical destruction, soft-tissue infection (cellulitis, abscess), and sinus tracts, even in early disease
- CT can be helpful in identifying cortical destruction when MRI is not possible

PEARL: MRI can be extremely useful in making the early diagnosis of osteomyelitis.

Treatment

- Antibiotic therapy
    - In the absence of sepsis, neutropenia, or other critical illness, it is reasonable to briefly delay antibiotics in order to improve yield and better guide therapy if a bone biopsy and culture can be obtained in a timely manner
    - Empiric coverage of Gram-positive organisms, including methicillin-resistant *Staphylococcus aureus* (MRSA) is recommended pending culture and sensitivity:
        - Vancomycin 15 mg/kg IV (based on actual body weight and normal renal function) every 12 hours
    - Gram-negative coverage is also warranted with the addition of one of the following:
        - Cefepime 2 g IV every 12 hours
        - Ciprofloxacin 750 mg PO twice daily
    - Coverage should always be narrowed once antibiotic sensitivities are known for any organisms cultured
    - Infectious disease consultation is recommended as prolonged antibiotic therapy (typically 6 weeks) is needed
- Surgery
    - Orthopedic surgery consultation is advised as operative debridement of infected or necrotic bone and removal of infected prosthetic hardware may be necessary
- Admit to hospital

Prognosis

- Outcomes are dependent on early diagnosis, antibiotic therapy, and operative debridement of infected bone, particularly in the setting of acute osteomyelitis
- Complications of untreated disease can include pathologic fracture, suppurative disease, and sepsis
- Chronic osteomyelitis can be a relapsing and remitting infection, even despite appropriate antibiotic therapy and surgical intervention

PEARL: Aggressive surgical debridement and appropriate antibiotic therapy (guided by culture) are essential to the successful treatment of osteomyelitis.

Vertebral osteomyelitis and discitis

Key facts

- Infection of the vertebrae (vertebral osteomyelitis) can result from hematogenous spread (e.g., bacteremia associated with endocarditis, urinary tract infection, or intravascular device infection), contiguous spread of an adjacent soft-tissue infection, or direct inoculation (e.g., trauma or spine surgery)
- Intervertebral disc spaces adjacent to infected vertebrae can subsequently become infected (discitis) as well
- Often seen in patients with underlying diabetes mellitus, intravenous drug abuse, immunosuppression, malignancy, or chronic kidney disease requiring hemodialysis
- *Staphylococcus aureus*, *Streptococcus*, *Escherichia coli*, and *Pseudomonas aeruginosa* are common causative organisms

Clinical presentation

- Back pain is a predominant complaint and may evolve over days to weeks, often without fever
- Neurologic symptoms including radiculopathy, sensory deficits, extremity weakness or paralysis, and urinary retention are uncommon unless an epidural abscess has formed
- Examination may reveal tenderness on palpation of the affected vertebrae

PEARL: The most common site for vertebral osteomyelitis is the lumbar spine, followed by the thoracic and cervical spine.

Diagnostic testing

- Check CBC, ESR, and C-reactive protein
- Obtain blood cultures prior to administering antibiotics
- Plain radiography of the spine may reveal vertebral endplate destruction and intervertebral disc space narrowing, but can be normal within the first few days to weeks of symptom onset
- MRI is highly sensitive and specific for detecting vertebral osteomyelitis, discitis, and epidural abscess, even in its earliest stages
- CT can be helpful in identifying cortical destruction and adjacent soft-tissue infection when MRI is not possible
- Biopsy and culture of the affected vertebral bone or disc space, either by a surgeon or interventional radiologist, confirms the diagnosis

PEARL: Vertebral osteomyelitis presenting as non-specific back pain frequently leads to diagnostic delay, resulting in significant morbidity and adverse sequelae.

Treatment

- Antibiotic therapy
  - In the absence of sepsis, neutropenia, or other critical illness, it is reasonable to delay

antibiotics briefly in order to improve yield and better guide therapy if a bone biopsy and culture can be obtained in a timely manner
    - Empiric coverage of Gram-positive organisms, including methicillin-resistant *S. aureus* (MRSA) is recommended pending culture and sensitivity:
        - Vancomycin 15 mg/kg IV (based on actual body weight and normal renal function) every 12 hours
    - Gram-negative coverage is also warranted with the addition of one of the following:
        - Cefepime 2 g IV every 12 hours
        - Ciprofloxacin 750 mg PO twice daily
    - Coverage should always be narrowed once antibiotic sensitivities are known for any organisms cultured
    - Infectious disease consultation is recommended as prolonged antibiotic therapy (typically 6 weeks) is needed
- Surgery
    - Spine surgery consultation is warranted in the following instances:
        - Cord compression or threatened cord compression caused by vertebral instability requiring stabilization and spinal decompression
        - Epidural or paravertebral abscess requiring operative drainage
        - Vertebral osteomyelitis because of infected spinal hardware requiring debridement and removal
- Admit to hospital

Prognosis

- Serious neurological complications (particularly with cervical spine osteomyelitis) can result from epidural abscess and cord compression when not identified early
- Other complications may include paravertebral or psoas abscesses
- Relapsing infection may occur, even despite appropriate antibiotic therapy and surgical intervention

PEARL: In most cases, antibiotic therapy alone guided by culture is sufficient to treat vertebral osteomyelitis.

Open fracture management

Key facts

- Open fractures are at significant risk of contamination with skin flora (primarily *Staphylococcus aureus*) and bacteria present in the environment that can lead to post-traumatic osteomyelitis, particularly in tibial fractures
- Early operative irrigation and debridement by an orthopedic surgeon reduces organism burden and is crucial to preventing later infections
- Administration of prophylactic antibiotics soon after the time of injury can further reduce the risk of infection

- Initial antibiotic prophylaxis in the ED should be guided by the Gustilo open-fracture classification (Table 8.1):
- In areas seeing high rates of methicillin-resistant *S. aureus* (MRSA), the use of vancomycin in place of cefazolin may be considered
- Duration of prophylaxis is dependent upon the extent of contamination and timing of surgical intervention
- Antibiotic prophylaxis is unnecessary in open fractures resulting from low-velocity civilian gunshot wounds that do not require open reduction and internal fixation

- Tetanus prophylaxis should be provided when indicated

PEARL: Early surgical intervention and antibiotic prophylaxis after an open fracture can significantly prevent later infectious complications.

Table 8.1 ***Gustilo open-fracture classification.***

Gustilo fracture type	Definition	Infection rate	Antibiotic
I	Wound < 1 cm with minimal soft-tissue damage	0–2%	Cefazolin 2 g IV
II	Wound > 1 cm but < 10 cm in length with moderate soft-tissue damage	2–5%	Cefazolin 2 g IV
III	Wound > 10 cm with extensive soft-tissue and/or vascular injury, or a traumatic amputation	5–50%	Cefazolin 2 g IV ± gentamicin 5 mg/kg IV*

* Prophylaxis against Gram-negative organisms (including *Pseudomonas aeruginosa*) remains controversial but is recommended by some experts.

Compartment syndrome

Key facts

- Normal compartment pressures are < 10 mmHg
- Pressures > 20 mmHg are associated with impaired capillary blood flow and ischemia; however, this is also dependent on the diastolic blood pressure. The higher the diastolic blood pressure the less likely there will be compromised capillary blood flow
- An increase in pressure in muscular compartments of the body can lead to death or loss of a limb
- Compartment syndrome is classically associated with symptoms described as the five "P"s
  - Pain out of proportion to what is expected
  - Paresthesia
  - Pallor
  - Paralysis

    - Pulselessness
- The loss of pulses is very uncommon and a very late sign. This ischemia occurs with loss of capillary flow, which occurs at pressures much lower than arterial blood pressures
- The pressure in the compartment must be relieved in order to prevent long-term damage. This can be done via a fasciotomy

Clinical presentation

- The majority of patients will present complaining of a painful and numb extremity

PEARL: Consider compartment syndrome in any patient with pain out of proportion to the injury or examination.

- The onset of compartment syndrome is often linked to:
    - Burns
    - Envenomation from insects, snakes, or marine animals
    - Injection into the compartment (i.e., high-pressure injection injuries, intravenous drug abuse, infusion of medications or intravenous contrast)
    - Overuse (i.e., repetitive exercises leading to edema and rhabdomyolysis)
    - Recent trauma (i.e., fractures, crush injuries)
    - Restrictive jewelry, clothing or casts
- Affected limb often held in flexion to reduce the stretch of the affected compartment, and pain is increased with extension of the limb

PEARL: Pain with stretching of the affected muscle groups is the most sensitive sign of compartment syndrome.

- Physical examination findings consistent with compartment syndrome are:
    - Pain out of proportion to light touch
    - Paresthesia
    - Diminished capillary refill
    - Tense and swollen skin

Diagnostic testing

- Definitive test is to measure the intra-compartment pressure
    - No laboratory or radiology studies can make the diagnosis
    - Check CBC, creatinine kinase (exclude rhabdomyolysis), renal function studies (exclude renal insufficiency secondary to rhabdomyolysis)
    - Obtain plain radiographs of the affected limb to exclude fracture
- Measuring the intra-compartment pressure:
    - Intra-compartment pressures should be < 20 mmHg
    - Several techniques are available to test the compartment pressure
        - Stryker pressure tonometer:
            - A commercial device that measures the pressure needed to inject a small amount

of fluid into the compartment
        - A self-contained unit that has a measure gauge, needle, and plunger
        - Can quickly estimate the pressure in the compartments
    - Pressure transducer – can be set up with supplies commonly found in the ED
        - Supplies needed:
            - 1–4-way stopcock
            - 1 – sterile 20 ml Luer-Lok syringe
            - 2 – IV extension tubing sets
            - 2 – 18-gauge needles
            - 1 – bag of normal saline
            - 1 – blood pressure manometer (manual guage)
            - Several gauze pads
            - Chlorhexidine scrub
        - Set up
            - Connect the 4-way stopcock to the 20 ml syringe
            - Connect one end of the IV extension tubing to the blood pressure manometer and the other end to a port on the stopcock
            - Connect the other IV extension tubing to another port on the stopcock and then to the bag of normal saline
            - Open the stopcock so that only the syringe and bag of normal saline are open
            - Aspirate ~15 ml of normal saline into the syringe
            - Disconnect the normal saline bag and attach an 18-gauge needle to the extension tubing
            - Clean the affected extremity with chlorhexidine
            - Using aseptic technique insert the 18-gauge needle into a compartment of the affected extremity
            - Turn the stopcock so that the syringe and both sets of IV tubing are open
            - Slowly and gently depress the plunger while watching the air/water meniscus that should be just below the syringe
            - The meniscus will move once the pressure on the syringe exceeds the pressure in the compartment. The pressure reading on the manometer at this point is the pressure in the compartment. Record in mmHg

Treatment

- Reduce swelling in the extremity (i.e., elevate, apply ice)
- Provide adequate pain control
- Remove any restrictive clothing, splints, casts, jewelry, etc
- Fasciotomy (consult orthopedics, surgeon or perform yourself if consultants are not available)
- Treat the underlying cause (i.e., reduce fractures, provide appropriate antivenom)
- Admit to hospital
    - All patients at high risk for development of compartment syndrome or those that have it should be admitted for definitive treatment and serial examinations

Prognosis

- Prognosis depends on the duration of symptoms and how quickly the pressures can be lowered
- A fasciotomy done within 6 hours of onset of pain is associated with good outcomes
- A fasciotomy done > 6 hours is often associated with irreversible necrosis and permanent disability

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Chapter 9 Procedures for orthopedic emergencies

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Orthopedic Emergencies, ed. Michael C. Bond, Andrew D. Perron, and Michael K. Abraham. Published by Cambridge University Press.

Local anesthetics

Key facts

- Ester anesthetics: procaine, tetracaine
- Amide anesthetics: bupivacaine, lidocaine
- Cardiac lidocaine is preservative free and may be used in patients with previous lidocaine allergy
- Onset of action and duration of action varies based on agent used, concentration of agent, amount of agent and location of injection
- Attention should be paid to the amount of anesthetic given to avoid toxicity
  - Lidocaine w/o epi max dose = 4 mg/kg
  - Lidocaine with epi max dose = 7 mg/kg
- CNS excitation and lightheadedness are typically associated with toxicity
- Lidocaine with epinephrine may be used on digits, nose, etc
- Ensure that anesthesia is achieved prior to starting the procedure
- Always use sterile gloves when administering local anesthetic agents

Indications

- Local anesthesia for procedures
  - Sutures
  - Fracture/dislocation reduction
  - Incision and drainage

Contraindications

- Cellulitis/infection at injection site
- Bleeding disorders (relative)
  - Anticoagulant use
- Previous allergic reactions to anesthetic agent

Risks

- Infection
- Bleeding

- Nerve damage
- Anxiety/agitation (particularly in children)
- Tissue distortion (particularly with larger volumes)

General suggestions

- Always obtain informed consent before performing a block or a procedure
- Aspirate slightly before injecting anesthetic to ensure that the needle is not in a vascular structure
- If paresthesias are elicited during a block it is likely that the needle is in close proximity to a nerve/nerve sheath. If this occurs withdraw the needle slightly and reassess location before continuing the injection

Regional anesthetics

Hematoma block

- Easily performed
- Achieves reasonable anesthesia
- Ideal for distal radial fractures, gaining popularity with ankle fractures
- Time to onset: approximately 5 minutes

Contraindications

- Open fracture
- Grossly contaminated skin

Supplies needed

- Chlorhexidine swabs (or other cleaning solution)
- Lidocaine 1% or 2%
- 10 cc syringe
- 25-gauge needle (length dependent on patient habitus) for injection
- 18-gauge needle (for preparation/aspiration of solution to be injected)

Technique

- Place the injured extremity in a position of relative comfort
- Clean the skin overlying the hematoma with chlorhexidine swabs
- Fill the 10 cc syringe with lidocaine
- Insert the needle into the center of the hematoma
    - Enter the skin at a 90° angle
- Advance the needle until it hits bone

- Pull the needle back 0.5–1 cm
- Draw back blood to confirm placement of the needle in the hematoma
- Inject the lidocaine in a fan-like distribution
  - Goal: Anesthetize bone and periosteum
- Remove the needle
- Cover the injection site with a sterile bandage
- Proceed with necessary reduction(s)

Regional anesthesia

(Bier block)

Indications

- Anesthesia of large portion of a limb
  - Large lacerations
  - Burn
  - Foreign body
  - Long-bone fracture

Contraindications

- Hypertension
- Altered mental status patient
- Crush injury (relative contraindication)

Supplies

- Lidocaine 0.5% solution
  - Dose: 3 mg/kg
  - Mini Bier block dose: 1.5 mg/kg
- Sterile saline (for dilution)
- Pressure control pneumatic tourniquet
- 20-gauge (or larger) IV catheter
- 50 cc syringe
- Compression bandage
- Gauze pads
- 18-gauge needle for preparation/aspiration of anesthetic
- Chlorhexidine swabs (or other cleaning solution)

Procedure

- Dilute the lidocaine to 0.5% (if not prepackaged at this concentration)

- Apply the pressure controlled pneumatic tourniquet to the proximal aspect of the affected extremity
- Place the 20-gauge IV on the affected extremity
- Secure the IV
- Elevate the extremity to facilitate effective exsanguination
  - Compression of proximal arteries (axillary artery in the upper extremity, femoral artery in the lower extremity) may increase the efficacy of exsanguination
- Wrap the extremity (distally to proximally) with a compression bandage to further facilitate exsanguination
- Inflate the tourniquet to 50 mm Hg above systolic blood pressure
- Place the extremity in a neutral position
- Slowly inject the lidocaine 0.5%
- If less than complete anesthesia is achieved, inject 10–20 cc of normal saline
- Perform the necessary procedure
- Deflate the tourniquet in a cyclic fashion
  - Do not deflate the tourniquet until 30 minutes after infusion of the anesthetic
  - Deflate for 10 seconds, reinflate for 1–2 minutes
  - Repeat four to five times before removing tourniquet completely
- Remove the IV
- Serial neurovascular checks should be performed every 15 minutes following the procedure until neurologic function returns to baseline

Two-tourniquet technique

- Updated technique designed to limit systemic lidocaine toxicity
- Place two tourniquets in close proximity to each other on the proximal aspect of the affected extremity
- Proceed with the exsanguination process as in a classic Bier block
- Inflate the proximal cuff first (to 50 mm Hg above systolic blood pressure)
- Inject the anesthetic
- Inflate the distal tourniquet to 50 mm Hg above systolic blood pressure
  - Do not inflate the distal tourniquet until at least 25 minutes after anesthesia is achieved
- Deflate the proximal tourniquet as per the classic technique
- Perform therapeutic procedure
- Deflate the distal tourniquet as per the classic technique

Results

- Anesthesia progresses distally to proximally
- Onset of anesthesia: 3–5 minutes
- Complete anesthesia: 10–20 minutes
- Muscle relaxation typically follows complete anesthesia
- Sensation returns within 5–20 minutes of cuff deflation

Ulnar nerve block at the elbow

- Not recommended because of high rate of chronic nerve complications

Ulnar nerve block at the wrist

Supplies

- 25-gauge needle for injection (length dependent on patient habitus)
- 18-gauge needle for preparation/aspiration of anesthetic
- 10 cc syringe
- Skin cleaning solution
- Lidocaine 1% or 2%

Positioning

- Place the patient in a position of comfort
- Keep the elbow in a position of comfort
- Supinate the hand

Anatomy

- Identify the flexor creases of the wrist (Figure 9.1)
- Palpate the ulnar artery
- Identify the flexor carpi ulnaris tendon by flexing the patient's wrist
- The ulnar nerve runs between the flexor carpi ulnaris tendon and the ulnar artery in the area between the proximal and distal palmar creases

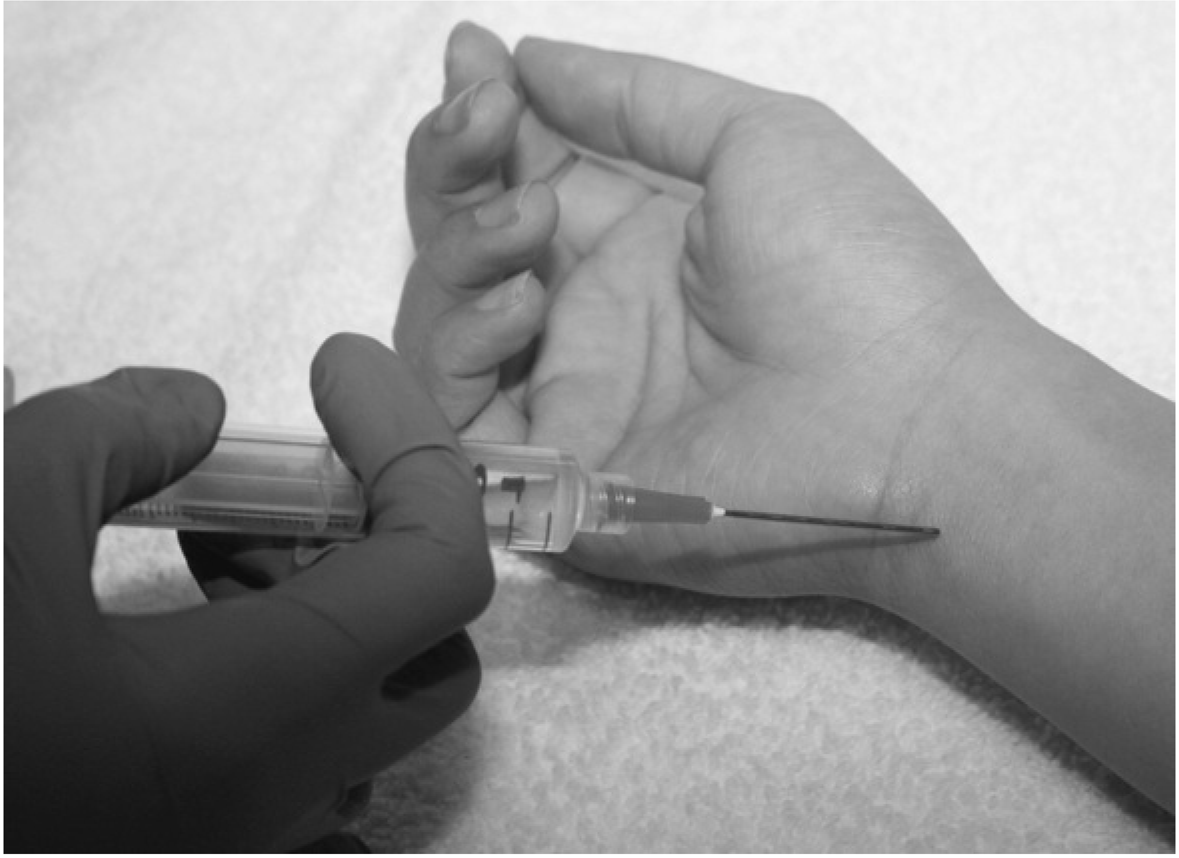

Figure 9.1 The needle cap is pointing to the location of the ulnar nerve where the block should be placed. The correct location is between the flexor carpi ulnaris tendon and the ulnar artery, which is medial to the nerve. (Image courtesy of Michael Bond, MD.)

