SECOND EDITION

CLINICAL EMERGENCY RADIOLOGY

EDITED BY J. Christian Fox

CAMBRIDGE Medicine

Clinical Emergency Radiology Second Edition

This book is a highly visual guide to the radiographic and advanced imaging modalities – such as computed tomography and ultrasonography – that are frequently used by physicians during the treatment of emergency patients. Covering practices ranging from ultrasound at the point of care to the interpretation of CT scan results, this book contains more than 2,200 images, each with detailed captions and line art that highlight key findings. Within each section, particular attention is devoted to practical tricks of the trade and tips for avoiding common pitfalls. This book is a useful source for experienced clinicians, residents, mid-level providers, and medical students who want to maximize the diagnostic accuracy of each modality without losing valuable time.

J. Christian Fox received his undergraduate degree at University of California, Irvine, and his MD at Tufts Medical School. Since joining the UC Irvine faculty in 2001 as Chief of the Division of Emergency Ultrasound, he has directed the Ultrasound Fellowship. In 2010 he created a fully integrated four-year ultrasound curriculum at the School of Medicine. He is the editor of *Clinical Emergency Radiology* as well as *Atlas of Emergency Ultrasound*, and has authored over eighty articles on ultrasound.

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Chapter 1

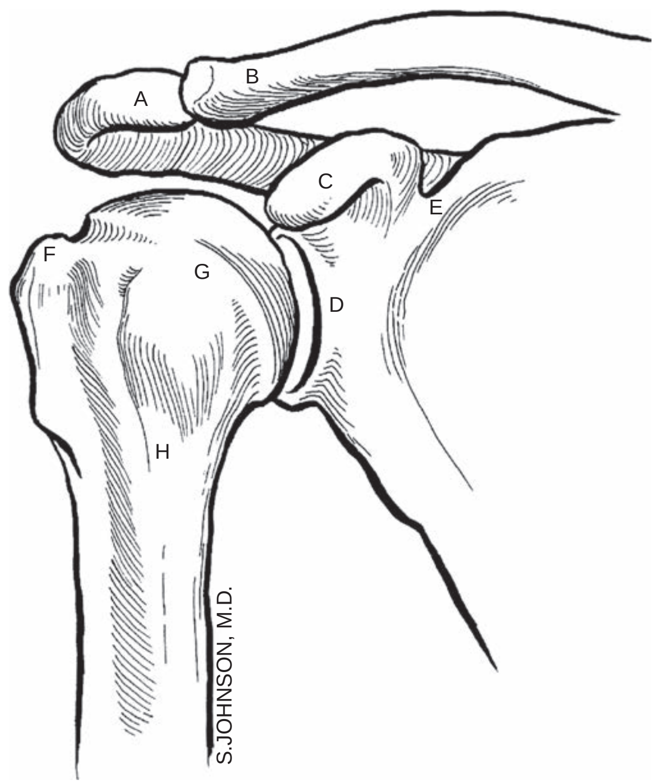
Plain Radiography of the Upper Extremity in Adults

Kenny Banh and Gregory W. Hendey

Plain radiography remains the imaging study of choice for most applications in the upper extremity. Far and away the most common indication for plain radiography in the upper extremity is acute trauma. The shoulder, humerus, elbow, forearm, wrist, and hand are common radiographic series that are useful in diagnosing an acute fracture. Other imaging modalities such as CT, ultrasound, and MRI are not generally indicated in acute trauma but have an important role in diagnosing soft tissue pathology.

Another common indication for plain radiography of the upper extremity is the search for a foreign body in a wound. Plain films are an excellent modality for detecting common, dense foreign bodies in wounds, such as glass and rock, but they are much less sensitive in detecting plastic or organic materials (1). Other imaging modalities such as CT, ultrasound, and MRI are superior for detecting organic and plastic foreign bodies (2). The principles of using plain films for foreign body detection are similar regardless of the location in the body and are not discussed in further detail here.

In this chapter, discussion of the upper extremity is divided into three sections: 1) the shoulder, 2) the elbow and forearm, and 3) the wrist and hand. Within each section, the indications, diagnostic capabilities, and pitfalls are discussed, followed by images of important pathological findings.



Anterior shoulder. A = acromion, B = clavicle, C = coracoid process, D = neck of scapula, E = scapular notch, F = greater tuberosity, G = anatomical neck, H = surgical neck

The shoulder

Indications

The main indication for plain radiography of the shoulder is acute trauma. There are a number of acute injuries that may be discovered on plain radiography after acute trauma, including fractures of the clavicle, scapula, and humerus, as well as shoulder (glenohumeral) dislocation or acromioclavicular (AC) separation. Although many patients may present with subacute or chronic, nontraumatic pain, the utility of plain films in that setting is extremely low. For chronic, nontraumatic shoulder pain, plain films may reveal changes consistent with calcific tendonitis or degenerative arthritis, but it is not necessary to diagnose such conditions in the emergency setting.

Several studies have focused on whether all patients with shoulder dislocation require both prereduction and postreduction radiographs (3). Some support an approach of selective radiography, ordering prereduction films for first-time dislocations and those with a blunt traumatic mechanism of injury, and postreduction films for those with a fracture-dislocation. It is also important to order radiographs whenever the physician is uncertain of joint position, whether dislocated or reduced. Therefore, it may be appropriate to manage a patient with a recurrent dislocation by an atraumatic mechanism without any radiographs when the physician is clinically certain of the dislocation and the reduction.

Diagnostic capabilities

In most settings, if the plain films do not reveal a pathological finding, no further imaging is necessary. MRI is an important modality in diagnosing ligamentous injury (e.g., rotator cuff tear), but it is rarely indicated in the emergency setting.

With the possible exception of the scapula, most fractures of the shoulder girdle are readily apparent on standard plain films, without the need for specialized views or advanced imaging. The shoulder is no exception to the general rule of plain films that at least two views are necessary for adequate evaluation. The two most common views in a shoulder series include the anteroposterior (AP) and the lateral, or "Y," scapula view. Other views that are sometimes helpful include the axillary and apical oblique views. The point of the additional views is to enhance the visualization of the glenoid and its articulation with the humeral head. These views may be particularly helpful in diagnosing a posterior shoulder dislocation or subtle glenoid fracture.

Another radiographic series that is sometimes used is the AC view with and without weights. Although the purpose of these views is to help the physician diagnose an AC separation, they are not recommended for the following reasons: 1) the views might occasionally distinguish a second-degree separation from a first-degree one, but that difference has little clinical relevance because both are treated conservatively, and 2) third-degree AC separations are usually obvious clinically and radiographically, without the need for weights or additional views.

Imaging pitfalls and limitations

Although most acute shoulder injuries may be adequately evaluated using a standard two-view shoulder series, posterior shoulder dislocation can be surprisingly subtle and is notoriously difficult to diagnose. When posterior dislocation is suspected based on the history, physical, or standard radiographic views, additional specialized views such as the axillary and apical oblique can be very helpful. Most radiographic views of the shoulder may be obtained even when the injured patient has limited mobility, but the axillary view does require some degree of abduction and may be difficult.

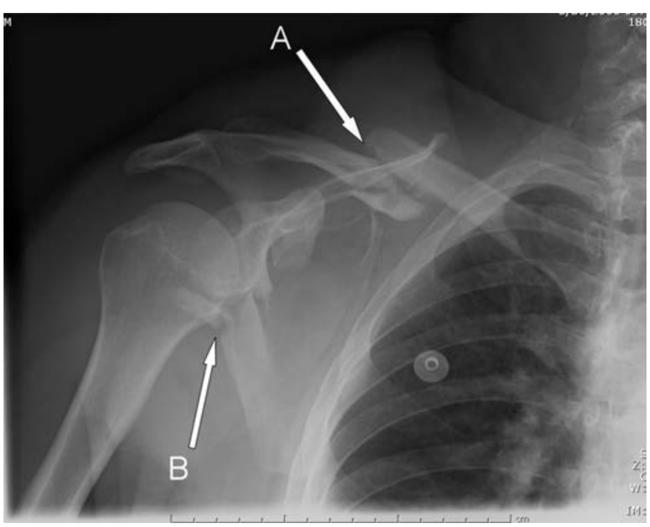


Figure 1.1. Clavicle fractures (A) are often described by location, with the clavicle divided into thirds: proximal, middle, or distal. Note the scapular fracture (B) as well.

Clinical images

Following are examples of common and important findings in plain radiography of the shoulder:

1. Clavicle fracture (fx)
2. AC separation
3. Anterior shoulder dislocation
4. Posterior dislocation (AP)
5. Posterior dislocation (lateral scapula)
6. Luxatio erecta
7. Bankart fx
8. Hill–Sachs deformity
9. Humeral head fracture

The elbow and forearm

Indications

Similar to the shoulder, the most common use of elbow and forearm plain radiography is with acute trauma. There are numerous fractures and dislocations that can be easily visualized with plain films. Chronic pain in these areas is often secondary to subacute repetitive injuries of the soft tissue such as epicondylitis or bursitis. Many of these soft tissue diseases such as lateral "tennis elbow" and medial "golfer's elbow" epicondylitis are easily diagnosed on clinical exam and generally require no imaging at all. Plain films may reveal such soft tissue pathologies as foreign bodies and subcutaneous air.

No well-established clinical decision rules exist for imaging elbows and forearms in acute trauma. Patients with full range of flexion-extension and supination-pronation of the

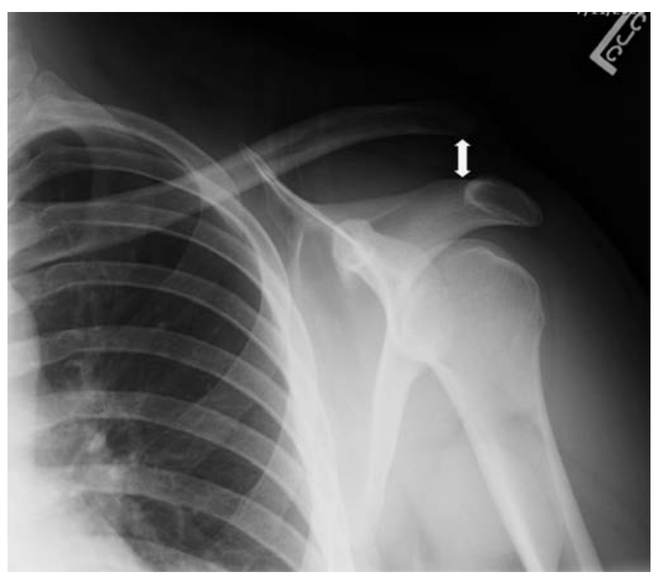


Figure 1.2. AC separation is commonly referred to as a "separated shoulder" and can be classified as grade 1 (AC ligament and coracoclavicular [CC] ligaments intact, radiographically normal), grade 2 (AC ligament disrupted, CC ligament intact), or grade 3 (both ligaments disrupted, resulting in a separation of the acromion and clavicle greater than half the width of the clavicle).

Figure 1.3. The large majority of shoulder dislocations are anterior, and the large majority of anterior dislocations are subcoracoid, as demonstrated in this AP view.

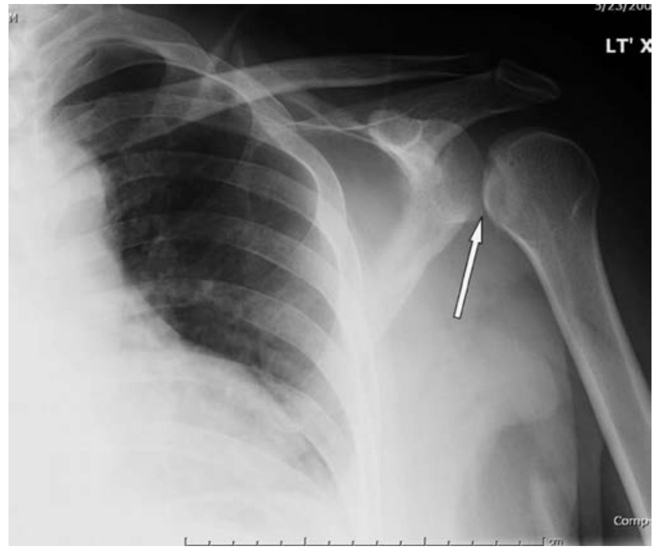


Figure 1.4. Posterior shoulder dislocation is uncommon and is difficult to diagnose on a single AP radiograph. Although it is not obvious in this single view, there are some hints that suggest posterior dislocation. The humeral head is abnormally rounded due to internal rotation (light bulb sign), and the normal overlap between the humeral head and glenoid is absent.