Procedure

- Identify the landmark
- Clean the skin
- Enter the skin at a 90° angle
- Inject 1–2 ml of lidocaine to the skin and subcutaneous tissue
- Advance the needle to the anatomic location of the ulnar nerve
    - The ulnar nerve is relatively superficial, sitting less than 1 cm deep
- Inject 3–5 ml of lidocaine

Radial nerve block at the elbow

- Not recommended because of high rate of chronic nerve complications

Radial nerve block at the wrist

Supplies

- 25-gauge needle for injection (length dependent on patient habitus)
- 18-gauge needle for preparation/aspiration of anesthetic

- 10 cc syringe
- Skin cleaning solution
- Lidocaine 1% or 2%

Positioning

- Place the patient in a position of comfort
- Keep the elbow in a position of comfort
- Place the hand in a neutral position

Anatomy

- Identify the flexor creases of the wrist (Figure 9.2)
- Palpate the radial artery at the level of the proximal flexor crease
- The radial nerve runs just lateral to the radial artery at this location

Figure 9.2 The needle cap is pointing to the location of the radial nerve where the block should be placed. The radial nerve is just lateral to the radial artery at the flexor crease. (Image courtesy of Michael Bond, MD.)

Procedure

- Identify the landmark
- Clean the skin
- Enter the skin at a 90° angle
- Inject 1–2 ml of lidocaine to the skin and subcutaneous tissue
- Advance the needle to the anatomic location of the radial nerve
    - The radial nerve is relatively superficial, sitting less than 1 cm deep
- Inject 3–5 ml of lidocaine

Digital block

Supplies

- 25-gauge needle for injection (length dependent on patient habitus)
- 18-gauge needle for preparation/aspiration of anesthetic
- 3 cc syringe
- Skin cleaning solution
- Lidocaine 1% or 2%

Positioning

- Place the patient in a position of comfort
- Keep the elbow in a position of comfort
- Pronate the hand

Anatomy

- Fingers are innovated via digital nerves, which run along both sides of the phalanx
- Identify the web space on both the radial and the ulnar aspects of the affected digit
- Identify the metacarpal head of the affected digit

Procedure

- Identify the landmarks
- Clean the skin
- Enter at the midportion of the web space (Figure 9.3) or at the base of the metacarpal (Figure 9.4)
- Hold the needle at a 90° angle to the skin
- Advance the needle to the anatomic location of the digital nerve
  - The digital nerves are relatively superficial, sitting less than 1 cm deep
- Inject 1 ml of lidocaine
- Repeat the procedure on the other side of the affected digit

Figure 9.3 The needle cap is pointing to one of the locations where a digital nerve block can be placed. (Image courtesy of Michael Bond, MD.)

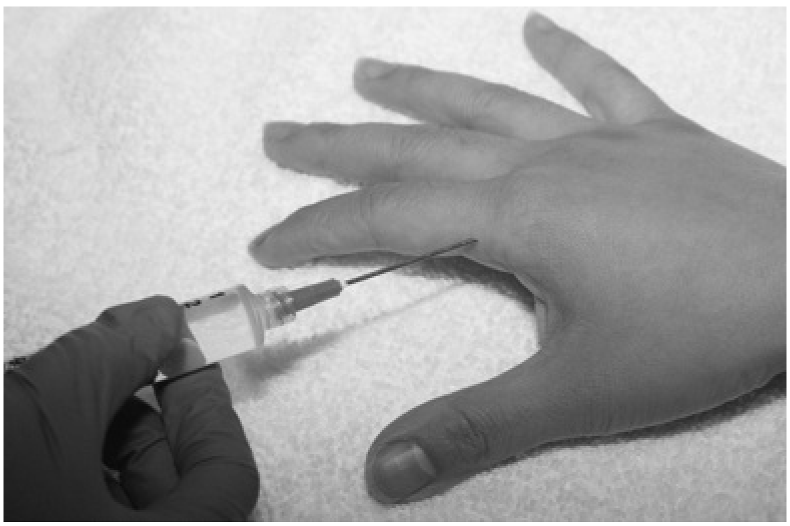

Figure 9.4 An alternate location for a digital nerve block is at the base of the metacarpal head. The needle cap is pointing to this location. (Image courtesy of Michael Bond, MD.)

Ring block

Supplies

- 25-gauge needle for injection (length dependent on patient habitus)
- 18-gauge needle for preparation/aspiration of anesthetic
- 3 cc syringe
- Skin cleaning solution
- Lidocaine 1% or 2%

Positioning

- Place the patient in a position of comfort
- Keep the elbow in a position of comfort

- Pronate the hand

Anatomy

- Fingers are innovated via digital nerves, which run along both sides of the phalanx
- Identify the web space on both the radial and ulnar aspects of the affected digit
- Identify the metacarpal head of the affected digit

Procedure

- Identify the landmarks
- Clean the skin
- Enter the radial aspect of the affected digit at the metacarpal head (Figure 9.5)
- Advance the needle horizontally across the base of the affected phalanx
- Inject 1 ml of lidocaine across the dorsum of the phalanx while withdrawing the needle to the point of insertion
- Remove the needle and then reinsert the needle, advancing toward the volar aspect of the digit
- Inject another 1 ml of lidocaine along the side of the digit
- Remove the needle
- Supinate the hand
- Insert the needle at the radial side of the volar aspect of the affected digit
- Advance the needle horizontally across the base of the affected phalanx
- Inject 1 ml of lidocaine across the volar surface of the phalanx while withdrawing the needle to the point of insertion

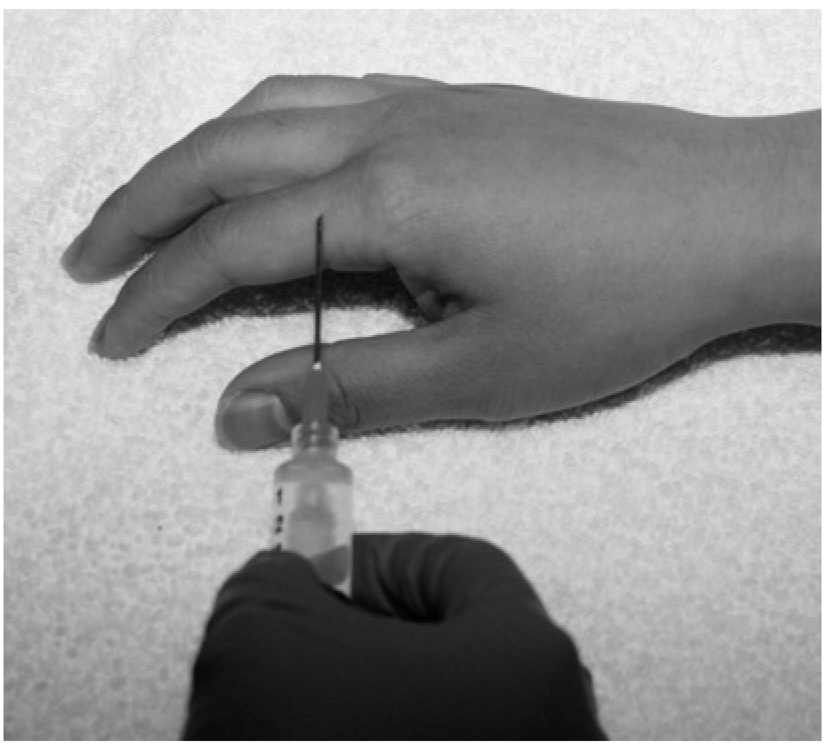

Figure 9.5 A ring block can be performed by infiltrating anesthetic in a ring-like distribution around the base of the finger. The needle is shown where you would typically enter the skin to place the anesthetic. (Image courtesy of Michael Bond, MD.)

Femoral nerve block

Supplies

- 25-gauge needle for injection (length dependent on patient habitus)
- 18-gauge needle for preparation/aspiration of anesthetic
- 30 cc syringe
- Skin cleaning solution
- Lidocaine 1% or 2%

Positioning

- Place the patient supine on a stretcher
- Externally rotate the leg approximately 15–20°

Anatomy

- The femoral nerve runs in parallel with the femoral artery and femoral vein in the inguinal area
  - The mnemonic NAVEL (nerve, artery, vein, empty space, lymphatic) is often used to remember the anatomy, with the femoral nerve being the most lateral of the structures
- The ideal approach is at the midpoint between the anterior superior iliac spine and the lateral aspect of the pubic symphysis, approximately 2 cm distal to the inguinal ligament

Procedure

- Identify the landmarks
- Clean the skin
- Palpate the femoral artery
- Inject 1–2 ml of lidocaine to the skin and subcutaneous tissue just lateral to the palpable femoral pulse
- Enter the skin at a 90° angle
- Advance the needle to the anatomic location of the femoral nerve
  - The needle is in the correct area when the patient develops paresthesias
- Pull the needle back 5 mm (or until paresthesias resolve) before injecting 15–20 ml of lidocaine

Arthrocentesis

Indications

- Diagnosis of joint disease (septic versus crystal-induced arthritis)
- Relief of pain from a large, tense joint effusion or acute hemarthrosis
- Inject lidocaine or steroids for pain relief in inflammatory arthritis
- Evaluating a joint to see if a laceration violates the joint capsule

Contraindications

- Absolute
  - Infection overlying the joint
- Relative
  - Known bacteremia
  - Bleeding diathesis
  - Prosthetic joint

Equipment

- Sterile drapes and gloves
- Skin preparations
- Local anesthetic
- Syringe
- Needles
- Collection tubes

Technique

- Use strict aseptic technique
- Local anesthesia
- Identify landmarks
- Ultrasound may help to localize the joint fluid collection
- 18–22-gauge needle attached to syringe (a 3-way stopcock may be used with large effusions)
- Aspiration of synovial fluid should flow easily. If fluid stops, advance or retract slightly, rotate bevel, or decrease the force of aspiration. If the needle is blocked, a small amount of sterile fluid may be injected
- Remove as much synovial fluid as possible

Key anatomy

- Specific sites
  - Knee
    - The knee should be near full extension (flexed 10–15°) but not locked as the quadriceps must be relaxed
    - The middle or superior portion of the patella is the landmark
    - Insert an 18-gauge needle 1 cm inferior to the medial aspect of the patella (Figure 9.6). Alternatively, a lateral approach can be used
    - Compression of the joint effusion can increase the amount of fluid removed
  - Wrist
    - Lister's tubercle, the dorsal radial tubercle, is a prominence located in the center of the distal end of the dorsal radius
    - The extensor pollicis longus (EPL) runs in a groove on the radial aspect of this tubercle

- Flex the wrist 20–30° with some ulnar deviation while applying traction to the hand
- Insert a needle perpendicularly distal to Lister's tubercle on the ulnar side of the EPL (see Figure 9.7)

◦ Elbow
  - Palpate the radial head with the arm extended then flex the elbow to 90° with the forearm pronated
  - Insert the needle from the lateral aspect at the center of the triangle between the radial head, olecranon, and the lateral epicondyle. Palpate a depression just proximal to radial head to identify this entry site (see Figure 9.8)
  - Direct the needle toward the distal edge of the antecubital fossa while keeping it perpendicular to the radius

◦ Ankle (medial approach)
  - The medial malleolus sulcus is bordered by the medial malleolus medially and the anterior tibial tendon laterally
  - Plantar flex the foot
  - Insert a 20–22-gauge needle just medial to the anterior tibial tendon directed at anterior edge of medial malleolus and advance 2–3 cm to penetrate joint

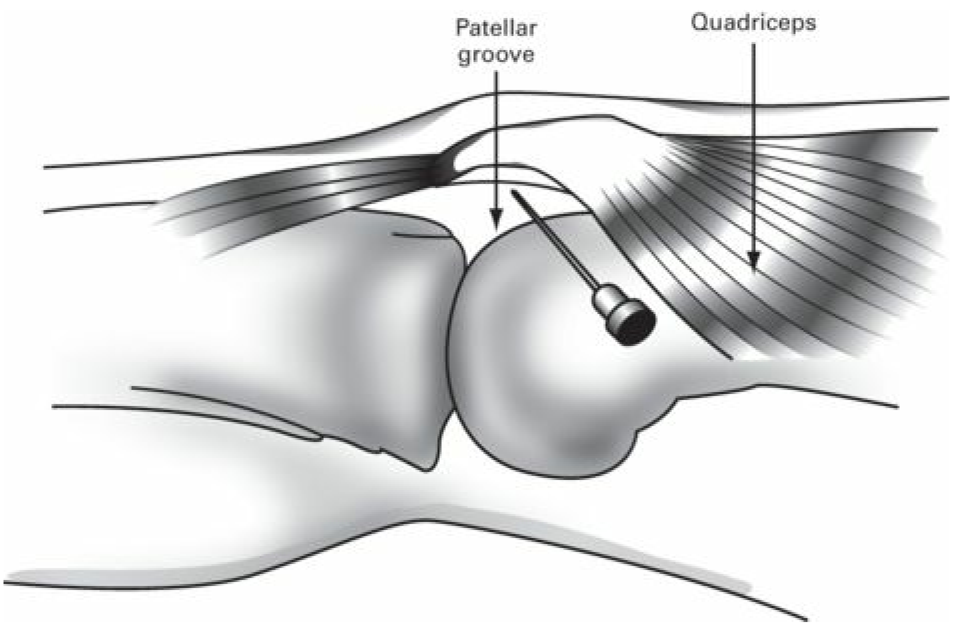

Figure 9.6 An arthrocentesis of the knee is performed by placing an 18-G needle 1cm inferior to the medial aspect of the patella as shown. (Image used with permission from McGraw-Hill; originally published in *Emergency Orthopedics*.)

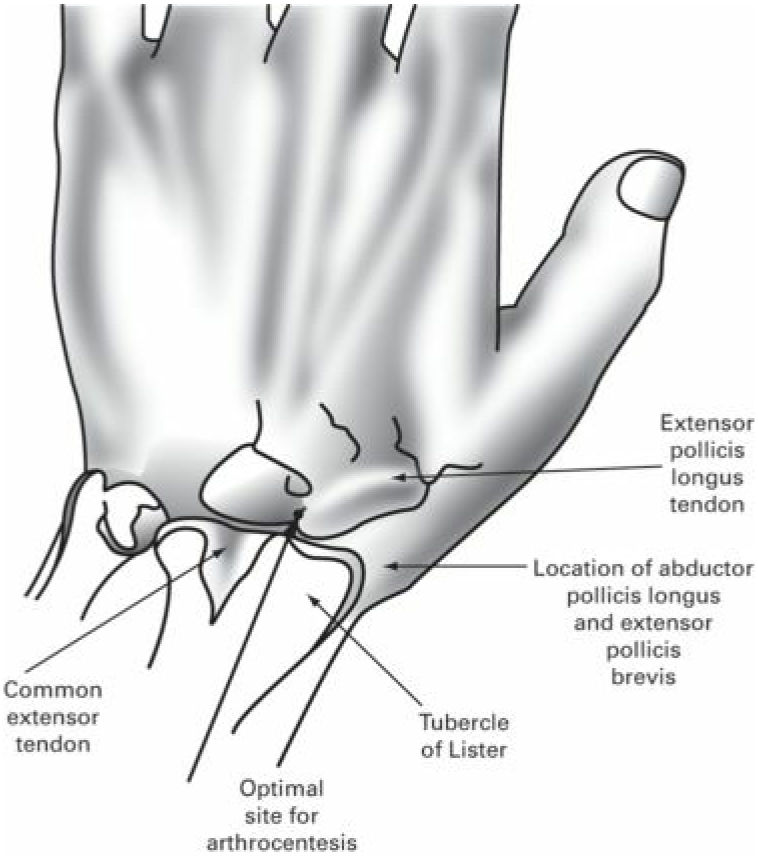

Figure 9.7 The optimal site for arthrocentesis of the wrist is shown. (Image used with permission from McGraw-Hill: originally published in *Emergency Orthopaedics*.)