Figure 1.5. Posterior shoulder dislocation is clearly evident on this lateral scapula view, while it was much more subtle on the preceding AP view (see Fig. 1.4). This illustrates the importance of obtaining a second view such as the lateral scapula view or axillary view.

Figure 1.6. Luxatio erecta is the rarest of shoulder dislocations in which the humeral head is displaced inferiorly while the arm is in an abducted or overhead position.

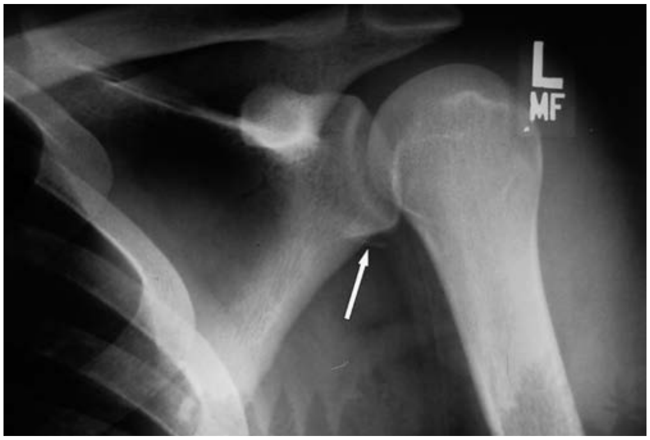


Figure 1.7. Although radiographically subtle, the Bankart fracture is a small avulsion of the inferior rim of the glenoid. The loss of the glenoid labrum destabilizes the glenohumeral joint and nearly ensures recurrent dislocations.

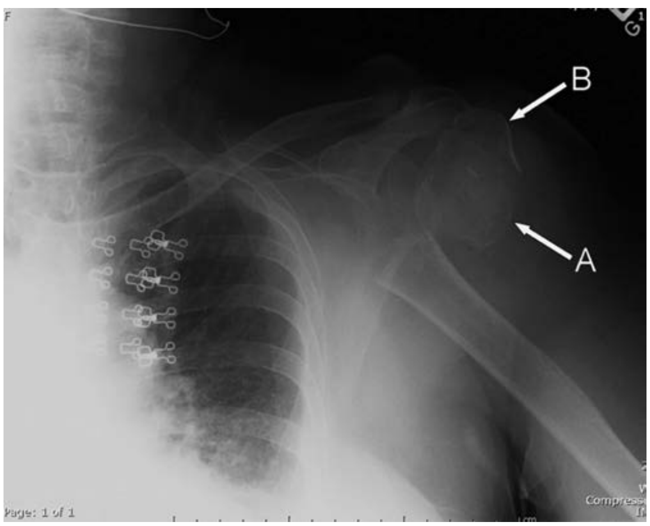


Figure 1.9. Humeral head fracture often occurs across the surgical neck (A) but may also occur at the anatomical neck (B).

elbow and no bony point tenderness rarely have a fracture, and they generally do not require imaging (4). Midshaft forearm fractures are usually clinically apparent, and deformity, swelling, and limited range of motion are all indications for obtaining radiographs. Some suggest ultrasonography may reduce the need for elbow radiography (5).

Diagnostic capabilities

In most cases, if no pathology is found in the plain films of the forearm or elbow, no further imaging is required. Although obvious fractures are easily visualized on plain film, some fractures leave more subtle findings. Radiographs of the elbow in particular may yield important indirect findings. The elbow joint is surrounded by two fat pads, an anterior one lying within the coronoid fossa and a slightly larger posterior fat pad located within the olecranon fossa. In normal circumstances, the posterior fat pad cannot be

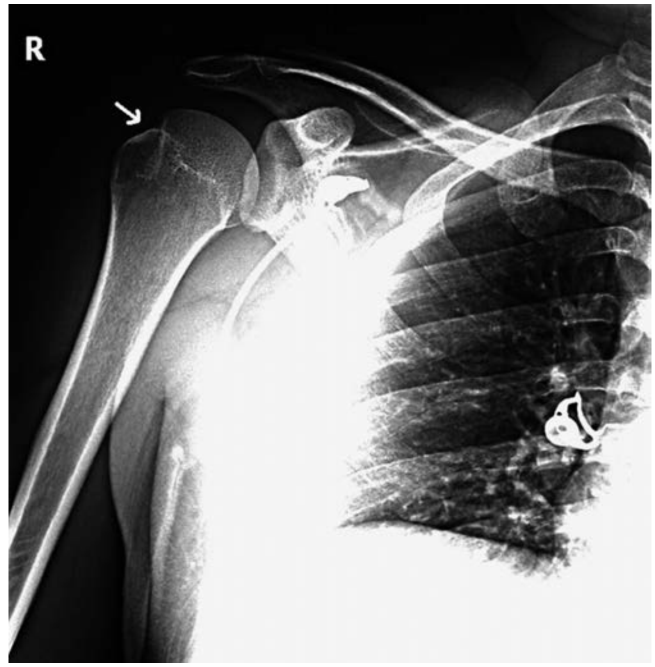


Figure 1.8. The Hill–Sachs deformity is a compression fracture of the superolateral aspect of the humeral head and is commonly noted in recurrent shoulder dislocations. It is believed to occur when the humeral head is resting against the inferior rim of the glenoid while dislocated.

visualized on plain films, but a traumatic joint effusion may elevate the posterior fat pad enough to be visualized on a 90-degree lateral radiograph. The anterior fat pad is normally visualized as a thin stripe on lateral radiographs, but joint effusions may cause it to bulge out to form a "sail sign" (6). Traumatic joint effusions are sensitive signs of an intra-articular elbow fracture (7). In an adult with fat pads and no obvious fracture, an occult radial head fracture is the usual culprit.

Imaging pitfalls and limitations

The two standard views of the elbow are the AP view and the lateral view with the elbow flexed 90 degrees. The majority of fractures can be identified with these two views, but occasionally supplementary views may be obtained to identify certain parts of the elbow and forearm. The lateral and medial oblique views allow easier identification of their respective epicondylar fractures. The capitellum view is a cephalad-oriented lateral view that exposes the radial head and radiocapitellar articulation. The axial olecranon is shot with a supinated and flexed forearm and isolates the olecranon in a longitudinal plane.