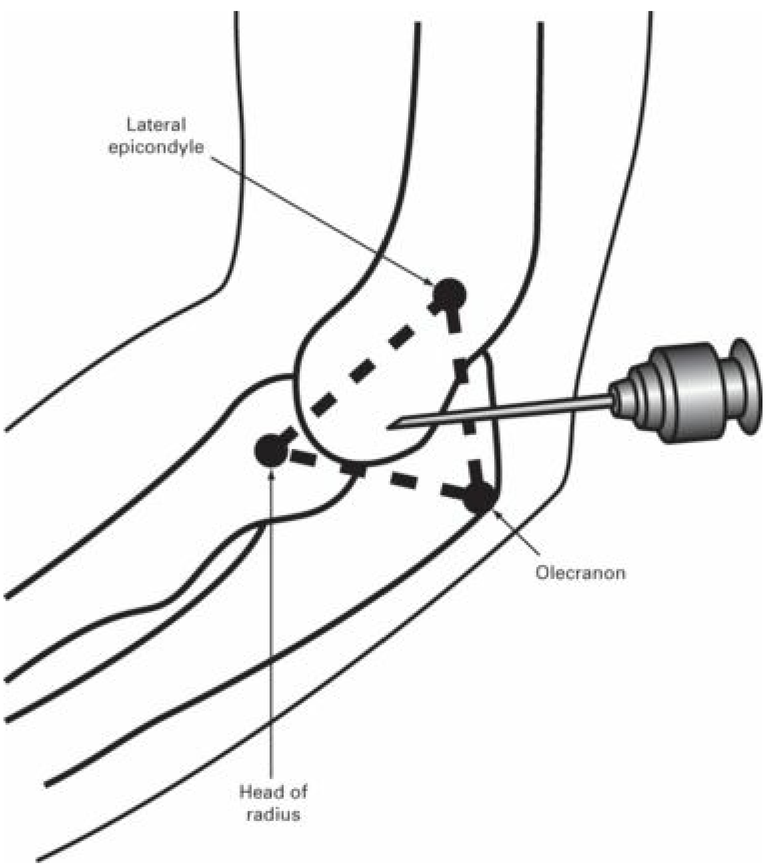

Figure 9.8 The optimal site for arthrocentesis of the elbow is shown. The needle should be inserted into the palpable depression just proximal to the radial head. (Image used with permission from McGraw-Hill; originally published in *Emergency Orthopedics*.)

Fluid analysis

- Gram stain, culture, and sensitivity
- Cell count with differential
- Crystals
- Lactate
- Glucose, protein
- May see fat globules if occult fracture

Complications

- Infection
- Bleeding
    - In hemophiliacs, clotting factor is administered before arthrocentesis
- Dry tap

• PEARLS:

- Aseptic technique is essential
- Most important aspect of technique is palpating the bony landmarks to define joint space. Ultrasound may assist
- Approach is usually on the extensor surface as major vessels and nerves are located on the flexor side
- Mild flexion and traction may open up the joint spaces that are being tapped from the extensor surface
- Prosthetic joints are at high risk for infection. Have a low threshold for orthopedic consultation

Nail trephination

Indications

- Subungal hematoma
    - Common, painful
    - Caused by nailbed injury
    - Described by the percentage of nail under which blood can be seen

Techniques

- Hot microcautery unit
    - Prep with povidone–iodine solution (***not*** alcohol, which catches fire)
    - Apply slight downward pressure
    - Stop applying pressure when resistance gives way, to avoid damage to the nailbed
- Heated paper clip

    - Same as above
- Needle
    - Prep with povidone–iodine solution
    - Apply slight downward pressure to needle as you rotate it back and forth
    - Widen opening to encourage continued drainage
    - Some authorities advocate multiple holes

Complications

- Nail loss or deformity (always warn patient)
- Paronychia
- Osteomyelitis (rare)

PEARLS:

- > 50% subungal hematoma may warrant nail removal for nail bed repair (traditional teaching, now controversial)
- Intact nail provides splint and better long-term results (modern philosophy)
- X-ray to rule out underlying fracture (not mandatory, may use clinical judgement)
- Trephination provides excellent pain relief

General fracture-reduction techniques

Indications

- Displaced fracture with neurovascular compromise requires immediate reduction
- Displaced fracture that will be definitively managed with a closed reduction

Key anatomy/techniques

- General principles
    - Always assess and document neurovascular status before and after reduction
    - The periosteum on the side of the fracture to which the fragment is displaced usually remains intact
    - This periosteum forms a hinge to relocate the displaced distal fragment (see Figure 9.9)
    - The type of fracture and the degree of displacement will determine how much force and manipulation are required (see Figure 9.10)
    - After a regional block, hematoma block, or procedural sedation, traction is applied to the distal fragment with countertraction applied to the proximal fragment
    - The deformity is exaggerated if necessary, and any rotational deformity is corrected
    - The distal fragment is then reduced as the angular deformity is corrected
    - Appropriate immobilization is then applied. The method of immobilization varies with the specific injury involved
    - How do you tell if reduction is adequate?

- Rotational deformity is completely corrected regardless of age
- Angular deformity is corrected for adults
- Children tolerate some angular deformity (15–20°) if it is near the joint and in the same plane of motion
- Weight-bearing joints require precise, anatomic reduction
- Proper length is mandatory in lower extremity injuries
- Anatomic reduction is confirmed by repeat radiographs, portable fluoroscopy, or bedside ultrasonography as clinical assessment of reduction is difficult

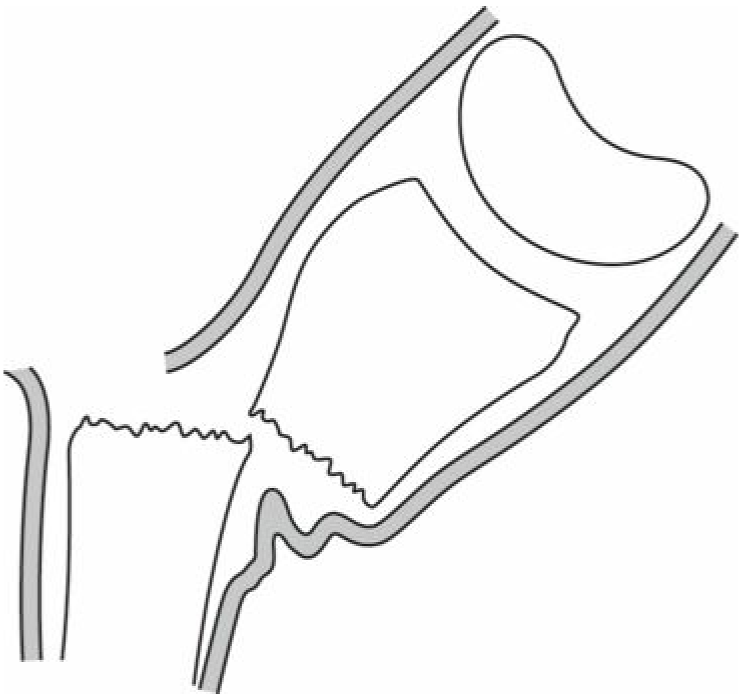

Figure 9.9 A diagram of how the periosteum acts as a hinge is shown.

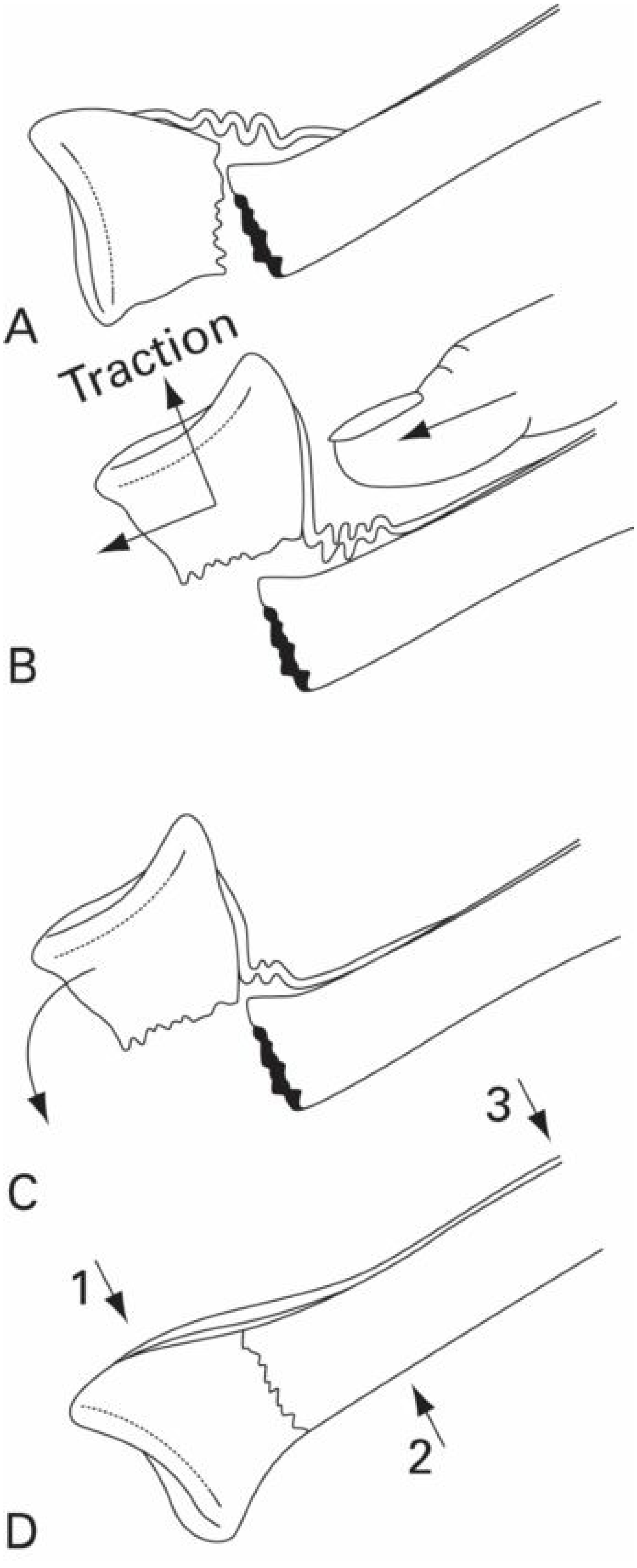

Figure 9.10 A: The fracture at baseline before any reduction attempt is made. Notice how the distal fragment is displaced superiorly in the photo; this could be reduced with longitudinal traction. B: Shows a distal fragment that is shortened and overlaps the proximal bone. The longitudinal traction will need to be applied to the distal fragment to disengage the bone from the proximal portion and pressure is applied to push the distal fragment into its proper position. C: Demonstrates the next step where the distal fragment is then swung into proper position. D: Shows how the well-reduced bone is properly aligned. Force was applied to points 1 and 2 while point 3 was stabilized in order to get a good reduction.

Specific sites

- **Distal radius fractures**
  - **Colles fracture** – refer to orthopedist after reduction because of high incidence of complications (stiffness, arthritis, compartment syndromes)
    - Only reduce those without intra-articular involvement
    - Procedural sedation, hematoma block, or Bier block can be used for anesthesia
    - Longitudinal traction (finger traps if available) to disimpact the distal fracture fragment (see Figure 9.11)
    - Recreating the mechanism of injury and the position of the bony fragments at injury to relax the periosteal ligaments allows more effortless reduction of the fracture
  - Extend the wrist to 90°, with the elbow fixed and the forearm supinated, and pull the distal segment back, up, and out at approximately 120°
  - Apply dorsal pressure over distal fragment with both thumbs and apply volar pressure. With the thenar eminence of physician's hand over fracture site, direct the fragment in an ulnar and volar direction to achieve proper position
  - Immobilize the wrist at 15° of flexion and with 20° of ulnar deviation. (Though some orthopedists prefer pronation) application of a plaster **sugar tong splint** or **bivalve cast** with the wrist held in slight flexion, with slight ulnar deviation and pronation of the forearm
  - Obtain post-reduction radiographs
    - Goals for adequate reduction
    - Restore length of radius. Normal distance from articular surface of ulnar to tip of radial styloid is 12 mm
      - Normal radial inclination is 15–30° (see Figure 9.12)
        Achieve at least a neutral volar tilt (0°). Optimally, re-establish a normal volar tilt (10–15°) (see Figure 9.13)
      - Reassess and document neurovascular status of the extremity after reduction. Document function of the median nerve and the sensory branch of the radial nerve
- **Metacarpal neck fractures**
  - Evaluate for rotational deformity
  - Mechanism of injury results in angulation of distal segment toward palm (volarly); usually occurs as a result of a direct blow to the knuckles
  - Index(2nd) and middle(3rd) fingers:
    - Eliminate angulation at the fracture sites of these fingers. Patients cannot tolerate more than 10–15° angulation of these fractures. Goal is minimal angulation to precise anatomic reduction
  - Ring(4th) and little(5th) fingers:
    - The metacarpals of the ring and little fingers allow flexion and extension at carpal attachments. These patients can tolerate greater angulation at the fracture site without loss of function. Although up to 30–40° of angulation is acceptable, the goal is 10–15° of angulation or less for 4th metacarpal neck fractures and 20–30° of angulation or less for 5th metacarpal neck fractures
  - Closed reduction
    - After hematoma block, apply longitudinal traction either manually or with finger traps to disimpact the distal fragment

- Flex the involved finger to 90° at MCP joint and 90° at PCP joint with the palm facing the floor
- Stabilize the metacarpal and apply force longitudinally upward through the proximal phalanx to reduce angulation deformity (see Figure 9.14)
- Immobilize with **ulnar gutter splint** for 4th and 5th metacarpal fractures with the wrist extended 20–30° and the MCP joint flexed 90°. Immobilize with a **radial gutter splint** for 2nd and 3rd metacarpal fractures
- Metacarpal neck fractures are easy to reduce but hard to maintain. These fractures often require wire placement to maintain alignment

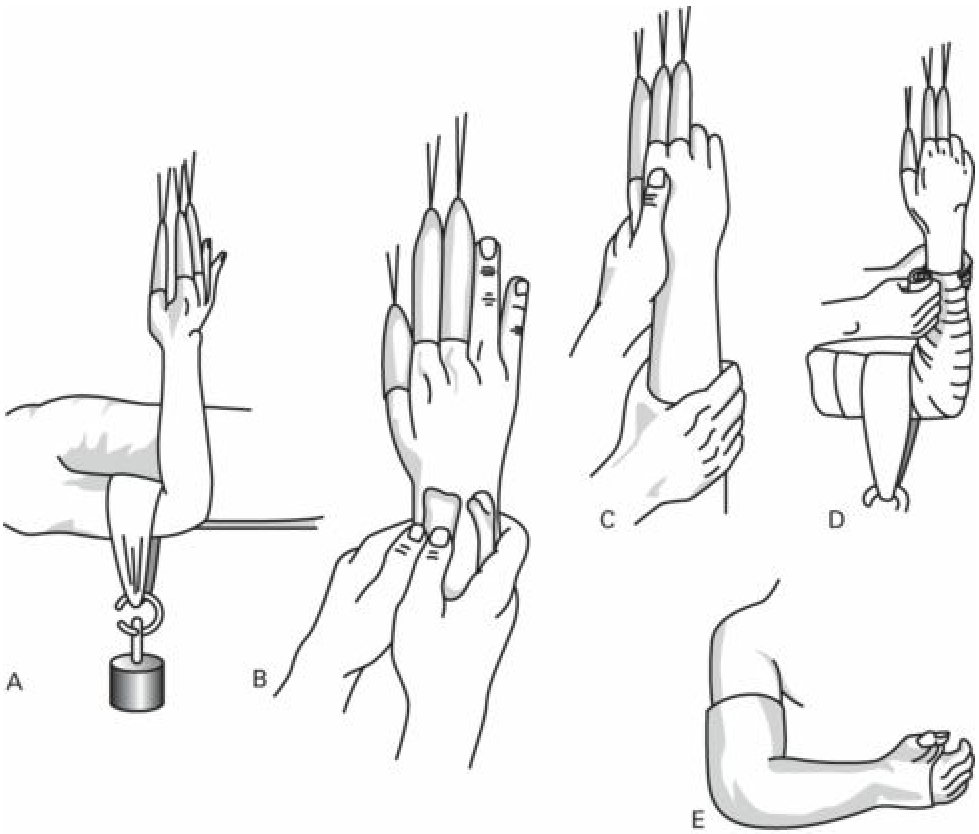

Figure 9.11 A: The fingers are placed in fingertraps and weight is applied to the flexed elbow in order to introduce traction that will separate the bone fragments. B: The fracture, that is under traction, is then manipulated with volar pressure to reduce the fracture. C: Longitudinal traction can be further applied to ensure proper alignment. D: A posterior arm or sugar tong splint can be applied while traction is maintained to ensure the reduction is maintained until splinted. E: The arm is shown with finished splint in place.

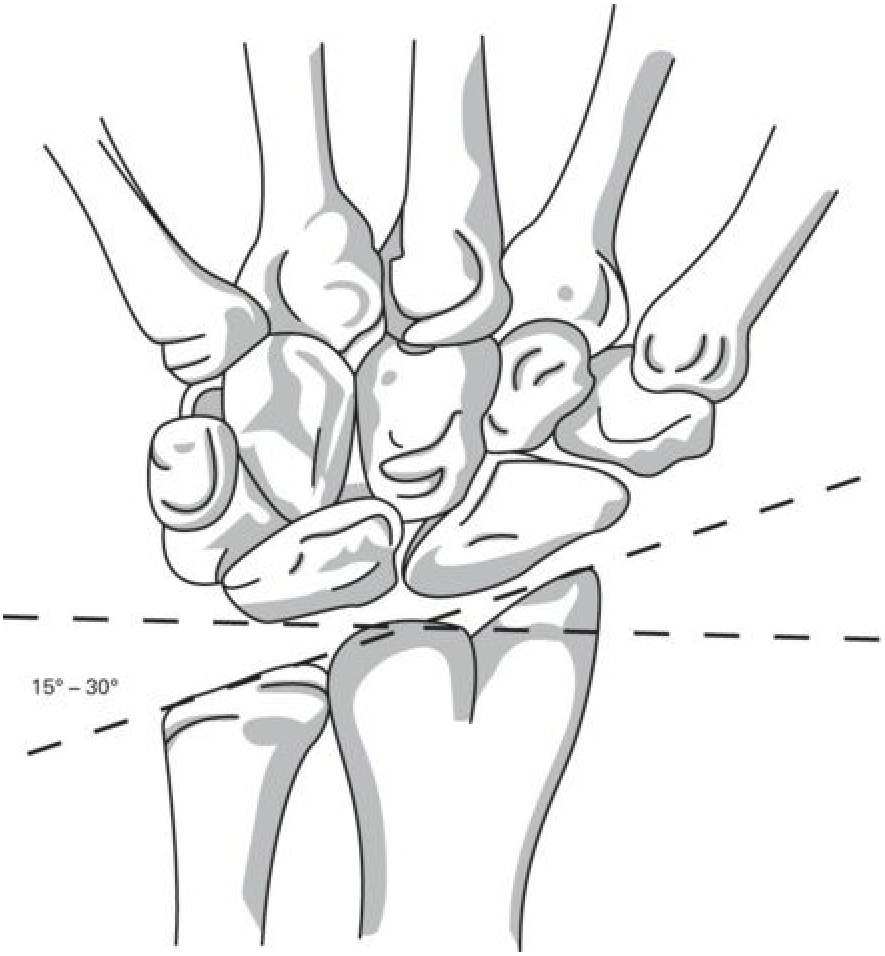

Figure 9.12 A goal of reduction is to ensure there is a normal radial inclination of 15–30°.