Clinical images

Following are examples of common and important findings in plain radiography of the elbow and forearm:

10. Posterior fat pad
11. Radiocapitellar line
12. Elbow dislocation, posterior

Figure 1.10. Subtle soft tissue findings such as this posterior fat pad (A) and sail sign (B) are markers for fractures that should not be dismissed.

Figure 1.11. A radiocapitellar line is drawn through the radius and should bisect the capitellum regardless of the position of the elbow.

Figure 1.12. Elbow dislocation is a common joint dislocation, outnumbered only by shoulder and interphalangeal dislocations. Most elbow dislocations occur during hyperextension. The majority are posterior and are obvious clinically and radiographically.

Figure 1.13. Monteggia fractures or dislocations are fractures of the proximal ulna with an anterior dislocation of the proximal radius. These injuries are usually caused by rotational forces, and the dislocation may not be obvious. Drawing a radiocapitellar line aids in diagnosis as it demonstrates the misalignment.

13. Monteggia fracture
14. Galeazzi fracture (AP)
15. Galeazzi fracture (lateral)

The wrist and hand

Indications

As with the rest of the upper extremity, the major indication for imaging of the wrist and hand is with acute trauma. It is one of the most difficult areas to differentiate between soft tissue and skeletal injury on history and physical examination alone. Imaging is necessary even with obvious fractures because the extent of the fracture, displacement, angulation, and articular involvement are important to determine if the patient needs closed reduction in the ED or immediate

Figure 1.14. A Galeazzi fracture, or Piedmont fracture, is a fracture of the distal third of the radius with dislocation of the distal ulna from the carpal joints. This is the exact opposite of a Monteggia fracture and is also caused by rotational forces in the forearm, although more distal.

Figure 1.15. Often mistaken for a simple distal radius fracture on AP radiograph, the dislocation is clearly evident on a lateral forearm or wrist.

orthopedic referral for possible open reduction and surgical fixation.

There are still settings where imaging of the hand and wrist is not indicated. Carpal tunnel disease and rheumatologic and gouty disorders are chronic diseases that usually do not involve acute trauma and can be diagnosed based on a good history and physical exam alone.

Diagnostic capabilities

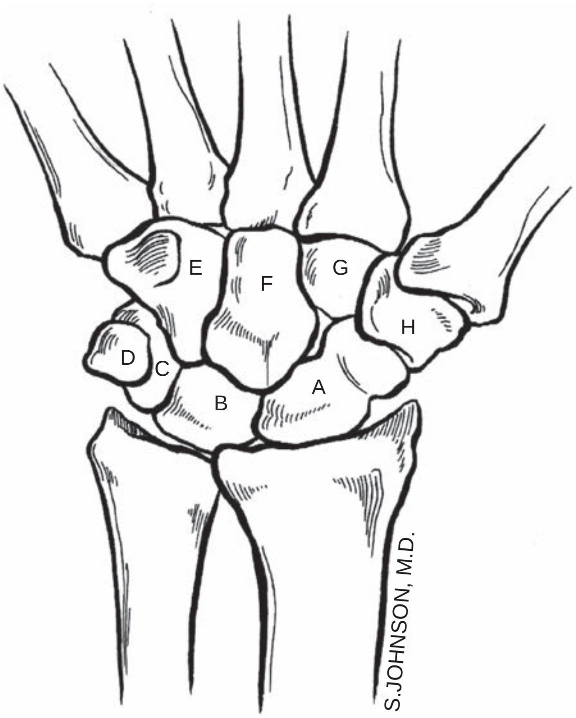
Besides searching for acute bony fractures and dislocations, plain films can reveal other important pathology. With high-pressure injection injuries to the hand, subcutaneous air is a marker for significant soft tissue injury and is often an indication for surgical exploration. Many carpal dislocations and ligamentous injuries are readily visualized on radiographs of the wrist and hand. Perilunate and lunate dislocations usually result from hyperextension of the wrist and fall on an outstretched hand (FOOSH) injury. They may be poorly localized on physical exam and films, and a good neurovascular exam, especially of the median nerve, is indicated.

Imaging pitfalls and limitations

Because of the size and number of bones, complete radiographic sets of hand and wrist films are often acquired. The minimum standard views of the hand and wrist involve a posterior-anterior, lateral, and pronated oblique. This third view helps assess angulated metacarpal fractures that would normally superimpose on a true lateral. Accessory views of the hand such as the supination oblique or ball catcher's view can help view fractures at the base of the ring and little finger, while a Brewerton view allows better visualization of the metacarpal bases. The wrist accessory films include a scaphoid view, a carpal tunnel view that looks at the hook of the hamate and trapezium ridge, and a supination oblique view that isolates the pisiform. These accessory films should be ordered whenever there is localized tenderness or swelling in these areas.

Unlike the proximal upper extremity, fractures in the wrist and hand may not always be readily apparent on plain films. Scaphoid fractures often result from a FOOSH injury. About 10% to 20% of scaphoid fractures have normal radiographs on initial presentation to the ED (8). Therefore, it is extremely important not to disregard these clinical signs of scaphoid fracture: "anatomical snuff box" tenderness, pain with supination against resistance, and pain with axial compression of the thumb. These signs merit immobilization of the wrist in a thumb spica splint and follow-up in one to two weeks.

More advanced imaging modalities of the wrist and hand such as CT, MRI, and high-resolution ultrasound are much more sensitive for identifying fractures, bone contusions, and ligamentous injury that would be missed



Bones of the wrist: palmar view. A = scaphoid, B = lunate, C = triquetrum, D = pisiform, E = hamate, F = capitate, G = trapezoid, H = trapezium

Figure 1.16. A Colles' fracture occurs at the distal metaphysis of the radius with dorsal displacement and radial length shortening. An extremely common injury pattern also seen in FOOSH injuries, the radial head is shortened, creating a disruption of the normally almost linear continuation of the radial and ulnar carpal surfaces.

on plain radiography (9). Whether advanced imaging is indicated in the emergency department may depend on local resources.

Clinical images

Following are examples of common and important findings in plain radiography of the wrist and hand:

16. Colles' fracture (AP)
17. Colles' fracture (lateral)
18. Smith's fracture (AP)
19. Smith's fracture (lateral)
20. Scaphoid fracture
21. Scapholunate dissociation
22. Lunate dislocation (AP)
23. Lunate dislocation (lateral)
24. Perilunate dislocation (AP)
25. Perilunate dislocation (lateral)
26. Boxer's fracture (AP)
27. Boxer's fracture (lateral)
28. Tuft fracture

Figure 1.17. The dorsal displacement is evident on the lateral radiograph, and proper reduction is needed to restore this alignment.

Figure 1.18. A Smith's fracture, also known as a reverse Colles' fracture, is a distal radius fracture with volar instead of dorsal displacement of the hand. Usually caused by direct blows to the dorsum of the hand, these fractures often need eventual surgical reduction.

Figure 1.19. Sometimes referred to as a "garden spade" deformity, the lateral view differentiates this type of fracture from the more common Colles' fracture.

Figure 1.20. Because of the size and number of hand and wrist bones, many subtle fractures are missed on cursory views of plain radiographs. All AP hand views should be checked for smooth carpal arches formed by the distal and proximal bones of the wrist. Evidence of avascular necrosis in scaphoid fractures occurs in the proximal body of the fracture because the blood supply of the scaphoid comes distally from a branch of the radial artery. The arrow denotes a scaphoid fracture.

Figure 1.21. A tight relationship between adjacent carpal bones and the distal radius and ulna should be observed as well. The loss of this alignment or widening of the space, as seen here between the scaphoid and lunate bones, is a sign of joint disruption from fracture, dislocation, or joint instability. A widening of greater than 4 mm is abnormal and known as the "Terry-Thomas sign" or rotary subluxation of the scaphoid. The scaphoid rotates away and has a "signet ring" appearance at times.

Figure 1.22. Lunate dislocations are the most common dislocations of the wrist and often occur from FOOSH injuries. They are significant injuries involving a volar displacement and angulation of the lunate bone. Notice how the carpal arches are no longer clearly seen.

Figure 1.23. The lateral view shows the obviously dislocated and tilted "spilled teacup" lunate. Observe how the capitate and other wrist bones are in relative alignment with the distal radius.

Figure 1.24. Perilunate dislocations are dorsal dislocations of the capitate and distal wrist bones. Once again, there is a loss of the carpal arcs with significant crowding and overlap of the proximal and distal carpal bones. Neurovascular exams for potential median nerve injuries are extremely important in these injuries.

Figure 1.25. The lateral view of a perilunate dislocation shows the lunate in alignment with radial head. It is the distal capitate that is obviously displaced, in contrast to the lunate dislocation.

Figure 1.26. Metacarpal neck fracture of the fifth metacarpal, commonly referred to as a boxer's fracture, typically occurs from a closed fist striking a hard object such as a mandible or wall.

Figure 1.27. The lateral view reveals the degree of angulation. The amount of angulation that requires reduction or impairs function of the hand is controversial, but many believe greater than 30 degrees of angulation requires reduction (8).

Figure 1.28. A crush injury to the distal phalanx often causes a tuft fracture. It is important to evaluate for open fractures, subungual hematomas, and concomitant nail bed injury.

References

1. Manthey DE, Storrow AB, Milbourn J, Wagner BJ: Ultrasound versus radiography in the detection of soft-tissue foreign bodies. *Ann Emerg Med* 1996;287–9.
2. Peterson JJ, Bancroft LW, Kransdorf MJ: Wooden foreign bodies: imaging appearance. *AJR Am J Roentgenol* 2002;**178**(3):557–62.
3. Hendey G, Chally M, Stewart V: Selective radiography in 100 patients with suspected shoulder dislocation. *J Emerg Med* 2006;**31**(1):23–8.
4. Hawksworth CR, Freeland P: Inability to fully extend the injured elbow: an indicator of significant injury. *Arch Emerg Med* 1991;**8**:253.
5. Rabiner JE, Khine H, Avner JR, et al.: Accuracy of point-of-care ultrasonography for diagnosis of elbow fractures in children. *Ann Emerg Med* 2013;**61**(1):9–17.
6. Hall-Craggs MA, Shorvon PJ: Assessment of the radial head-capitellum view and the dorsal fat-pad sign in acute elbow trauma. *AJR Am J Roentgenol* 1985;**145**:607.
7. Murphy WA, Siegel MJ: Elbow fat pads with new signs and extended differential diagnosis. *Radiology* 1977;**124**:659.
8. Byrdie A, Raby N: Early MRI in the management of clinical scaphoid fracture. *Brit J Rad* 2003;**76**:296–300.
9. Waeckerle JF: A prospective study identifying the sensitivity of radiographic findings and the efficacy of clinical findings in carpal navicular fractures. *Ann Emerg Med* 1987;**16**:733.

Chapter 2

Lower Extremity Plain Radiography

Anthony J. Medak, Tudor H. Hughes, and Stephen R. Hayden

Indications

Lower extremity injuries are common in ED and urgent care settings. As part of the workup of these patients, healthcare providers typically use some type of imaging modality. Plain radiography is frequently a starting point, as it is readily available, is inexpensive, and has few contraindications. In addition, plain radiography involves much lower levels of ionizing radiation than CT, for example. The medical literature has discussed at length the long-term risks and effects from ionizing radiation (1). As such, healthcare providers should give strong consideration to using additional plain radiograph views (gravity stress, weight bearing, etc.) rather than automatically opting for other modalities such as CT.

Plain radiography is useful in a number of clinical situations, including diagnosing fractures and dislocations and evaluating the end result after closed reductions performed in the ED. In addition, it is helpful in evaluating for radiopaque foreign bodies and assessing joint spaces for evidence of autoimmune or degenerative processes such as rheumatoid arthritis or avascular necrosis. Finally, plain films are also helpful in evaluating possible infections, including those involving the bone, as in osteomyelitis, or the adjacent soft tissues, as in necrotizing soft tissue infections.

Diagnostic capabilities

Lower extremity radiography is useful for diagnosing fractures and dislocations of the hip, knee, foot, and ankle, as well as demonstrating pathology of the femur, tibia, and fibula. Plain radiography is helpful in evaluating fractures of the lower extremity bones, as well as masses and malignancies, including pathological fractures. In some cases, these films will be supplemented with CT or MRI of the affected area to provide additional information. In addition to bony pathology, lower extremity radiography is helpful in assessing the soft tissues, as in the setting of joint effusions, inflammation of bursae, soft tissue calcifications, or soft tissue infections. Finally, plain radiography is also useful for visualizing radiopaque foreign bodies of the lower extremity.