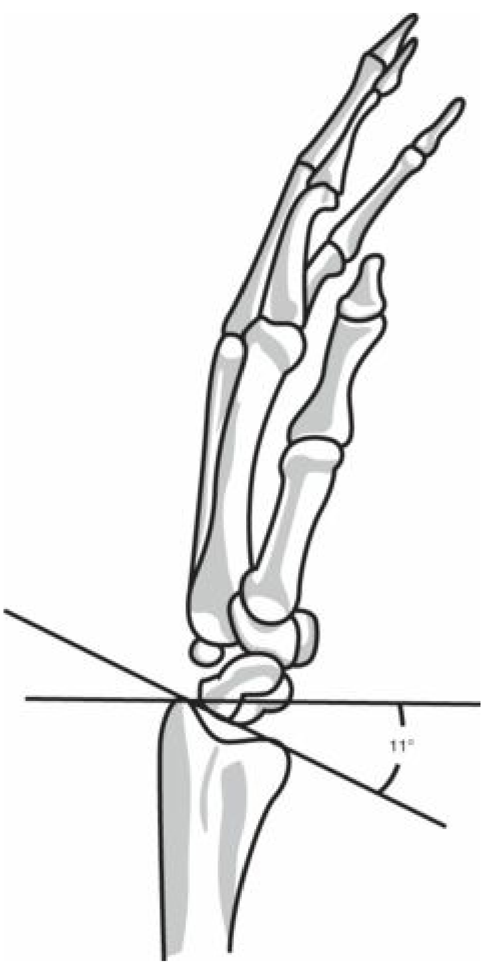

Figure 9.13 A goal of reduction is to ensure there is a normal volar tilt of 10–15°, but you need to

ensure that the volar tilt is at least neutral. The volar tilt angle is shown.

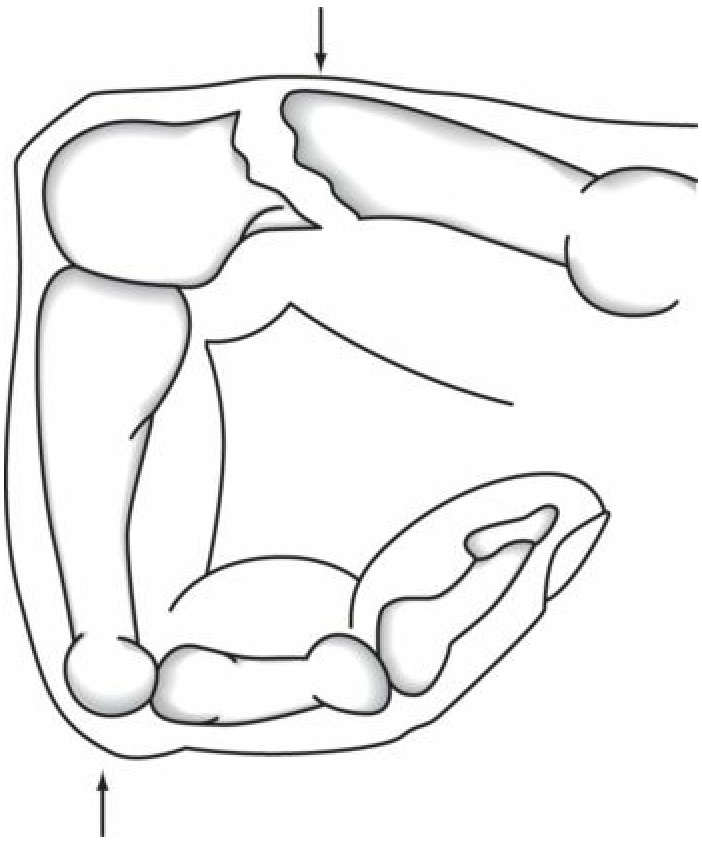

Figure 9.14 In order to reduce a metacarpal shaft fracture, longitudinal traction is applied to the distal finger while palmar pressure is applied to the dorsal proximal metacarpal to cause the reduction.

Complications of closed reductions

- Irreducible fractures
- Failure to maintain reduction
- Neurovascular injuries
- Malrotation

PEARLS:

- Closed reduction is ineffective for spiral fractures or comminuted fractures as the ends cannot be engaged to prevent shortening
- Accurate reduction of the fracture is essential for obtaining good functional results
- Early reduction lessens morbidity and improves patient comfort
- Pediatric Salter–Harris Type III and IV fractures require precise anatomic reduction to prevent growth disturbance

Ankle dislocation

Key facts

- Tibiotalar dislocations without fracture are rare and often are open dislocations caused by the amount of force required to cause the dislocation
- Bimalleolar and trimalleolar fractures often are associated with tibiotalar subluxation or dislocation
- Early reduction is recommended to prevent further osteochondral injury and vascular injuries
- Subtalar dislocations are rare with medial dislocation making up 85% of these dislocations

Clinical presentation (see Chapter 5: Foot and ankle emergencies)

PEARL: Evaluate for vascular compromise, specifically dorsalis pedis artery, which is often compressed with anterior dislocations.

Fast facts

- Lateral ankle fracture dislocations are most common, followed by posterior and then anterior. Usually there is obvious deformity of the foot and ankle with foot displaced laterally and skin very taut medially
- Foot is usually plantar flexed and shortened
- Decreased dorsalis pedis pulse is common with anterior dislocations
- Open dislocations occur in up to 25% of ankle dislocations

Reduction techniques (see Figure 9.15)

- Always flex hip and knee to 90° to relax gastroc-soleus complex
- Posterior dislocation: Grasp heel with one hand and dorsum of mid-foot with other hand. Pull longitudinal traction and then anterior traction. Second practitioner can place hands under distal thigh and pull countertraction while hip and knee are 90° flexed. Can also perform one person reduction while patient is seated with leg hanging off edge of stretcher
- Anterior dislocation: Grasp foot in same way as posterior dislocation. Initially dorsiflex the foot slightly to disengage the talus. Then apply axial traction followed by pushing foot posteriorly. Second practitioner can hold traction on tibia while pulling it anteriorly
- Lateral dislocation: Apply distal traction to plantar flexed foot and then rotate to proper anatomic position

Figure 9.15 Ankle dislocation reduction. An assistant should stabilize the proximal leg as marked by the red arrow. The provider will apply longitudinal traction as noted by (1) while applying first an upward force (2) and then a downward force (3) to cause the reduction. (Images courtesy of Ryan Friedberg, MD.)

Post reduction

- Check pulses after reduction. If pulses are not palpable after reduction, emergent orthopedic and vascular consultation are needed
- Splint in **posterior and sugar tong splint**
  - Often dislocation is very unstable and proper splinting with foot in 90° flexion is important to maintain reduction

Clavicle dislocations/fractures

Key facts

- Sternoclavicular joint is made up of sternoclavicular ligament and costoclavicular ligament
- Acromioclavicular joint is made up of acromioclavicular ligament, coracoclavicular ligament and coracoacromial ligament
- Posterior sternoclavicular dislocation can be a **true orthopedic emergency** because of other injuries including tracheal rupture, pneumothorax, esophageal injuries or vascular injuries, thus requiring emergent reduction

Clinical presentation (see Chapter 2: Shoulder and elbow emergencies)

PEARL: Always evaluate for associated injuries because of a high-energy mechanism causing sternoclavicular dislocation.

Fast facts

- High-energy mechanism such as motor vehicle crash, fall or collision sport are usual cause
- Anterior sternoclavicular dislocation more common than posterior
- Anterior: Protrusion of proximal clavicle with obvious asymmetry
- Posterior: Unable to palpate medial end of clavicle
  - Soft-tissue swelling could give impression of anterior dislocation
- Numbness and edema in the extremities can occur secondary to venous compression from posterior dislocation

Treatment

- Procedural sedation often required for reduction of posterior dislocations

Closed reduction technique (Figure 9.16)

- Patient in supine position with folded sheet between scapula with arm abducted to 90°
- One practitioner pulls traction on arm, while second practitioner pushes down on proximal clavicle for anterior dislocations and pulls out on clavicle for posterior dislocations
- If unable to reduce posterior dislocations, towel clips could be used to grasp clavicle to aid reduction
  - Use lidocaine to anesthetize skin
  - Use aseptic technique
  - Make small incision where puncture sites will be
  - Grasp sides of clavicle
  - Be careful of underlying vascular structures

Figure 9.16 Clavicle dislocation reduction. A sheet should be placed across the patient's chest and held by an assistant. Traction is applied to the arm (as shown by red arrow), while pressure is applied to the clavicle to cause the reduction. (Image Courtesy of Ryan Friedberg, MD.)

Post reduction

- Place pressure dressing on joint after anterior reduction with figure-of-8 sling
- Posterior dislocations can be placed in figure-of-8 sling or shoulder sling
  - Posterior dislocations are usually stable, once reduced
- All posterior dislocations that are not reducible by closed treatment should be reduced with open reduction by orthopedic or thoracic surgeon
- Decision to reduce anterior dislocations not reducible by closed methods should be made by orthopedic or thoracic surgeon as these dislocations can be unstable and often re-dislocate

Elbow dislocations

Key facts

- 90% of elbow dislocations are posterior
- Common mechanism is fall on to extended and abducted arm
- Neuropraxia can occur in 20% of dislocations with ulnar and median nerve being most common
- Anterior dislocations more likely to cause vascular injury of brachial artery

Clinical presentation (see Chapter 2: Shoulder and elbow emergencies)

PEARL: Examine whole upper extremity for shoulder and/or wrist injuries.

Fast facts

- Common mechanism for posterior dislocation is fall on to extended and abducted arm
- Common mechanism for anterior dislocation is a result of a blow to olecranon while the elbow is in extension and forearm is supinated
- Patients present with obvious deformity of elbow usually with olecranon protruding posteriorly
- Elbow held in flexed position: posterior dislocation
- Elbow held in extension: anterior dislocation

PEARL: Fractures can occur in up to 60% of elbow dislocations with supracondylar fractures in children and medial epicondyle fractures in adults being most common.

Prior to reduction attempts

- Always check skin integrity as open dislocations should always be evaluated by orthopedic surgery
- Evaluate neurologic function distal to elbow
- Evaluate for vascular injury
- Evaluate for compartment syndrome in forearm
- Evaluate shoulder and wrist for associated injuries
- Obtain AP and lateral plain radiographs before and after reduction

Treatment

- Procedural sedation will likely be needed to reduce the elbow dislocation
- Posterior reduction techniques:
  - Traction–counter-traction
    - Patient lies supine while one person grabs wrist and forearm and applies longitudinal traction, while other person holds counter-traction by grasping mid-humerus
    - Person holding forearm then flexes elbow while keeping longitudinal traction
    - Palpable clunk should be felt as elbow is reduced (Figure 9.17)
  - Alternate position for traction–counter-traction:
    - Patient lies prone while one person grasps forearm and applies longitudinal traction with elbow in extension
    - Second person applies counter-traction by grasping mid-humerus
    - The first person then flexes elbow and can use thumb on olecranon to help guide elbow back in place (Figure 9.18)
  - Stimson technique
    - Prone position: Hang weight from hand with elbow flexed at 90°
    - With muscle relaxation the elbow will typically self-reduce
    - If not self-reduced the provider can help push the olecranon into position
- Anterior dislocation: Rare
  - Higher concern for neurovascular compromise
  - Consider urgent orthopedic consultation
  - Reduction technique:

        - Patient is supine while one person grasps wrist and applies in-line traction while other hand applies downward pressure to proximal forearm
        - Second person applies counter-traction by grabbing humerus
- Medial/lateral dislocations:
    - Same reduction technique as posterior dislocations

Figure 9.17 Elbow dislocation reduction. – An assistant should stabilize the proximal arm as shown by red arrow. The provider will apply longitudinal traction as noted by 1, and then flex the elbow in direction 2 to reduce the dislocation. (Image courtesy of Ryan Friedberg, MD.)

Figure 9.18 Elbow dislocation reduction. With the patient lying prone, the arm can be hung off the edge of the bed. Longitudinal traction is applied on the distal arm while the proximal arm is stabilized with your other hand. (Image courtesy of Ryan Friedberg, MD.)

Post reduction

- Post-reduction films should be done to evaluate for fractures and proper reduction
- Neurovascular status should be evaluated post reduction
- Patients should be splinted with **posterior splint** in 90–100° of flexion to prevent redislocation and then sling for comfort
- If concerned about elbow instability in splint, place forearm in pronation with elbow in 90–100° of flexion
- Orthopedic follow up within 1 week

Prognosis

- Redislocations are rare with posterior dislocation
- Early protected mobilization within 2 weeks is recommended to prevent flexion contracture
- Be aware that delayed vascular compromise could occur

Fibular dislocations

Key facts

- Rare injury that accounts for less than 1% of knee injuries
- Reported in football, ballet, snowboarding, and parachuting
- Easily missed on plain radiographs and comparison views are recommended when it is suspected

Clinical presentation (see Chapter 4: Knee and leg emergencies)

PEARL: Always check for proximal fibular pain with ankle sprains.

Fast facts

- Anterolateral dislocations account for ~85% of dislocations
- Posterior medial dislocations: ~10%
- Superior dislocations: ~2%
- Associated with peroneal nerve injuries
- Congruity of the proximal tibiofibular joint on lateral views is the key to diagnosis

Treatment

- Pain medication or procedural sedation may be necessary for reduction
- Reduction techniques:
  - Attempt closed reduction
    - Flex knee to 90°, evert, and dorsiflex ankle
    - Then apply direct pressure to the fibular head (Figure 9.19)
    - If unable to reduce, will need ORIF by orthopedic surgery

Figure 9.19 Fibula reduction – flex knee to 90°, evert and dorsiflex the ankle with one hand while

applying direct pressure to the fibular head with the other. (Image courtesy of Ryan Friedberg, MD.)

Post reduction

- If reduction successful, place in posterior and sugar tong splint with crutches and non-weight-bearing
- Patient should follow up with orthopedic surgeon within 1 week for repeat radiographs to make sure fibula is stable

Prognosis

- If closed reduction is successful, patients usually will not need surgical fixation
- If unable to reduce closed, open reduction with capsular and ligament repair is performed
- Missed dislocations could result in chronic pain and disability

Finger dislocations

Key facts

- PIP joint dislocations are the most common finger dislocation
- Dorsal dislocations much more common then volar dislocations, which are rare
- The volar plate can become trapped inside the joint, making reduction difficult

Clinical presentation (see Chapter 1: Hand and wrist emergencies)

PEARL: Make sure to evaluate skin integrity, as open PIP dislocations are not uncommon.

Fast facts

- MCP joint dislocations are rare. Dorsal dislocation most common
- Classic presentation is the joint held in 60–90° of hyperextension with the finger ulnar-deviated
- Complex dislocations can be subtle. Findings could include dimpling of palmar skin or palpable metacarpal head on volar surface
- Volar dislocations often involve rupture of central slip and can result in a Boutonniere deformity
- Volar plates are usually disrupted in both dorsal and volar PIP dislocations
- DIP dislocations are usually dorsal and often result in an open dislocation

Treatment

PEARL: Avoid urge to apply direct longitudinal traction initially during reduction as this may trap volar plate in joint and prevent reduction.

PEARL: Use a metacarpal or digital nerve block for anesthesia.

- **Reduction techniques**
  - MCP dislocations:
    - Dorsal:
      - Place wrist in flexion to relax flexor tendons
      - Hyperextend joint and then apply pressure at base of proximal phalanx while bringing finger into flexion
    - Volar:
      - Very difficult to reduce because of volar plate entrapment. Often need open reduction
      - Attempt close reduction by first pushing proximal phalanx toward metacarpal and then hyperflex finger
      - Once hyperflexed, pull traction and then attempt to extend finger
      - Can attempt to guide base of proximal phalanx back into position with thumb
  - PIP dislocation:
    - Dorsal:
      - Place wrist in flexion and hyperextend joint followed by gentle longitudinal traction and then dorsal pressure on base of middle phalanx while moving digit back into flexion
      - Use other hand to stabilize proximal phalanx
    - Volar:
      - Place the wrist in flexion
      - Hyperflex the PIP joint
      - Apply gentle longitudinal traction and then extend middle phalanx
    - Lateral: Gentle extension and longitudinal traction
  - DIP dislocation:
    - Dorsal:
      - Place wrist in flexion and hyperextend joint followed by gentle longitudinal traction. Apply dorsal pressure on base of middle phalanx while moving digit back into flexion
    - Volar:
      - Place the wrist in flexion
      - Hyperflex the PIP joint
      - Apply gentle longitudinal traction and then extend middle phalanx

Post reduction

- MCP dislocation – Splint with MCP joint in 30° flexion
- PIP dislocation – Splint with PIP in 30° flexion
- DIP dislocation – Splint DIP joint in extension
- Hand surgeon should be consulted if unable to reduce dislocation or signs of ischemia exist after reduction

Prognosis

- Most dislocations are stable after reduction and do not usually require operative intervention

- Because of possible complications associated with finger dislocations, patients should follow up with hand specialist within two weeks

Hip dislocation

Key facts

- Posterior dislocations make up 90% of hip dislocations
- Native hips should be reduced within 6 hours to decrease risk of avascular necrosis
- Look for acetabular rim fractures with dislocation

Clinical presentation (see Chapter 3: Pelvic emergencies)

- Posterior dislocations usually present with hip flexed, adducted and internally rotated
- Anterior dislocations usually present with hip abducted and externally rotated

PEARL: On AP radiographs, the femoral head will migrate superiorly with posterior dislocations and inferiorly or medially with anterior dislocations.

Treatment

- Make sure an associated femoral neck fracture is not present prior to reduction. If fracture present, orthopedic consultation recommended prior to attempted reduction
- Procedural sedation is often necessary for hip reductions
- **Hip reduction techniques:**
  - Allis technique
    - Patient is supine with hip flexed
    - One person holds counter-traction on pelvis while other person bends knee to 90°
    - Apply traction in-line with femur until reduction successful (Figure 9.20)
    - Slow steady traction is better than abrupt pulls that can increase muscle spasm
    - Alternative technique is to use a strap or sheet to secure pelvis to bed when additional providers are not available to provide counter-traction
  - Lateral position
    - Place patient in lateral position with affected side up
    - Use same two-person technique with one person holding counter-traction on pelvis and other person pulling in-line traction of femur
  - With patient in supine position
    - Grab foot and ankle and apply traction axially while internally and externally rotating hip
    - Use slow steady traction
    - A palpable clunk is usually felt when hip is reduced
    - Works well with anterior dislocations
  - Captain Morgan technique
    - Place patient in supine position

- Provider stands on floor or step stool with one foot on the bed
- Flex the patient's knee and drape patient's leg over the provider's knee
- While holding patient's leg firmly to the provider's knee, the provider lifts up on toes, which lifts the leg, causing the reduction (Figure 9.21)
- Slow steady lifting is ideal

- When having difficulty reducing patients with a hip arthroplasty, consider the type of liner they may have had placed. Certain liners can make reduction very difficult and must have open reduction by an orthopedist

Figure 9.20 Hip dislocation reduction. Allis technique – with the patient supine, have an assistant stabilize the pelvis or secure the patient to the bed with a strap or sheet across the pelvis. Flex the hip and knee to 90°. While standing over the patient, grab the patient's knee and apply longitudinal traction to the leg. (Image courtesy of Ryan Friedberg, MD.)