When ordering radiographs of the lower extremity, one must give careful consideration to selecting the optimal views. Obtaining the proper radiographic views will significantly affect the utility of the study. For example, when looking for calcaneal pathology, it is advisable to obtain dedicated calcaneal views as opposed to imaging the entire foot, as this allows for better visualization of subtle pathology.

Imaging pitfalls and limitations

Information obtained from plain radiographs may be limited by several factors. Most notable is the quality of the technique employed. Penetration of the image and proper patient positioning are crucial to obtaining useful images. Improper positioning can mask findings of subtle hip, tibial plateau, or foot and ankle fractures.

Additionally, postoperative patients sometimes pose a challenge. If a patient has had prior surgeries or has an internal fixation device in place, interpretation of the films may be difficult. Also, plain radiography itself has inherent limitations, regardless of patient or technique. For example, many foreign bodies, including organic material, plastics, and some types of glass, are radiolucent and, therefore, not well visualized with plain radiography. Ultrasound and MRI are other imaging options in these cases.

Plain radiography is very good for evaluating most bony pathology; however, there are exceptions. In the case of osteomyelitis, for example, there is often a delay of 2 to 3 weeks between onset of symptoms (pain, fever, swelling) and onset of radiographic findings. As a result, plain radiography alone is relatively insensitive in diagnosing acute osteomyelitis (2). Other modalities, including MRI and bone scan, are often used in these cases.

Other limitations of plain radiography include failure to detect fractures with subtle radiographic findings, such as acetabular, tibial plateau, or midfoot (Lisfranc's) fractures. In many such instances, CT or MRI is necessary if clinical suspicion is high, even in the setting of negative plain films. It is well reported that, in patients with complex foot and ankle fractures, the sensitivity and negative predictive value of plain radiography alone are inadequate (3). In these cases, multidetector CT is the modality of choice. Another area where plain radiography alone yields insufficient anatomical detail is the proximal tibia. Many authors support supplemental imaging with CT to better delineate the anatomy and allow for preoperative planning and fracture management (4, 5).

Despite these limitations of lower extremity radiography, some simple measures may be taken to improve overall diagnostic accuracy. As noted previously, proper image penetration and patient positioning are imperative. Beyond this, the

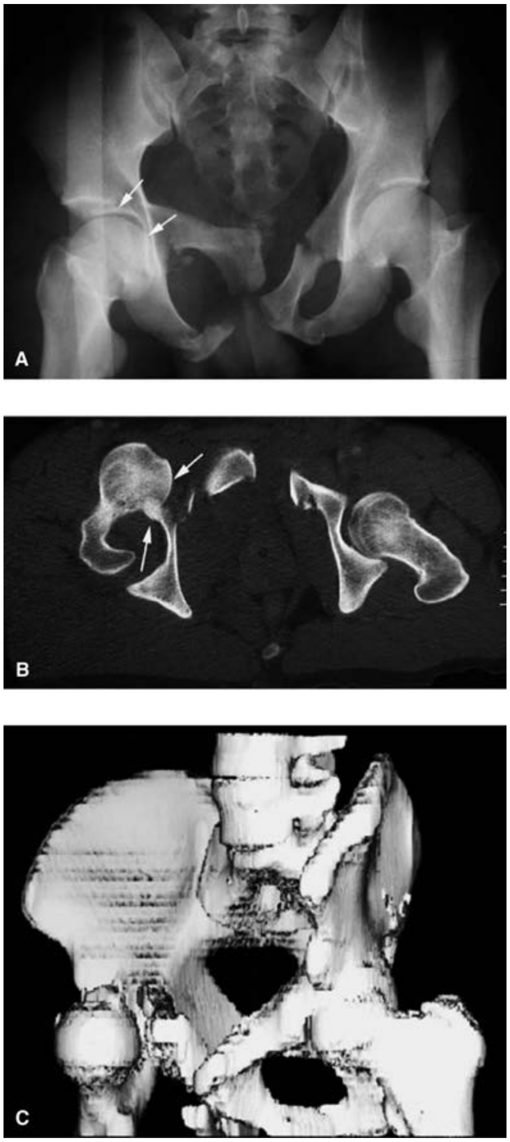


Figure 2.1. Anterior hip fracture-dislocation. The initial AP radiograph (A) shows the right leg to be externally rotated and the superior acetabulum to have a discontinuous margin due to an accompanying acetabular fracture. The CT scans, both axial (B) and 3D reconstructions (C), show the anterior dislocation of the femur, with both acetabular fracture and impaction fracture of the femoral head.

use of stress imaging, whether it be weight bearing (to enhance Lisfranc injury) or gravity stress (to enhance ankle instability), can be very useful (6, 7). Stress views can reveal much more about the function of ligaments and as such are often superior and complementary to MRI.

Finally, as with any radiographic imaging, one must have sufficient knowledge of the normal anatomy to be able to recognize pathology. This includes the ability to distinguish normal variants from true pathology. For example, bipartite patella, presence of a growth plate, or sesamoid bone may all be mistaken for abnormalities if a basic understanding of normal anatomy is lacking.

Figure 2.2. Open anterior fracture-dislocation of hip. An AP radiograph shows the left hip to be dislocated with the femoral head inferior, compatible with anterior dislocation. The leg is abducted and externally rotated, which is commonly the leg position that predisposes to anterior dislocation. In addition, note the acetabular fracture on the right.

Figure 2.3. Posterior hip dislocation. AP (A) and lateral (B) radiographs of a 15-year-old male with a posterior left hip dislocation. Note the high position of the left femoral head on the AP view and the posterior position on the lateral view, which is projecting supine with the ischium (a posterior structure) at the bottom of the image (*arrow*).