Figure 9.21 Hip dislocation reduction Captain Morgan technique – with the patient supine, have an assistant stabilize the pelvis or secure the patient to the bed with a strap or sheet across the pelvis. Flex the hip and knee to 90°. The provider should have one leg on the floor and the other flexed with their foot on the bed. Drape the patient's leg across your knee. The provider lifts up on their toes, while pushing down slightly on the patient's distal leg. While standing over the patient, grab the patient's knee and apply longitudinal traction to the leg. (Image courtesy of Ryan Friedberg, MD.)

Post reduction

- Obtain post-reduction films
- Consider CT if concerned about occult fracture
- Use hip abduction pillow or knee immobilizer to prevent repeat dislocation
- Admission usually required after reduction

Prognosis

- Concern for avascular necrosis of native hip dislocations
- Simple dislocations (without associated fracture) usually do not need surgery

Knee dislocation

Key facts

- A true orthopedic emergency
- High risk of popliteal artery and vein injury
- Peroneal nerve injuries occur in 20–40% of dislocations

- Reduction should be performed as soon as possible

Clinical presentation (see Chapter 4: Knee and leg emergencies)

PEARL: Be aware of dislocations reduced in the field. Be sure to evaluate neurovascular status pre and post reduction techniques.

Fast facts

- Anterior dislocations (40%) usually occur from a hyperextension injury causing tearing of the anterior cruciate ligament (ACL) and partial or complete tear of posterior cruciate ligament (PCL)
- Posterior dislocations (33%) are usually caused by a direct force on the proximal tibia with the knee slightly flexed
- Up to two-thirds of knee dislocations can present already reduced
- A grossly unstable knee after trauma with a normal radiograph should be considered a reduced dislocation
- Foot drop (loss of dorsiflexion) is a sign of peroneal nerve injury
- Avoid hyperextension during examination or splinting, to prevent traction on popliteal artery or peroneal nerve

Treatment

- Urgent orthopedic consultation
- Rapid reduction should be performed
- Procedural sedation is often required for reduction
- **Reduction techniques:**
  - Posterior dislocation reduction technique (Figure 9.22)
    - Practitioner holds distal femur and applies counter-traction
    - Second practitioner holds proximal tibia and pulls distally and then anteriorly
    - Knee should be flexed from 30–90°
    - Reduction should be done with gentle force to prevent further arterial injury
  - Anterior dislocation reduction technique
    - Practitioner holds traction on proximal tibia and gently distracts distally
    - Second practitioner holds distal femur and pulls proximally and anteriorly (Figure 9.23)

Figure 9.22 Knee dislocation reduction. An assistant stabilizes the proximal femur while the provider applies longitudinal traction (1) to the distal leg while guiding the tibia back into the proper position (2). (Image courtesy of Ryan Friedberg, MD.)

Figure 9.23 Knee dislocation reduction. An assistant stabilizes the proximal femur while the provider applies longitudinal traction to the distal leg while guiding the tibia back into the proper position (2). The assistant can also guide the femur into the proper position (1). (Image courtesy of Ryan Friedberg, MD.)

Post reduction

- Check neurovascular status after reduction
  - If pulses absent after reduction, immediate vascular consultation
  - If pulses present after reduction, perform ankle brachial index (ABI)
    - If ABI < 0.9, vascular surgery consultation and consider arteriogram vs. ultrasound

        - If ABI > 0.9, admit for serial examination
- After reduction, place in posterior leg splint in 10–15° flexion
- Most patients will require operative repair of the ligamentous injuries

Patella dislocations

Key facts

- Almost all patella dislocations are lateral
- Adolescent females are most commonly affected
- Dislocations are most often the result of indirect trauma

Clinical presentation (see Chapter 4: Knee and leg emergencies)

PEARL: Consider patellar dislocation with spontaneous reduction in patients with knee effusion and a history that suggests a dislocation.

Treatment

- Consider procedural sedation in patients that are very anxious
    - Because of usual ease and rapidity of reduction, author's preference is to manage pain and reduce without sedation
    - This method is often successful and very tolerable by the patient. It eliminates risk of sedation and need for monitoring post reduction
- **Reduction technique:**
    - Closed reduction
        - Gentle flexion of hip
            - Have patient sit at 20–30°on stretcher
        - Slowly bring knee into extension with one hand while holding traction on patella with other hand (Figure 9.24)
        - Holding traction on the patella should decrease pain and prevent forceful reduction of patella
        - Once knee is extended allow the patella to slide back into its proper position. Some medial pressure can be applied as needed

Figure 9.24 Patellar dislocation reduction. The provider should hyperextend the knee while holding the patella. Once the knee is extended the provider can apply pressure to the lateral side of the patella until it reduces. (Image courtesy of Ryan Friedberg, MD.)

Post reduction

- Place patient in a **knee immobilizer**
- Obtain post-reduction radiographs to confirm reduction and evaluate for occult fractures
- Place patient on crutches with partial weight-bearing as tolerated
- Arrange for orthopedic follow-up within 1 week

Radial head subluxation/dislocation

Key facts

- Radial head subluxation or nursemaid's elbow usually occurs in children age 2–4 years, but has been described in children up to 6 years old
- The mechanism of a nursemaid's elbow is sudden traction of the wrist or hand in an upward motion such as when a parent picks a child up by the wrist to prevent a fall
- Isolated radial head dislocations in adults are very rare. Usually caused by high-force injury and associated with other injuries such as complete elbow dislocations and Monteggia fractures (associated ulna fracture)

Clinical presentation (see Chapter 7: Pediatric orthopedic emergencies)

PEARL: Consider other injuries such as fracture or infection if the history or examination is not consistent with radial head subluxation.

Fast facts

- Children with a radial head subluxation present with the arm slightly flexed and pronated. They are unwilling to move arm
- Nursemaid's elbows are not swollen or warm. If there is bruising, swelling or warmth, consider other etiologies
- Adults with radial head dislocation present with arm flexed to 90° and resist all movements of the elbow including pronation and supination

PEARL: Always get radiographs before attempting reduction on children with swelling or bruising to elbow, or if mechanism does not suggest radial head subluxation.

Treatment

- Sedation not usually required for reduction of radial head subluxation
- **Reduction technique for radial head subluxation in children:**
    - Hyperpronation/extension:
        - Cradle elbow with one hand with thumb on radial head and grasp wrist with other hand
        - Hyperpronate forearm. If not reduced with pronation, then gently extend elbow (Figure 9.25)
        - Click of radial head usually felt with reduction
        - 95% initial success rate
    - Supination/flexion:
        - Cradle elbow with one hand with thumb on radial head and grasp wrist or distal forearm with other hand
        - First supinate forearm
        - If not reduced, then gently flex elbow (Figure 9.26)
        - Click of radial head usually felt with reduction
        - 77% initial success rate

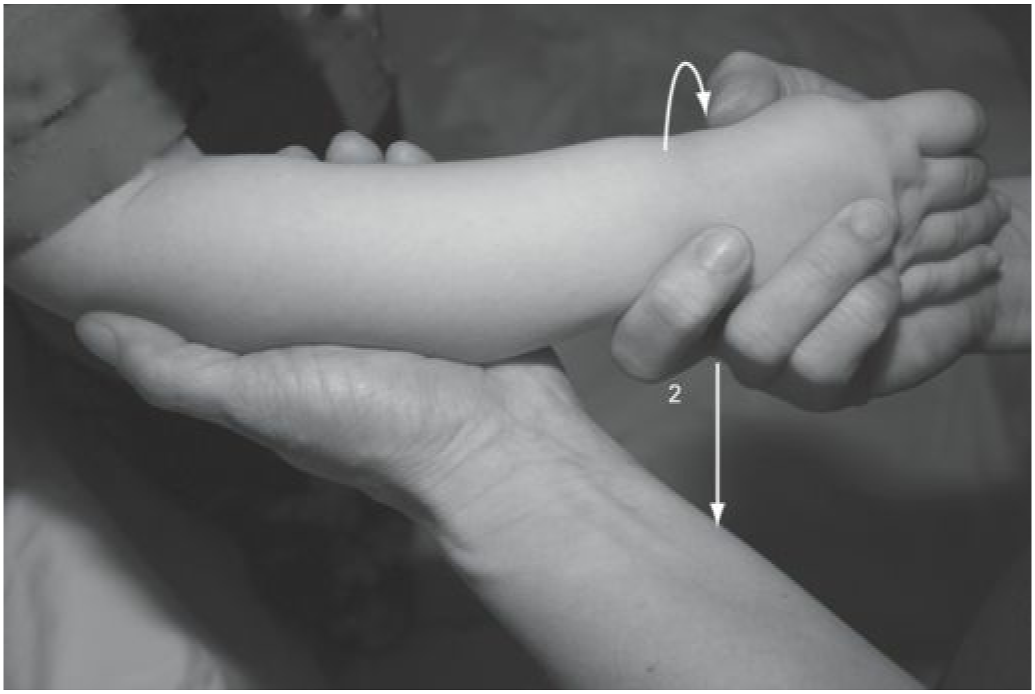

Figure 9.25 Nursemaid's elbow. The forearm should be hyperpronated and then the elbow can be extended to cause the reduction. Proximal pressure on the radial head can help ease the reduction. (Image courtesy of Ryan Friedberg, MD.)

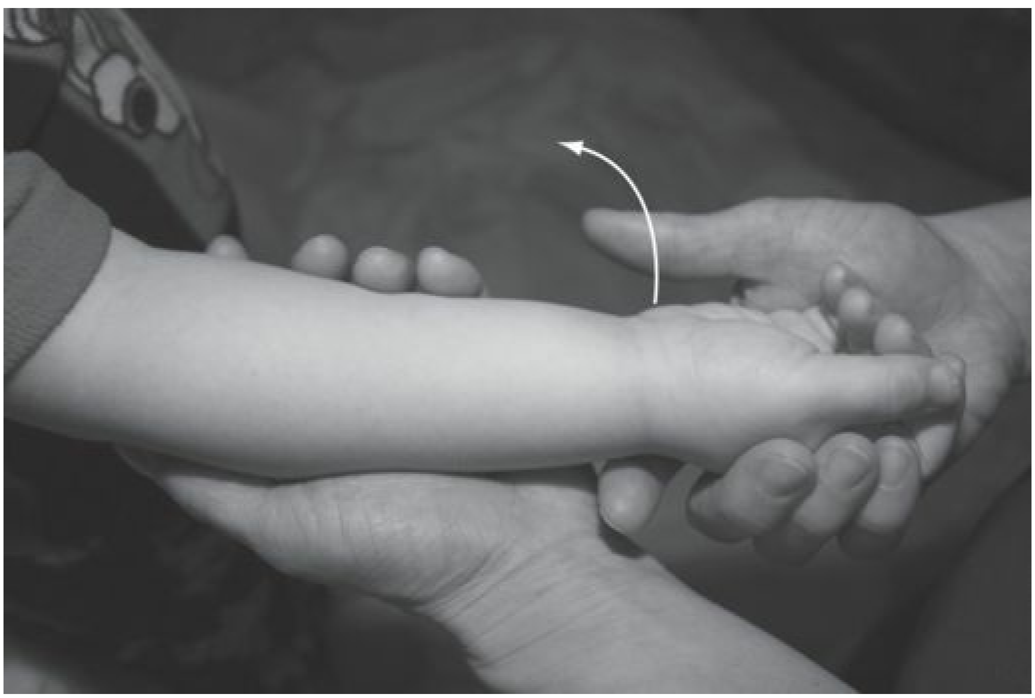

Figure 9.26 Nursemaid's elbow. The forearm is supinated and then the elbow flexed to cause the reduction. (Image Courtesy of Ryan Friedberg, MD.)

Post reduction

- Child should be observed in ED until witnessed to be moving extremity in normal fashion
- Post-reduction imaging not necessary
- Immobilization is not necessary
- Adult radial head dislocation
    - Anesthesia with joint injection or procedural sedation

- Reduction techniques:
  - Anterior dislocation
    - Supinate arm and flex elbow to 115°
    - Grasp elbow with one hand and apply posterior pressure to radial head with thumb
    - Apply distal traction to wrist with other hand
    - Assistant could assist with counter-traction by holding humerus in counter-traction (Figure 9.27)
  - Posterior dislocation
    - Arm is held supinated in extension at patient's side
    - Grasp elbow with one hand and apply anterior pressure to radial head with thumb
    - Other hand is grasping wrist and applying distal traction
    - Assistant could assist with counter-traction by holding humerus in counter-traction (Figure 9.28)
  - Lateral
    - Same as posterior technique, but apply medial pressure to radial head

Figure 9.27 Anterior radial head dislocation in adult. Supinate arm and flex elbow to 115°. Grasp elbow with one hand and apply posterior pressure to radial head with thumb while applying distal traction to wrist with other hand. Assistant could assist with counter-traction by holding humerus in counter-traction. (Image courtesy of Ryan Friedberg, MD.)

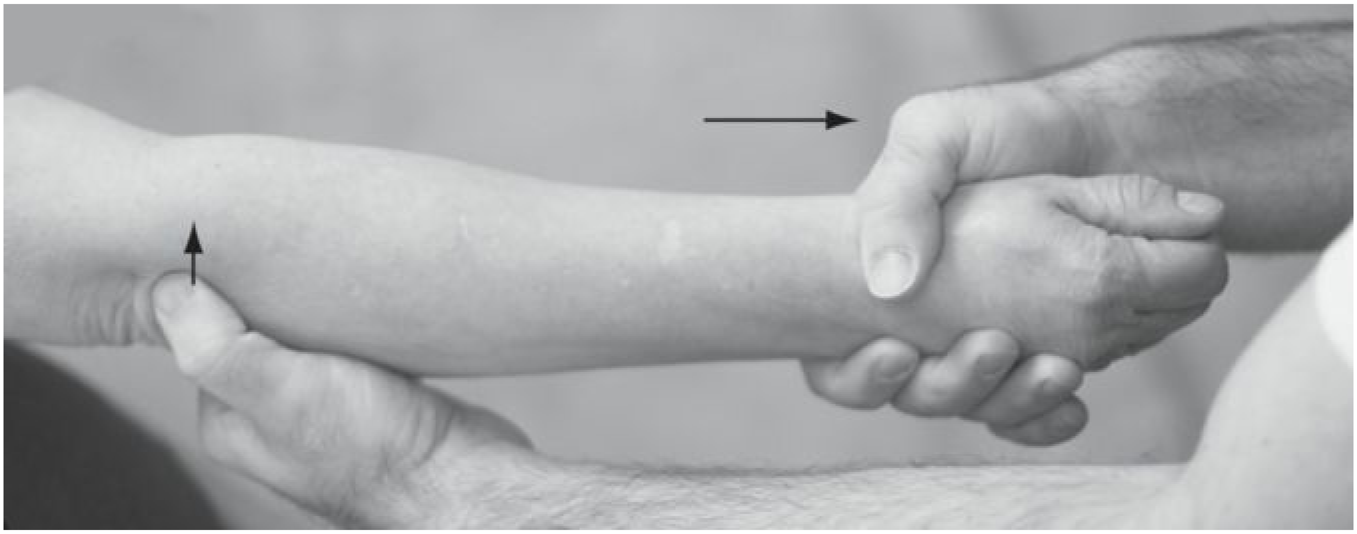

Figure 9.28 Posterior radial head dislocation in adult. Arm is held supinated in extension at patient's side. Grasp elbow with one hand and apply anterior pressure to radial head with thumb while other hand is grasping wrist and applying distal traction. Assistant could assist with counter-traction by holding humerus in counter-traction. (Image courtesy of Ryan Friedberg, MD.)

Post reduction

- Post-reduction radiographs should be performed
- Reassess neurovascular status
  - Posterior interosseous nerve is the most commonly injured nerve. Results in weakness of finger or thumb extension
- Place in **posterior splint** with elbow at 90° flexion and forearm in supination
- If Monteggia-type fracture, orthopedic surgeon should be consulted as radial head will usually self-reduce once ulna is stabilized intraoperatively

Shoulder dislocations

Key facts

- Anterior dislocations very common (95% of shoulder dislocations)
- Posterior dislocations (5%)
  - Usually caused by falls, seizures, or electric shocks
- Inferior dislocations (luxatio erecta) are very rare
- Axillary nerve injury is the most common neurologic injury (12%)
- Hill–Sachs lesions are defects in the posterolateral portion of humeral head
- Bankart lesions are defects of the glenoid labrum (rim)

Clinical presentation (see Chapter 2: Shoulder and elbow emergencies)

PEARL: The mechanism of injury is usually abduction and external rotation of the arm.

- The majority of patients will present with their arm at their side supported by unaffected arm

- The acromion is usually prominent with an empty sulcus (absence of humeral head)
- Patient usually very resistant to any movement
- If unable to externally rotate shoulder, be concerned for posterior dislocation
- Arm raised above head with inability to lower arm suggests inferior dislocation

PEARL: Posterior shoulder dislocations are often missed because of suboptimal radiographic evaluation. An axillary or Y-view can be diagnostic.

Fast facts

- Evaluate sensory and motor function of arm
    - Specifically test axillary nerve
- Axillary lateral radiograph – most sensitive to diagnose dislocation, but hardest to accurately perform in dislocated patient
- Pre-reduction radiographs are not necessary if:
    - Sure of diagnosis clinically
    - Multidislocator
    - Atraumatic
    - Under 40

Treatment

- Procedural sedation is not always required
    - Consider for patients who are unable to co-operate with reduction techniques because of pain or anxiety
- An intra-articular lidocaine injection can be used to decrease pain and decrease time to discharge (when compared with procedural sedation)
- Anterior dislocation reduction techniques:
    - Cunningham technique – massage technique
        - Have patient sit in chair (or on stretcher)
        - Have arm fully adducted with elbow flexed
        - Patient must be relaxed
        - Massage trapezius of affected side
        - Massage biceps tendon
        - Alternate massaging trapezius, deltoid, and biceps until reduction occurs
    - Self-reduction
        - Have patient adduct shoulder and touch nose with fingers
        - Walk fingers up to forehead
            - Results in internal rotation and forward flexion of shoulder
    - Stimson technique (Figure 9.29)
        - Place patient in the prone position
        - Elevate the stretcher and apply 10–20 lbs of weight to the affected arm
        - Shoulder will typically reduce in 20–30 minutes
        - If not effective, practitioner can apply traction while externally and then internally rotating arm

- Scapular manipulation (Figure 9.30)
  - Place the patient in the prone position
  - This technique can be combined with the Stimson technique with weight applied to the affected arm
  - Once relaxed, apply pressure to the inferior border of the scapula in order to rotate it medially, while the superior border is rotated laterally
  - Slow steady pressure will often reduce the shoulder
- External rotation (Hennepin) (Figure 9.31)
  - Patient can be supine or sitting in a chair
  - Flex the patient's elbow to 90°, and forward flex the shoulder approximately 20°
  - With the elbow at the patient's side, externally rotate the arm outward
  - If reduction has not occurred when arm is at 90° external rotation, you can attempt to adduct the shoulder to accomplish reduction
  - Author's note: Having patient in supine position using other hand to apply downward pressure to humeral head can decrease pain and improve effectiveness
- Milch technique
  - Place the patient in the supine position
  - Abduct the arm to greater than 90° with the arm externally rotated (once again, recommend applying pressure to humeral head)
  - Reduction normally accomplished as the arm extends past the shoulder
- Traction–counter-traction (Figure 9.32)
  - A technique often favored by many
  - Recommended as the last method of reduction
  - Procedural sedation should be used
  - Requires two providers
  - Place the patient in the supine position
  - Place a sheet around torso under the ipsilateral axilla and tie around the waist of the provider providing counter-traction. The provider should just lean back and provide a steady force
  - Second provider should flex elbow to 90° and place a sheet across the patient's forearm and tie it around their waist
  - The second provider then applies steady constant traction on the forearm and arm in the inferolateral direction until reduction is successful
  - If unable to reduce with traction can try internally and externally rotating the arm to facilitate the reduction

- Posterior dislocation
  - Consider orthopedic consultation prior to reduction
  - Place the patient in the supine position
  - The traction–counter-traction method can be used with the second provider applying axial traction on the flexed and adducted shoulder
  - Forward pressure can be applied to the humeral head to facilitate the reduction
- Inferior dislocation (luxatio erecta)
  - Procedural sedation recommended
  - Place the patient in the supine position
  - Set up for traction and counter-traction

- The counter-traction sheet should be placed over the patient's shoulder (supraclavicular) with the provider standing by the patient's hip
- The second provider should apply axial traction with added hyperabduction of the shoulder

- Two-step reduction (Figure 9.33)
  - Convert the inferior dislocation to an anterior dislocation and then reduce anterior dislocation
  - Push/pull technique
    - Push hand is placed on the lateral aspect of the mid-shaft of the humerus
    - Pull hand is placed on the medial epicondyle of elbow
    - Push hand manipulates humeral head from an inferior to an anterior position
    - Pull hand provides gentle superior (cephalic) directed force at distal humerus
  - Once humeral head is anterior, switch to your preferred anterior dislocation technique

Figure 9.29 Stimson technique for shoulder dislocation. With the patient lying prone apply weight to the wrist/hand. Wait 20–30 minutes and the shoulder will typically self-reduce; if not, additional traction with internal rotation of the arm can help cause the reduction. (Image courtesy of Ryan Friedberg, MD.)

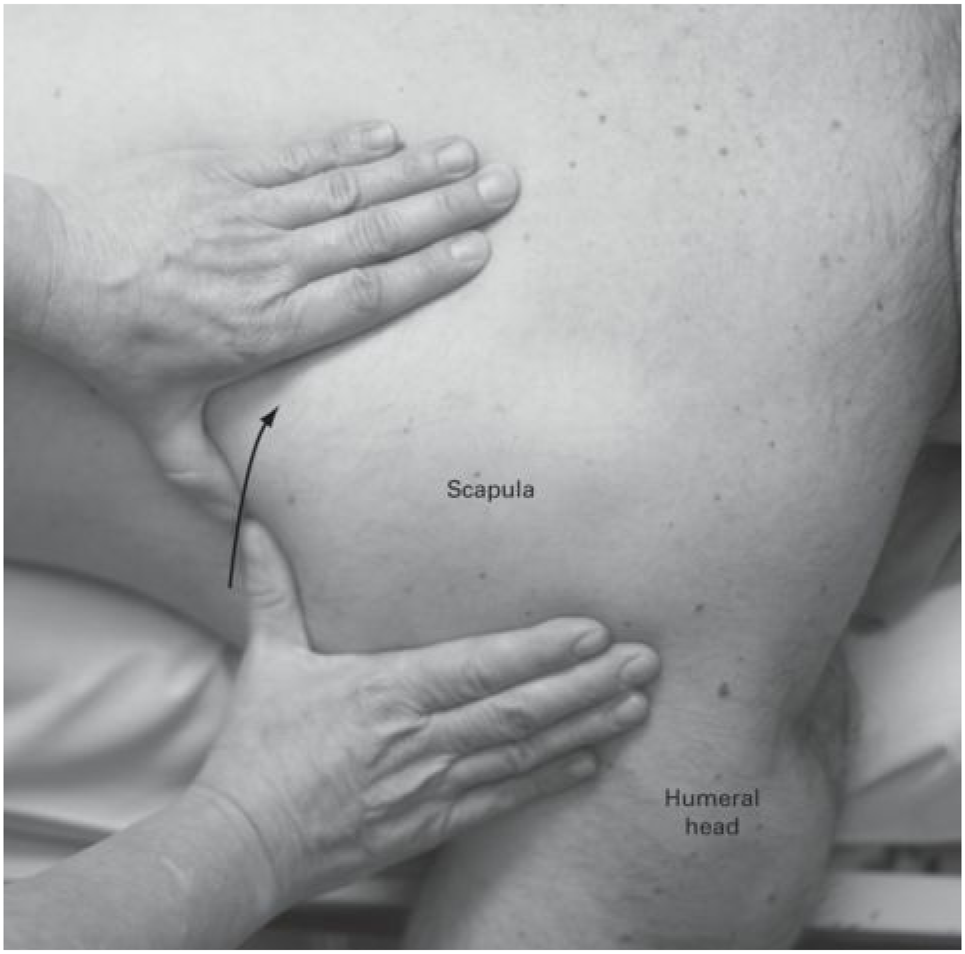

Figure 9.30 Scapular manipulation technique for shoulder dislocation. With the patient lying prone, a gentle force is applied as shown by red arrow to rotate the scapula and cause the reduction. This can be combined with the Stimson technique. (Image courtesy of Ryan Friedberg, MD.)

Figure 9.31 External rotation method for shoulder dislocation. With the patient lying supine the patient's elbow is flexed to 90° and the arm is flexed approximately 20° forward. With the elbow remaining at the patient's side the arm is externally rotated. Applying pressure to the humeral head as shown (hand on shoulder) can reduce pain and improve effectiveness. (Image courtesy of Ryan Friedberg, MD.)

Figure 9.32 Traction–counter-traction shoulder reduction method. With the patient supine a sheet is applied across their chest and held by an assistant (counter-traction). The affected arm is flexed at the elbow. A sheet applied to the flexed forearm and wrapped around the provider's waist allows for steady gentle traction to be applied without risk of the provider's hands slipping. The arm can also be internally and externally rotated while traction is applied to cause the reduction. (Image courtesy of Ryan Friedberg, MD.)

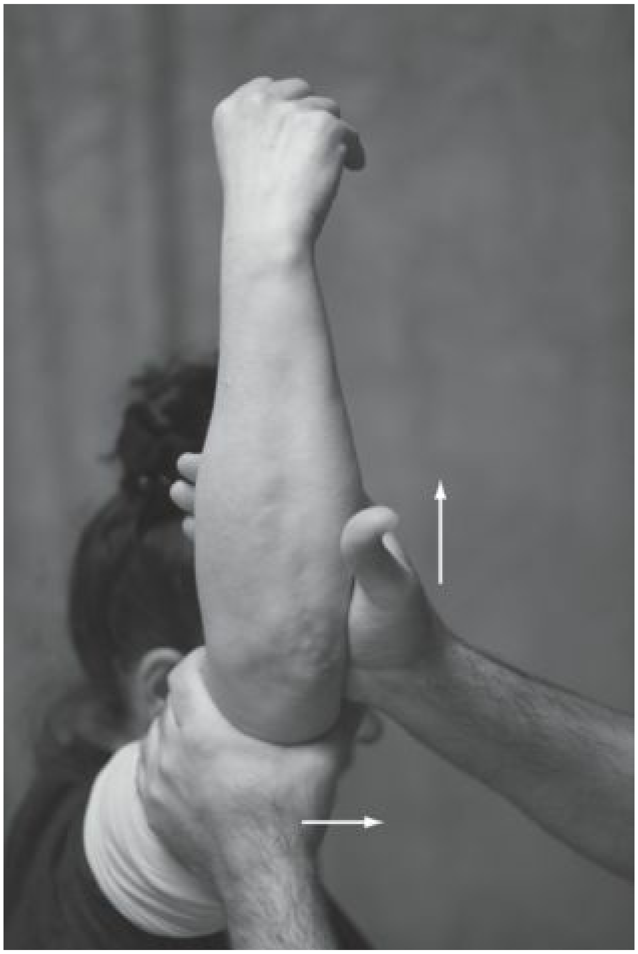

Figure 9.33 Two-step reduction method for luxatio erecta. Push/pull technique – push hand is placed on lateral aspect of mid-shaft of humerus. Pull hand on medial epicondyle of elbow. Push hand manipulates humeral head from an inferior to an anterior position. Pull hand provides gentle superior-directed force at distal humerus. (Image courtesy of Ryan Friedberg, MD.)

Post reduction

- Obtain post-reduction radiographs
- Place patient in sling
  - If first-time dislocator, consider placing the patient in a sling with 30° external rotation. This has been shown to reduce the risk of multiple dislocations
- Follow up with an orthopedist

Wrist fractures/dislocations

Key facts

- Radiocarpal dislocations are very rare and usually caused by a high-energy mechanism
- Associated injuries including fractures, ligamentous rupture and neurovascular injuries are common
- Fall on to an outstretched hand is the most common mechanism for distal radius fractures
- Be aware of median nerve injuries with volar angulated fractures (Smith fractures)

Clinical presentation (see Chapter 1: Hand and wrist emergencies)

PEARL: Always examine the proximal forearm and elbow for associated injuries.

Treatment

PEARL: Consider using C-arm fluoroscopy guidance, if available, to help with reduction.

- Perform a hematoma block for analgesia
- Consider procedural sedation
- Radiocarpal dislocation reduction technique
  - Dorsal dislocation
    - Grasp hand with your hand and their forearm with your other hand
    - Hyperextend their wrist, and apply traction to the hand with flexion of the wrist to reduce wrist into position
    - Use other hand to apply counter-traction
  - Volar dislocation
    - Hyperflex wrist and apply traction while extending the wrist
- Distal radius fracture-reduction technique
  - Traction technique with finger traps and hanging weight
    - Place thumb, index, and middle finger in finger trap and hang 10 lb weight from arm for 10 minutes (Figures 9.34 and 9.35)
    - Use thumbs to reposition fracture while still hanging
  - Manipulation
    - Dorsal angulated fractures
      - Place thumbs opposite each other on dorsum of fracture site
      - Initially hyperextend the fracture
      - Apply longitudinal traction
      - Finally, flex the arm into the properly aligned position
    - Volar angulated fractures
      - Place thumbs opposite each other on volar aspect of fracture and initially hyperflex fracture
      - Apply longitudinal traction
      - Finally extend the arm into proper alignment

Figure 9.34 Finger traps. An image of the fingers placed in a finger trap in order to place traction on the arm. (Image courtesy of Ryan Friedberg, MD.)

Figure 9.35 Weights are applied to the flexed elbow to apply gentle traction and cause the reduction. (Image courtesy of Ryan Friedberg, MD.)

Post reduction

- Dorsal dislocation
  - Immobilize in **volar splint** with 10° of extension
- Volar dislocation
  - Immobilize in **volar splint** with 10° of flexion
- Distal radius fracture
  - Recommend **sugar-tong splint** with wrist in neutral position or slight extension
- Follow up with orthopedic surgery within 1 week

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Chapter 10 Immobilization and splinting

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General

Splint material (Figures 10.1 and 10.2)

- Stockinette (Figure 10.1C) – a cloth sleeve that helps provide protection to the skin, and helps to hold the splint in place during application. Also gives a cleaner appearance to the splint/cast.
- Plaster of Paris (Figure 10.2B) – available in sheets or rolls. Sheets typically come 5 inches wide in 30- or 45-inch lengths. Eight to ten sheets typically needed for upper-extremity splints, and 15–20 sheets for lower-extremity splints. Width and length can easily be adjusted to the patient's needs by ripping or cutting the sheets. Plaster of Paris takes approximately 20 minutes to cure and a full day to reach maximum strength. The curing process is an exothermic reaction, so patients may complain of significant heat and can suffer burns. The risk of excessive heat production increases with the number of sheets used and if the water used to wet the plaster of Paris is hot
- Fiberglass (Figure 10.1D) – (e.g., Orthoglass®, Scotchcast®) sold as rolls of fiberglass wrapped in cotton padding. Supplied in predetermined widths (2″, 3″, 4″, 5″, and 6″). Fiberglass requires minimal water to aide the activation process, will cure and reach maximum strength in about 20–30 minutes. Not as moldable as plaster of Paris. Care needs to be made to trim or cover the cut edges in order to prevent fiberglass barbs from poking the patient. Orthoglass® has the same padding on both sides of the splint, whereas Scotchcast® has padding on one side and a breathable backing on the other
- Cast padding (e.g., Webril™) (Figure 10.1A and Figure 10.2C) – rolls of cotton padding that must be used with plaster of Paris. Care should be taken to prevent creases or lumps as this can lead to pressure points that can result in skin breakdown and pain. Typically two to three layers provide enough padding. Additional layers should be used on bony prominences
- Elastic bandage (Figure 10.1B and Figure 10.2D) – used to hold the splint in place. Do not apply with excessive force as this can lead to numbness and reduced blood flow

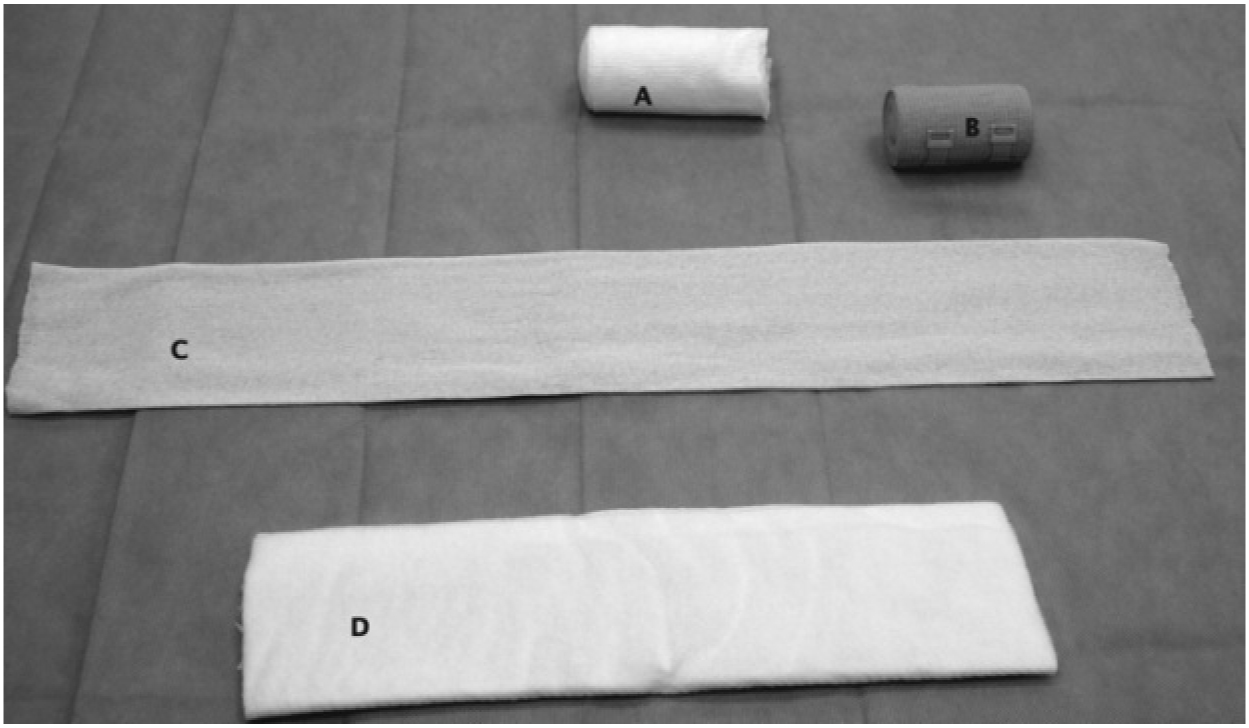

Figure 10.1 Typical supplies used for splinting: A – cotton padding. B – elastic bandage. C – stockinette. D – fiberglass splinting material.

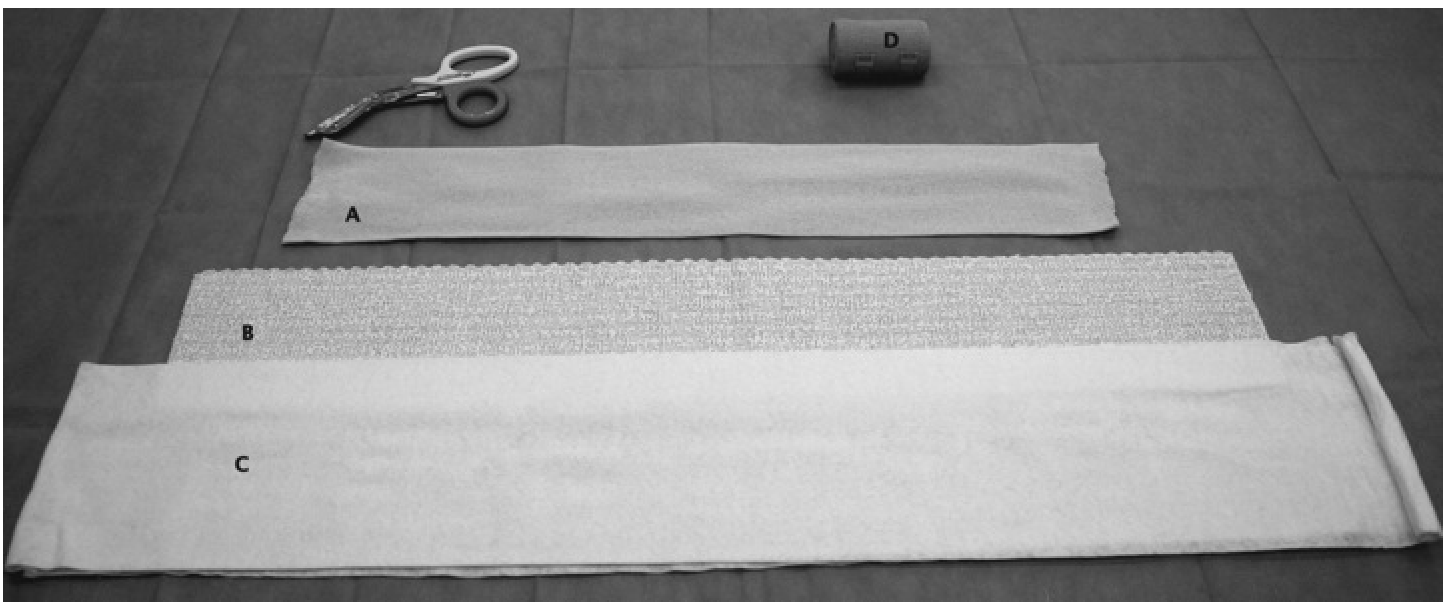

Figure 10.2 Typical supplies used for splinting. A – stockinette. B – plaster of Paris sheets. C – cotton padding. D – elastic bandage. Ensure the cotton padding is wider and longer than the plaster of Paris to ensure that the plaster is completely covered.