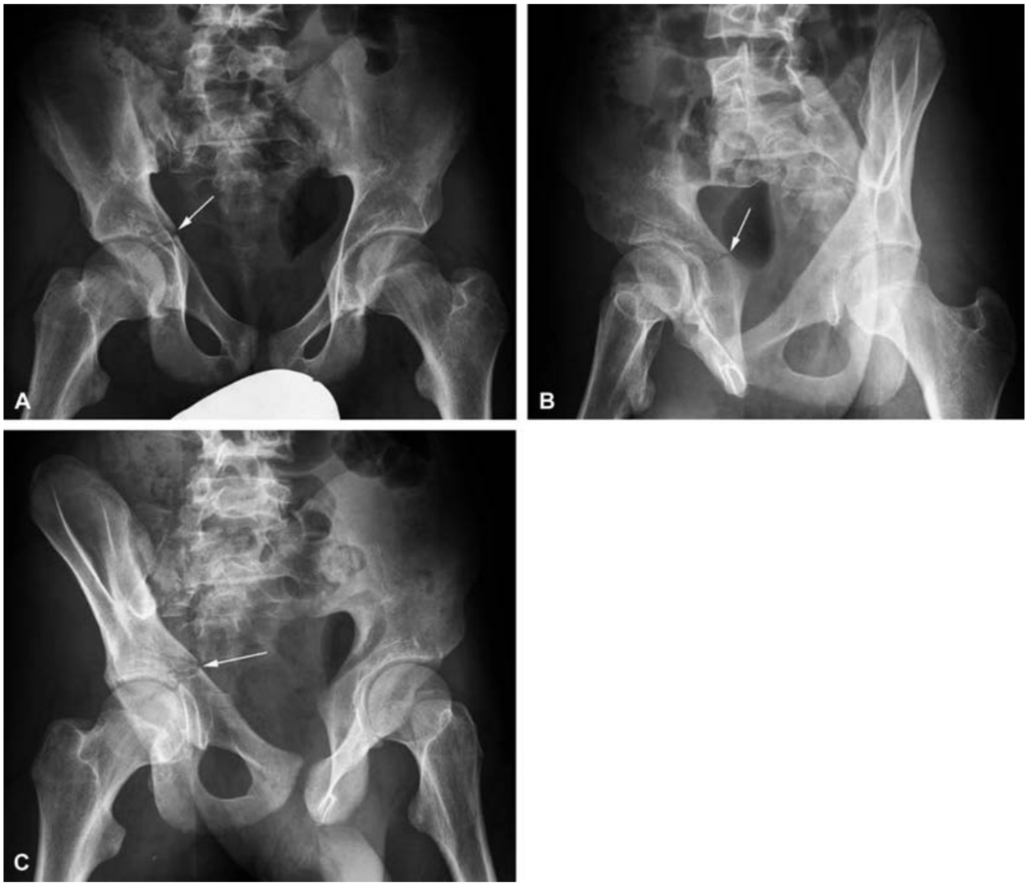


Figure 2.4. Acetabular fracture not well visualized on CT. This 19-year-old male sustained a horizontal fracture of the right acetabulum in a motor vehicle collision. The AP view (A) shows the fracture line over the medial acetabulum, and the Judet views (B, C), RPO (right posterior oblique), and LPO (left posterior oblique) show the involvement of the posterior column and anterior column, respectively (*arrows*). This fracture was very difficult to see on CT due to the fracture plane being the same as that of the axial CT images. This underscores the importance, in some cases, of multiple imaging modalities to properly characterize the injury.

Figure 2.5. Posttraumatic avascular necrosis (AVN). This 17-year-old male sustained a femoral neck fracture (A). Four years later following decompression, the subsequent radiograph (B), as well as the coronal plane T1-weighted MRI (C), show sclerosis and lucencies on the radiograph (*arrows*) and well-defined margins of AVN on the MRI (*arrow*).

Figure 2.6. Impacted fracture of right femoral neck. An AP radiograph shows impaction of the lateral femoral neck as well as a band of sclerosis (*arrows*) in this 46-year-old male.

Figure 2.8. Horizontal intertrochanteric fracture. The left posterior oblique radiograph of the pelvis shows a relatively horizontal intertrochanteric fracture. Most fractures in this region are more oblique from superolateral to inferomedial.

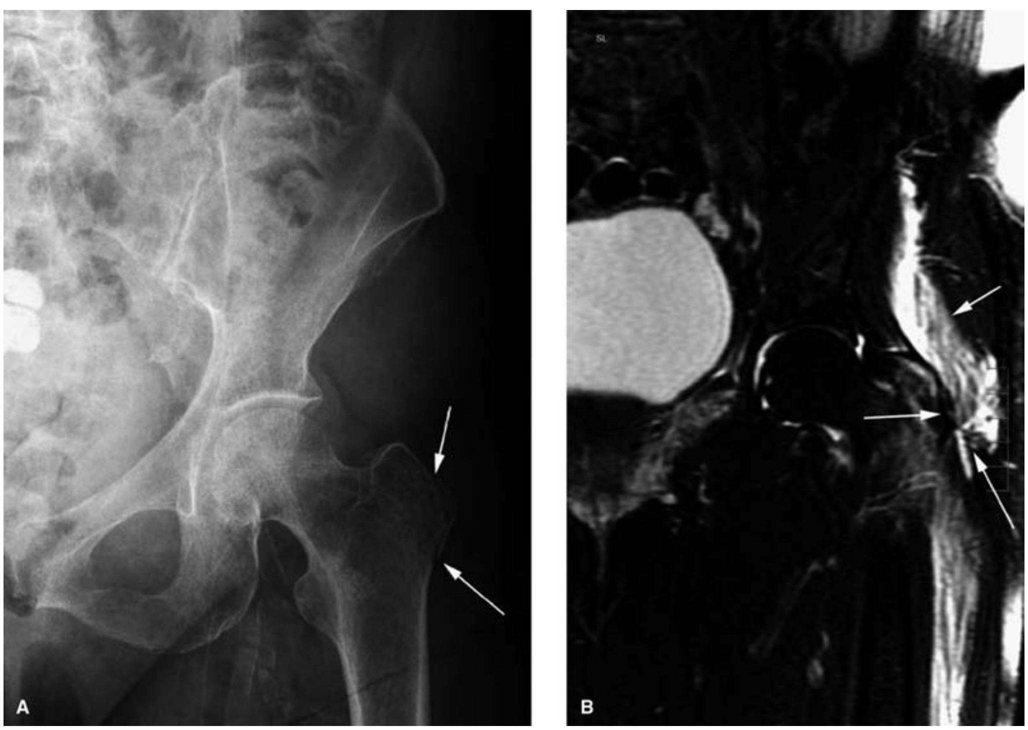


Figure 2.7. Greater trochanter fracture. This 68-year-old female sustained a greater trochanter fracture, difficult to appreciate with plain radiography (A). The subsequent coronal T2-weighted MRI (B) shows the edema in the greater trochanter and adjacent hip abductors (*arrows*). MRI is useful in the differentiation of surgical and nonsurgical management.