Sugar tong splint (Figure 10.3)

Indications

- Radius and ulna fractures
- Supracondylar humeral fractures
- Carpal bone fractures

PEARL: The sugar tong splint prevents flexion and extension at the wrist, supination, pronation, and greatly inhibits flexion and extension at the elbow. Can be combined with a second sugar tong splint (double sugar tong) that starts at the axilla and wraps around the elbow to the shoulder. This double sugar tong will prevent all flexion and extension at the elbow.

Figure 10.3 Traditional sugar tong splint. Used for fractures of the radius, ulna, carpal bones, and supracondylar fractures. Note the final hand position.

Materials

- Stockinette
- Plaster of Paris or fiberglass splint
- Cast padding
- Elastic bandages

Application

- Two methods possible
    - Traditional sugar tong (Figure 10.3)
        - Apply stockinette from the hand to mid-bicep
        - Measure splinting material (plaster of Paris, or fiberglass) from the dorsum of the hand, around the elbow, to the volar surface of the hand
        - Ensure that the width is thin enough that it does not come up the sides of the forearm, which would essentially form a circumferential cast. Most splints will be 2 or 3 inches wide (5 to 7.5 cm)
        - If using plaster of Paris, roll out two to three layers of cast padding. Consider adding additional padding over areas of bony prominence
        - Wet the plaster of Paris, or slightly dampen the fiberglass splinting material
        - Apply the cast padding to the wet splint material, and apply to the arm as one unit starting at the hand, wrapping around the elbow and returning to the hand (Figure 10.4). Splinting material can bunch up at the elbow (Figure 10.5)
        - Starting at the hand, apply elastic bandages to hold the splint in place. Make sure not to to apply the elastic bandages too tightly
        - Once the splint is applied, the hand and wrist should be placed in the position of function

Figure 10.4 Traditional sugar tong splint with the fiberglass placed over the stockinette. The splint should go from the dorsal side of the hand, wrap around the elbow, and return to the volar side of the hand.

Figure 10.5 Demonstrates the bunching that can occur with the splinting material at the elbow.

Double sugar tong splint

Indications

- Humerus fractures
- Supracondylar fractures
- Radius and ulna fractures
- Carpal bone fractures

PEARL: Prevents flexion and extension at the wrist, and elbow and metacarpal joint if extended into the fingers. Also prevents supination and pronation of the forearm.

Materials

- Stockinette
- Plaster of Paris or fiberglass splint
- Cast padding
- Elastic bandages

Application

- Apply stockinette from the hand to axilla
- Measure 2 pieces of splinting material (plaster of Paris, or fiberglass). The first will go from the axilla, around the elbow and wrap back up the arm to the shoulder. The second piece will go from the dorsum of the hand, wrap around the elbow, to the volar surface of the hand
- Most splints will be 2 or 3 inches wide (5 to 7.5 cm)

- If using plaster of Paris, roll out 2–3 layers of cast padding. Consider adding additional padding over areas of bony prominence
- Wet the plaster of Paris, or slightly dampen the fiberglass splinting material
- Apply the cast padding to the wet splint material, and apply to the arm as two units. The first unit will be applied from the axilla, wrap around the elbow, and extend back up to the shoulder. The second unit will extend from the dorsum of the hand, wrap around the elbow, and extend back to the volar surface of the hand
- Starting at the hand, apply elastic bandages to hold the splint in place. Make sure not to apply the elastic bandages too tightly
- Once the splint is applied, the hand and wrist should be placed in the position of function, and the elbow flexed at 90°

Reverse sugar tong splint (Figure 10.6)

- Apply stockinette from the hand to mid-bicep
- Measure splinting material (plaster of Paris, or fiberglass) from the dorsum of the hand, around the elbow, to the volar surface of the hand
- Ensure that the width is thin enough that it does not come up the sides of the forearm, which would essentially form a circumferential cast. Most splints will be 2 or 3 inches wide (5 to 7.5 cm)
- If using plaster of Paris, roll out two to three layers of cast padding. Consider adding additional padding over areas of bony prominence
- Fold the splint in half, and in the middle, cut through the splinting material except for a small piece (~1/2 inch [1 cm]) (Figure 10.7)
- Wet the plaster of Paris, or slightly dampen the fiberglass splinting material
- Apply the cast padding to the wet splint material, and apply to the arm as one unit starting at the hand. The area that was not cut should be placed in the webspace of the first and second digits of the hand, with the splint hanging down from the hand (Figure 10.8)
- Starting at the hand, apply elastic bandages to hold the splint in place. Make sure not to apply the elastic bandages too tightly
- Once the splint is applied, the hand and wrist should be placed in the position of function

Figure 10.6 A reverse sugar tong splint. The splinting material is cut so that it can rest in the first and second web space, and then drapes down the arm, where the ends can be wrapped around the elbow. More easily held in place while wrapping with elastic bandages than a traditional sugar tong, and prevents some of the bunching of splint material at the elbow.

Figure 10.7 Fold the splinting material in half and cut through the material, leaving about 1 cm uncut.

Figure 10.8 Reverse sugar tong shown in place with the uncut splint material resting in the first and second web space.

Volar splint (Figure 10.9)

Indications

- Carpal bone fractures
- Metacarpal bone fractures
- Carpal tunnel syndrome
- Soft-tissue injuries of wrist

PEARL: A volar splint prevents flexion and extension at the wrist and metacarpal joint if extended into the fingers.

Figure 10.9 A volar splint used for the treatment of fractures of the carpal bones, metacarpals, carpal tunnel syndrome, and soft-tissue injuries of the wrist.

Materials

- Stockinette
- Plaster of Paris or fiberglass splint
- Cast padding
- Elastic bandages

Application

- Apply stockinette from the hand to mid-forearm
- Measure splinting material (plaster of Paris, or fiberglass) along the volar side of the hand from the mid-fingers to the mid-forearm
- Most splints will be 2 or 3 inches wide (5 to 7.5 cm)
- If using plaster of Paris, roll out two to three layers of cast padding. Consider adding additional padding over areas of bony prominence
- Wet the plaster of Paris, or slightly dampen the fiberglass splinting material
- Apply the cast padding to the wet splint material, and apply to the arm as one unit starting at the distal hand along its volar surface (Figure 10.10)
- Starting at the hand, apply elastic bandages to hold the splint in place. Make sure not to apply the

elastic bandages too tightly

- Once the splint is applied, the hand and wrist should be placed in the position of function

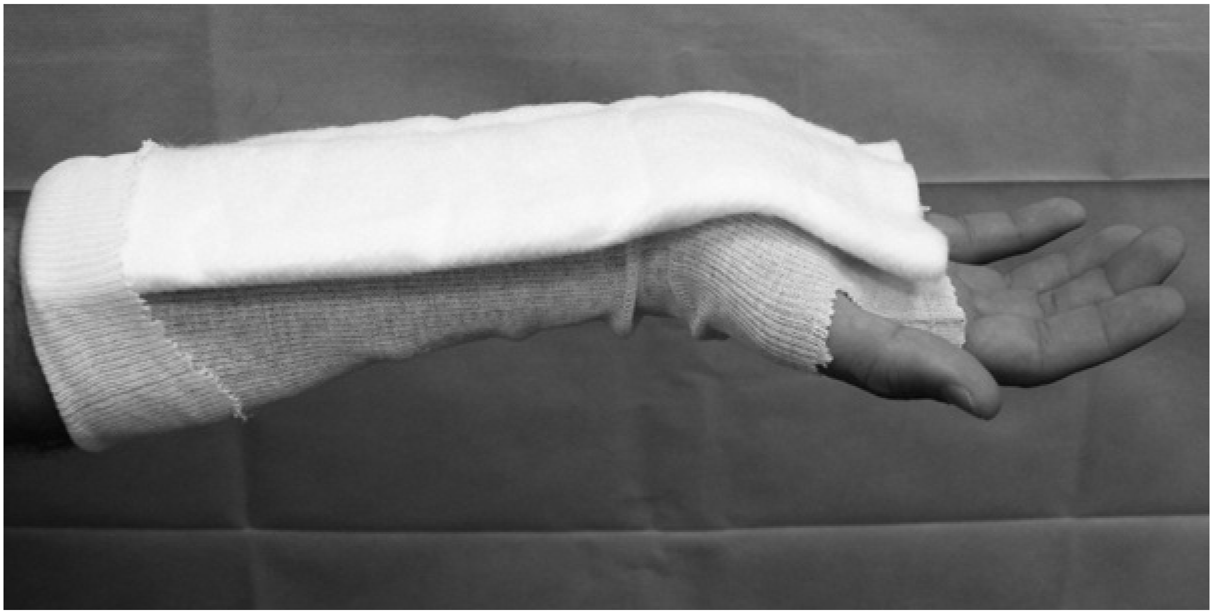

Figure 10.10 A volar splint being placed. The stockinette is in place and the splinting material is placed on the volar surface of the hand/wrist.

Dorsal splint (Figure 10.11)

Indications

- Carpal bone fractures
- Metacarpal bone fractures
- Carpal tunnel syndrome
- Soft-tissue injuries of wrist

PEARL: A dorsal splint prevents flexion and extension at the wrist and metacarpal joint if extended into the fingers.

Figure 10.11 A dorsal splint used for the treatment of fractures of the carpal bones, metacarpals, carpal tunnel syndrome, and soft-tissue injuries of the wrist.

Materials

- Stockinette
- Plaster of Paris or fiberglass splint
- Cast padding
- Elastic bandages

Application

- Apply stockinette from the hand to mid-forearm
- Measure splinting material (plaster of Paris, or fiberglass) along the dorsal side of the hand from the mid-fingers to the mid-forearm
- Most splints will be 2 or 3 inches wide (5 to 7.5 cm)
- If using plaster of Paris, roll out two to three layers of cast padding. Consider adding additional padding over areas of bony prominence
- Wet the plaster of Paris, or slightly dampen the fiberglass splinting material
- Apply the cast padding to the wet splint material, and apply to the arm as one unit starting at the distal hand along its dorsal surface (Figure 10.12)
- Starting at the hand, apply elastic bandages to hold the splint in place. Make sure not to apply the

elastic bandages too tightly
- Once the splint is applied, the hand and wrist should be placed in the position of function

PEARL: Dorsal and volar splints do not prevent supination and pronation. If concerned about this movement you can place both dorsal and volar splints (sandwich splint) and the combination will prevent supination and pronation.

Figure 10.12 A dorsal splint being placed. The stockinette is in place and the splinting material is placed on the dorsal surface of the hand/wrist.

Posterior long-arm splint (Figure 10.13)

Indications

- Supracondylar fractures
- Radius and ulna fractures
- Carpal bone fractures
- Soft-tissue injuries of elbow

PEARL: A posterior long-arm splint prevents flexion and extension at the elbow, and flexion and extension at the wrist. Does not prevent supination or pronation of the forearm.

Figure 10.13 Posterior long-arm splint is shown. Used for supracondylar, radius, ulna, and carpal bone fractures.

Materials

- Stockinette
- Plaster of Paris or fiberglass splint
- Cast padding
- Elastic bandages

Application

- Apply stockinette from the hand to mid-forearm
- Measure splinting material (plaster of Paris, or fiberglass) along the posterior side of the arm, forearm to the hand
- Most splints will be 2 or 3 inches wide (5 to 7.5 cm)
- If using plaster of Paris, roll out two to three layers of cast padding. Consider adding additional padding over areas of bony prominence
- Wet the plaster of Paris, or slightly dampen the fiberglass splinting material
- Apply the cast padding to the wet splint material, and apply to the arm as one unit starting at the distal hand along its posterior surface (Figure 10.14)
- Starting at the hand, apply elastic bandages to hold the splint in place. Make sure not to apply the elastic bandages too tightly
- Once the splint is applied, the hand and wrist should be placed in the position of function

Figure 10.14 A posterior long-arm splint shown with the stockinette and plaster in place awaiting placement of elastic bandage.

Posterior leg splint (Figure 10.15)

Indications

- Ankle sprains
- Tibia and fibula fractures
- Tarsal and metatarsal fractures
- Achilles tendinopathy or rupture
- Soft-tissue injuries of ankle or foot

PEARL: A posterior leg splint prevents dorsiflexion and plantar flexion of the ankle. If extended to the mid-thigh will prevent extension and flexion of the knee.

Figure 10.15 Posterior leg splint is shown. Used for the treatment of ankle sprains, tibia, fibula, tarsal, and metatarsal fractures, and Achilles tendinopathy or rupture.

Materials

- Stockinette
- Plaster of Paris or fiberglass splint
- Cast padding
- Elastic bandages

Application

- Apply stockinette from the foot to mid-calf or mid-thigh (if splinting a tibia or fibula fracture you need to extend to thigh) (Figure 10.16)
- Measure splinting material (plaster of Paris, or fiberglass) along the dorsal side of the leg from the toes to the mid-calf or mid-thigh
- Most splints will be 3 to 5 inches wide (7.5 to 12.5 cm)
- If using plaster of Paris, roll out two to three layers of cast padding. Consider adding additional padding over areas of bony prominence
- Wet the plaster of Paris, or slightly dampen the fiberglass splinting material
- Apply the cast as a single unit from the plantar surface of the foot along the posterior surface of the leg (Figure 10.17)
- Consider cutting the plaster/fiberglass near the heel of the foot to allow the material to be folded with less bulk (Figure 10.18)
- Starting at the foot, apply elastic bandages to hold the splint in place. Make sure not to apply the elastic bandages too tightly
- Once the splint is applied, the ankle should be placed at 90°, unless the specific injury requires different positioning (e.g., Achilles tendon rupture – often splinted with ankle in plantar flexion)

Figure 10.16 Stockinette shown in place in preparation of placement of posterior leg splint.

Figure 10.17 Posterior leg splint with stockinette and splinting material in place.

Figure 10.18 Splinting material is cut at the heel in order to facilitate folding it and preventing it from bunching up at the heel.

Stirrup splint (Figure 10.19)

Indications

- Tibia and fibula fractures
- Ankle sprains
- Tarsal bone fractures

PEARL: A stirrup splint prevents inversion and eversion of the ankle joint.

Figure 10.19 A stirrup splint is shown. Used in the treatment of ankle sprains and fractures of the tibia, fibula or tarsal bones. Prevents inversion and eversion at the ankle.

Materials

- Stockinette
- Plaster of Paris or fiberglass splint
- Cast padding
- Elastic bandages

Application

- Apply stockinette from the foot to mid-calf
- Measure splinting material (plaster of Paris, or fiberglass) from mid-calf, around foot to the opposite side of the mid-calf (Figure 10.20)

- Most splints will be 3 or 4 inches wide (7.5 to 10 cm)
- If using plaster of Paris, roll out two to three layers of cast padding. Consider adding additional padding over areas of bony prominence
- Wet the plaster of Paris, or slightly dampen the fiberglass splinting material
- Apply the cast padding to the wet splint material, and apply to the leg as one unit starting with the middle of the splint at the foot, and extending up both sides of the leg (Figure 10.21)
- Starting at the foot, apply elastic bandages to hold the splint in place. Make sure not to apply the elastic bandages too tightly
- Once the splint is applied, the ankle should be placed at 90°

Figure 10.20 Splinting material shown in proper position with the stockinette in place.

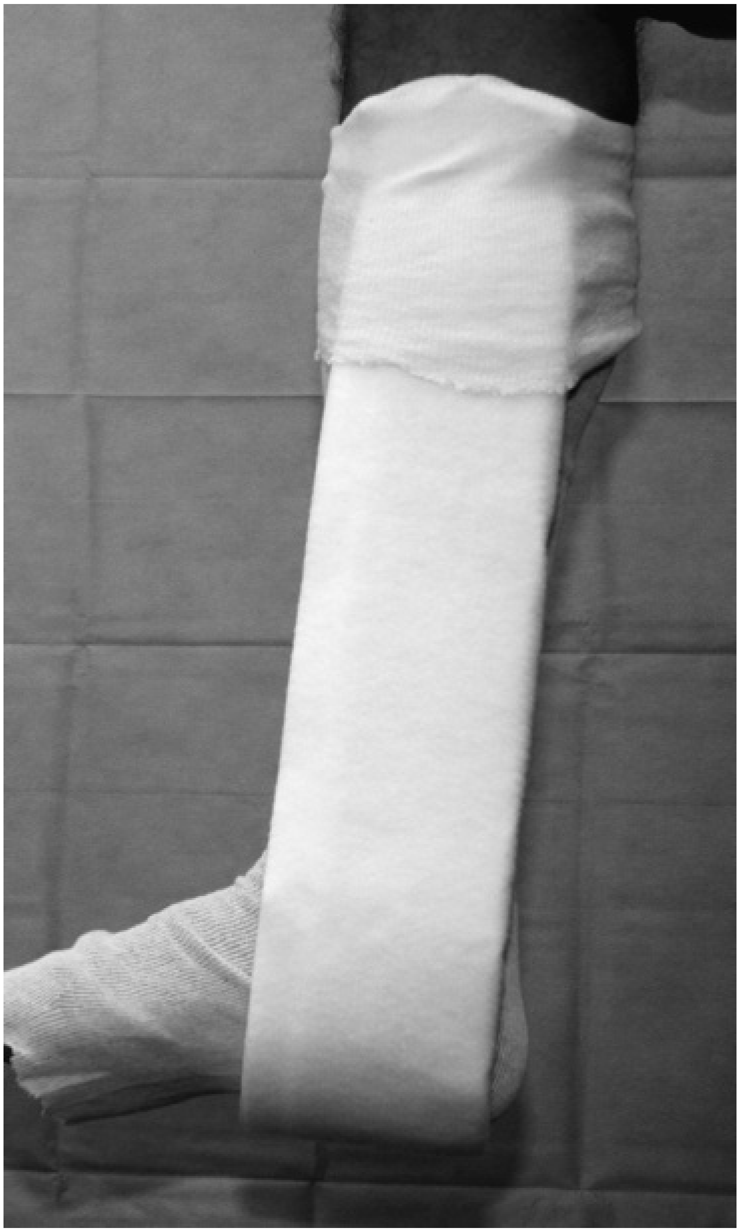

Figure 10.21 Another view of the splinting material in place, awaiting the placement of elastic bandage.

Thumb spica splint (Figure 10.22)

Indications

- First metacarpal and phalangeal fractures
- Scaphoid fractures
- Lunate fractures
- DeQuervain's syndrome
- Soft-tissue injuries of first digit

PEARL: A thumb spica splint prevents flexion, extension, abduction and adduction of the first finger.

Figure 10.22 A thumb spica splint is shown. This splint is used to treat first metacarpal and phalangeal fractures, scaphoid fractures, lunate fractures, and soft-tissue injuries of the first digit.