Figure 2.9. Pathological fracture of the left subtrochanteric femur. AP radiograph of the left hip in this 70-year-old male with Paget disease shows abnormal architecture of the proximal femur with a coarse trabecular pattern and cortical thickening typical of the sclerotic phase of this disease. A pathological fracture has occurred through the weakened abnormal bone.

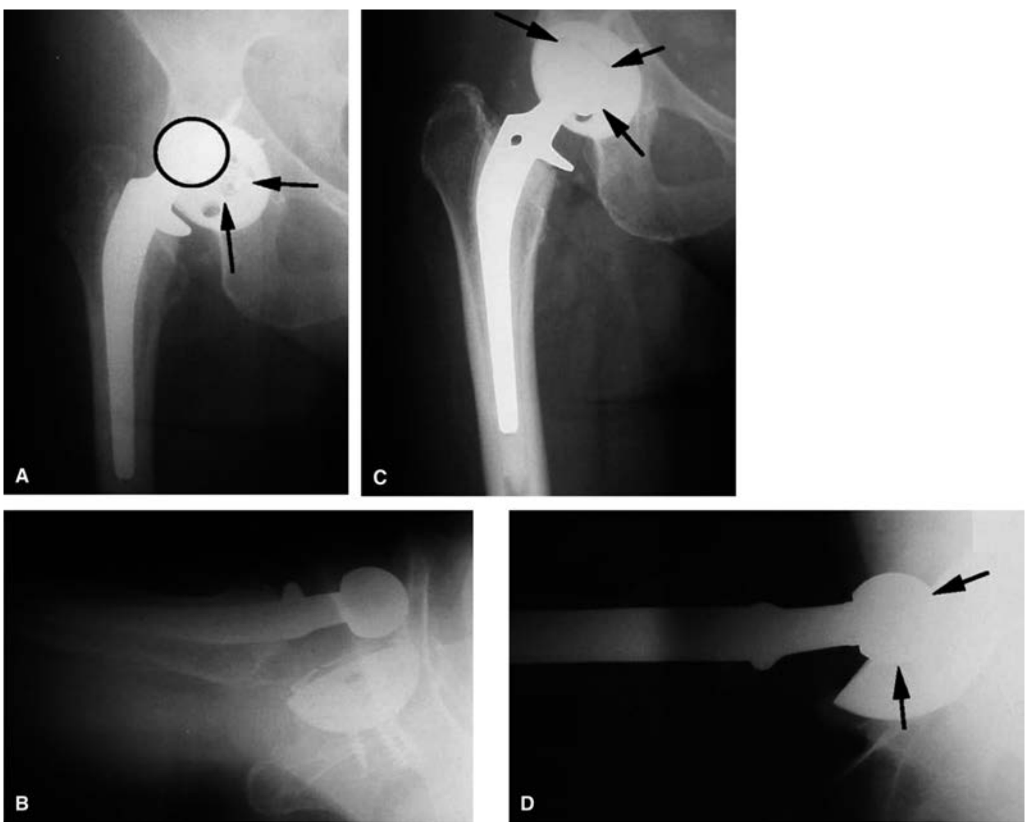


Figure 2.10. Dislocated total hip arthroplasty. AP and lateral views of the right hip with anterior dislocation (A, B) (the ring represents the femoral head) and following reduction (C, D). Note the femoral head must be concentric with the acetabulum on both views for it to be correctly located.

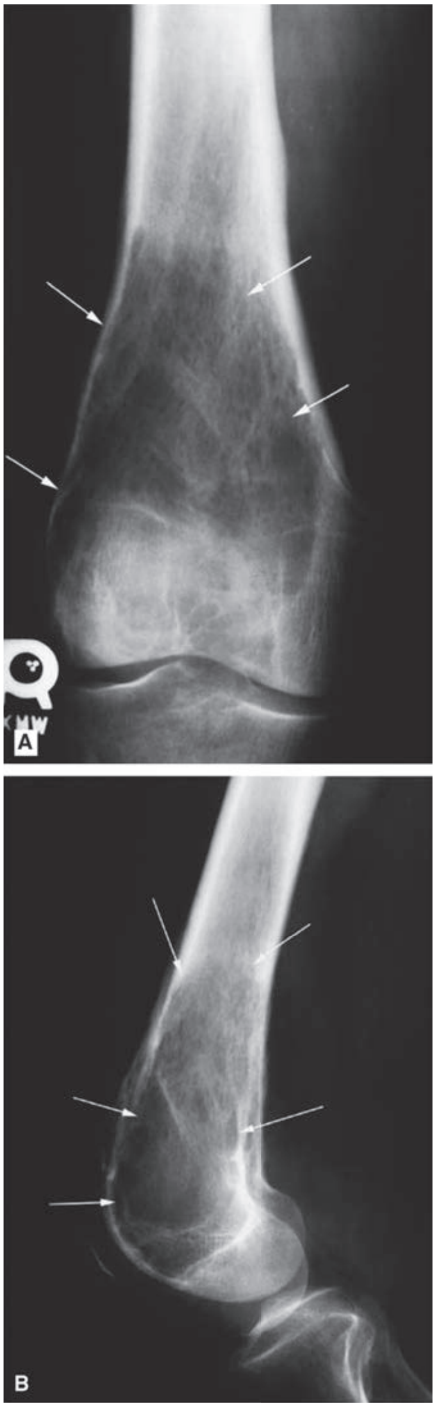


Figure 2.11. Giant cell tumor of bone involving the right distal femur. AP (A) and lateral (B) radiographs in a 37-year-old male show a lytic lesion involving the metaphysis and extending to the epiphysis (*arrows*). It has a mixed benign and aggressive appearance, with the lateral margin being well defined and the proximal margin more ill defined.

Figure 2.12. Subluxed patella. A bilateral Merchant view of the patellae shows the right patella to be laterally subluxed. Axial views of the patella are taken with the knees flexed 40 degrees and with the film either on the shins (Merchant projection) or on the thighs (Inferosuperior projection).

Figure 2.13. Bipartite patella. AP (A) and axial (B) views of the left knee in a 16-year-old male. Note that the accessory bone fragment is always superolateral. The margins are rounded and sclerotic, excluding an acute fracture.