Materials

- Stockinette
- Plaster of Paris or fiberglass splint
- Cast padding
- Elastic bandages

Application

- Apply stockinette from the hand to mid-forearm (Figure 10.23)
- Measure splinting material (plaster of Paris, or fiberglass) from the tip of the thumb to the mid-forearm
- The splint material can be wrapped around the thumb, or cuts can be made in the material in the shape of two triangles to prevent the bulking up of the splinting material, and allowing it to circumferentially wrap around the first digit (Figure 10.24)
- Most splints will be 2 or 3 inches wide (5 to 7.5 cm)
- If using plaster of Paris, roll out two to three layers of cast padding. Consider adding additional padding over areas of bony prominence
- Wet the plaster of Paris, or slightly dampen the fiberglass splinting material
- Apply the cast padding to the wet splint material, and apply to the arm as one unit starting at the thumb and lying along the radial side of the forearm (Figure 10.25)
- Starting at the hand, apply elastic bandages to hold the splint in place. Make sure not to apply the elastic bandages too tightly
- Once the splint is applied, the thumb should be placed in anatomical position with the thumb in its natural position

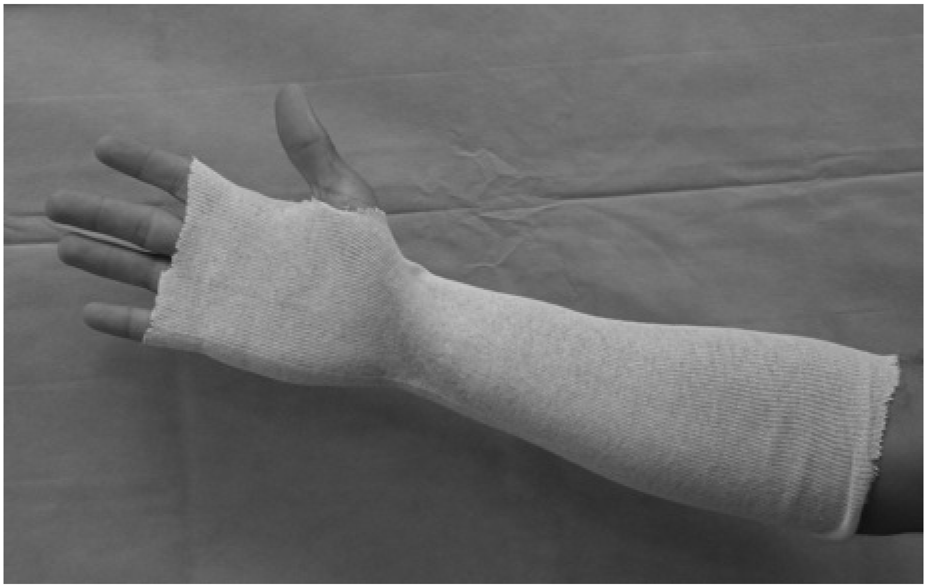

Figure 10.23 A stockinette is applied to the arm in preparation of the splint. Cut a hole in it to allow the thumb to poke through.

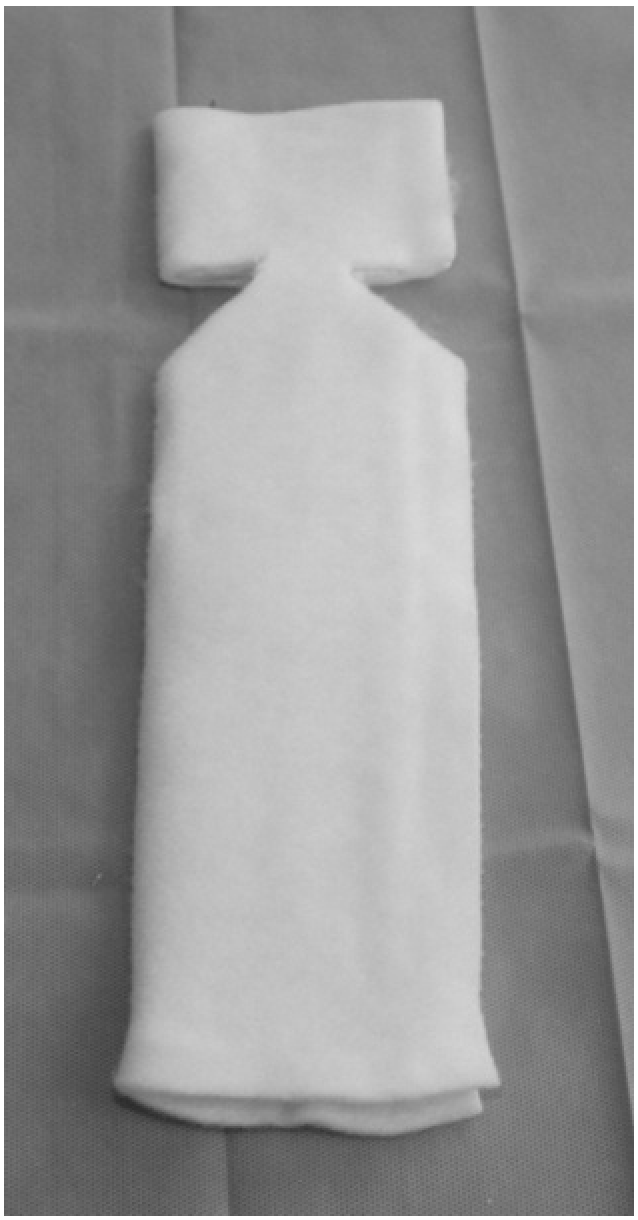

Figure 10.24 Cuts are made in the splinting material, as shown, to allow the material to wrap around the thumb more easily.

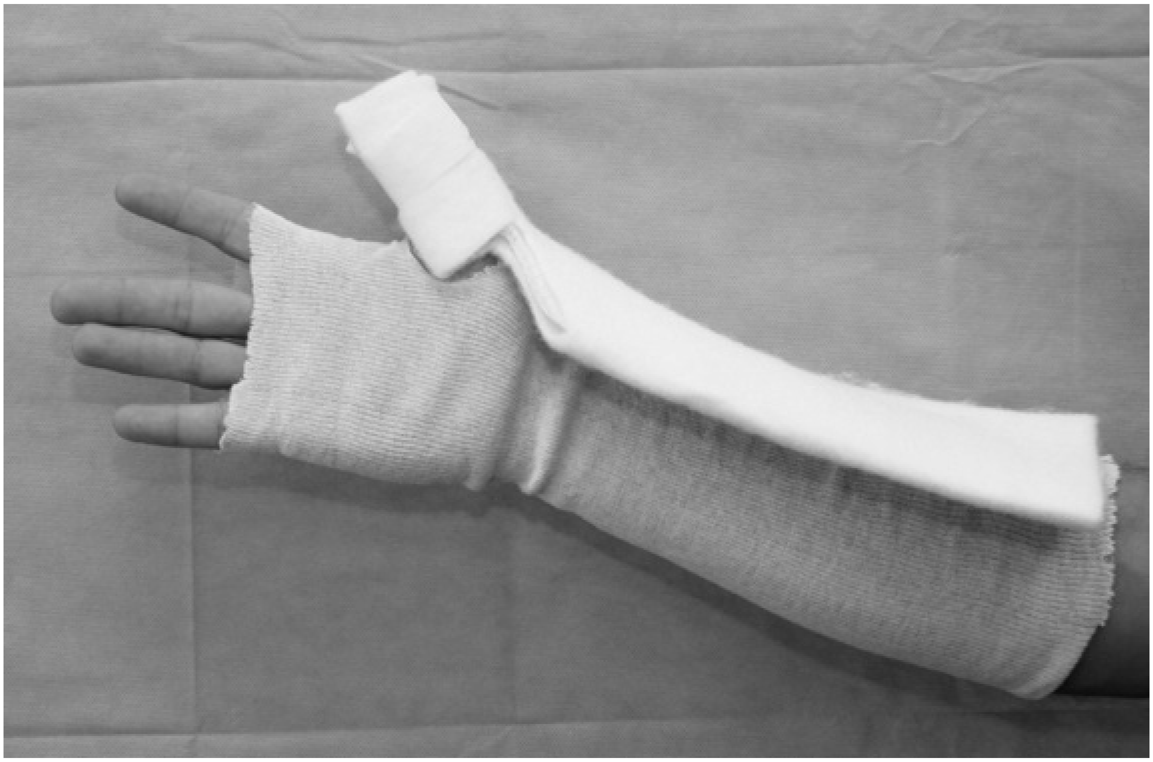

Figure 10.25 Thumb spica splint shown in place with stockinette, awaiting the placement of elastic bandage.

Ulnar gutter splint (Figure 10.26 and Figure 10.27)

Indications

- Fourth and fifth digit phalanx and metacarpal fractures
- Soft-tissue injuries of fourth and fifth digits

PEARL: An ulnar gutter splint prevents flexion and extension of the distal interphalangeal, proximal interphalangeal, metacarpophalangeal and wrist joints.

Figure 10.26 An ulnar gutter splint is shown – side view. This splint is used for the treatment of fractures and soft-tissue injuries of the fourth and fifth digits.

Figure 10.27 An ulnar gutter splint is shown – front view. This splint is used for the treatment of fractures and soft-tissue injuries of the fourth and fifth digits.

Materials

- Stockinette
- Plaster of Paris or fiberglass splint
- Cast padding
- Elastic bandages

Application

- Apply stockinette from the hand to mid-forearm
- Measure splinting material (plaster of Paris, or fiberglass) along the ulnar side of the hand from the distal fingers to distal forearm
- Most splints will be 3 or 4 inches wide (7.5 to 10 cm)
- If using plaster of Paris, roll out two to three layers of cast padding. Consider adding additional padding over areas of bony prominence
- Apply a piece of cast padding between the fourth and fifth digits (Figure 10.28)
- Wet the plaster of Paris, or slightly dampen the fiberglass splinting material
- Apply the cast padding to the wet splint material, and apply to the hand along the ulnar side of the hand making sure the splinting material wraps around the fourth and fifth digits (Figure 10.29)
- Starting at the distal fingers, apply elastic bandages to hold the splint in place. Make sure not to apply the elastic bandages too tightly. The ace wrap should not wrap around the second and third digits
- Once the splint is applied, the hand and wrist should be placed in the position of function

Figure 10.28 A piece of cast padding is placed between the fourth and fifth digits in order to prevent skin maceration while in the splint.

Figure 10.29 An ulnar gutter splint is shown with the splinting material and stockinette in place awaiting the placement of the elastic bandage. Be sure to wrap the fourth and fifth digits separately in

order to allow maximum movement of the second and third digits.

Radial gutter splint (Figure 10.30)

Indications

- Second and third digit phalanx and metacarpal fractures
- Soft-tissue injuries of second and third digits

PEARL: A radial gutter splint prevents flexion and extension of the distal interphalangeal, proximal interphalangeal, metacarpophalangeal and wrist joints.

Figure 10.30 A radial gutter splint is shown. This splint is used for the treatment of fractures and soft-tissue injuries of the second and third digits.

Materials

- Stockinette
- Plaster of Paris or fiberglass splint
- Cast padding
- Elastic bandages

Application

- Apply stockinette from the hand to mid-forearm
- Measure splinting material (plaster of Paris, or fiberglass) along the dorsal side of the hand from the mid-fingers to the mid-forearm
- Most splints will be 3 or 4 inches wide (7.5 to 10 cm)
- If using plaster of Paris, roll out two to three layers of cast padding. Consider adding additional padding over areas of bony prominence
- Apply a piece of cast padding between the second and third digits
- Consider cutting a notch out of the material to allow the thumb to sit into the splint without excess contact with the splinting material (Figure 10.31). Make sure to pad the edges (Figure 10.32)
- Wet the plaster of Paris, or slightly dampen the fiberglass splinting material
- Apply the cast padding to the wet splint material, and apply to the hand along the radial side of the hand making sure the splinting material wraps around the second and third digits. The thumb should remain out of the splint (Figure 10.33)
- Starting at the distal fingers, apply elastic bandages to hold the splint in place. Make sure not to apply the elastic bandages too tightly. The ace wrap should not wrap around the fourth and fifth digits
- Once the splint is applied, the hand and wrist should be placed in the position of function

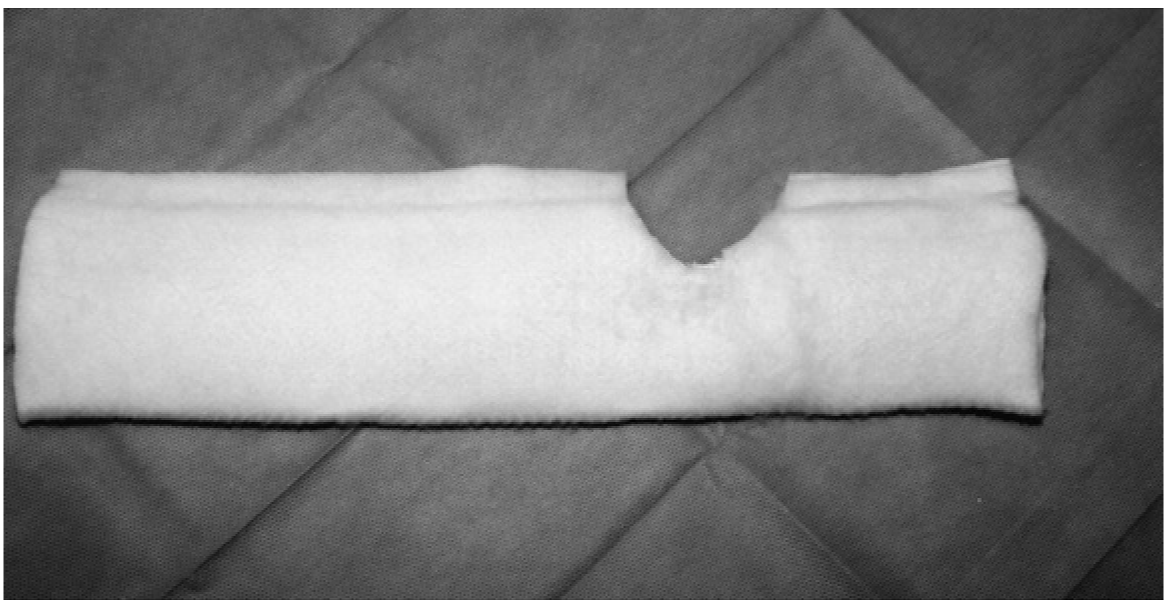

Figure 10.31 A notch is cut into the splinting material in order to prevent the thumb from becoming splinted too.

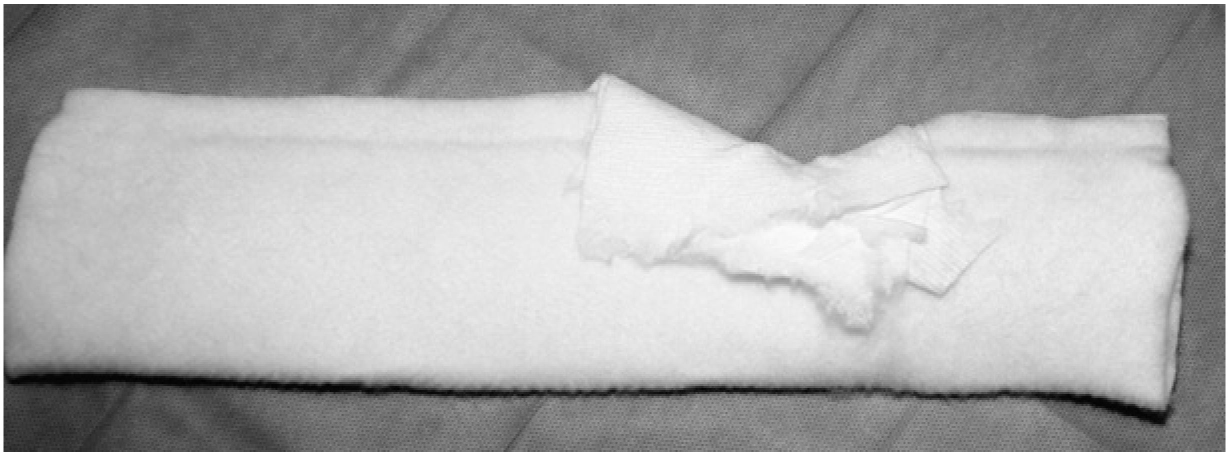

Figure 10.32 The notch is padded in order to prevent plaster or fiberglass from rubbing on the thumb and causing irritation.

Figure 10.33 The radial gutter splint is shown with splinting material and stockinette in place awaiting the placement of the elastic bandages. Only the second and third digits should be wrapped in the elastic bandage in order to allow maximum movement of the fourth and fifth digits.

Immobilization devices

PEARL: In addition to splinting, various immobilization devices can be utilized by the ED provider to facilitate patient comfort and healing, while stabilizing the injured area. These include hinged knee braces, figure-of-8 braces, boot immobilizers, and arm slings.

PEARL: Instructing the patient on the proper use of immobilization devices is crucial to prevent further complications, i.e., DVT or nerve palsies.

Knee braces

- There are two types: hinged "braces" and unhinged "immobilizers"
- Can be used in both acute and chronic injuries
- Knee immobilizers will be more readily available in the ED compared to hinged braces
- Hinged knee braces should be used in consultation with orthopedic or sports medicine consultants
- Hinged braces can be used for rehabilitation and protection from re-injury during sports participation
- Hinged knee braces can be used for isolated mid-grade MCL injuries that do not require operative repair
- Immobilizers are used for a litany of ED complaints but are rarely used properly
- Immobilizers can be used when instability in one of the knee ligaments is detected on examination, or when the patient is unable to co-operate for a full exam and there is concern for a ligamentous injury
- Knee immobilizers can cause DVTs; therefore patients should not remain in them for a prolonged period and should have close follow-up to determine the continued necessity of the immobilizer
- Both knee braces and immobilizers can be used with or without crutches

Arm slings

- Indications include clavicle and humeral fractures, AC joint separation, rotator cuff injuries, wrist and forearm fractures, and after upper-extremity dislocation reduction
- Arm slings provide upper-extremity immobilization and patient comfort
- Mainly used to immobilize the shoulder and elbow joints
- They can be used with or without an underlying brace or splint
- Unless contraindicated because of the injury, i.e., proximal humerus fracture, patients should be instructed to perform shoulder range of motion exercises
- Range of motion exercises will prevent complications including adhesive capsulitis or "frozen shoulder"
- Proper sizing of the arm sling will prevent excessive ulnar deviation of the wrist as the forearm rests on the sling. This deviation can cause significant ulnar neuropathy if not adjusted. The sling should extend to the MCP joint of the immobilized arm

PEARL: A properly fitted arm sling extends to the MCP joint of the affected arm in order to prevent an ulnar neuropathy that can develop with excessive ulnar deviation of the wrist.

CAM walking boots

- Indication – isolated distal fibular fractures, Achilles tendon injuries, and severe ankle sprains
- Can be hinged or fixed depending on the injury
- Provides similar immobilization as a posterior splint
- When used for Achilles tendon rupture the patient should be placed in approximately 15° of plantar flexion
- Can be used for weight-bearing injuries or with crutches when the injury is non-weight-bearing
- Unless contraindicated because of the injury, the patient should be instructed on proper removal of the boot to allow calf massage in order to prevent DVTs

Other devices

- There are many different devices available for immobilization, comfort, or protection
- Dynamic splinting and figure-of-8 braces are examples of advanced immobilization devices
- These should only be used in conjunction with orthopedic consultation and if the ED provider feels comfortable fitting the devices, and instructing the patient on their use

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