Single Joint Pain

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This chapter reviews imaging of symptoms confined to single joints within the musculoskeletal system. The main points of this chapter are:

1. Monoarthropathy may be a precursor of polyarthropathy.
2. Imaging should be tailored by which joint (shoulder, elbow, wrist, etc.) is symptomatic. When imaging is required, plain film evaluation should generally precede use of computerized tomography (CT), magnetic resonance imaging (MRI), arthrography, and nuclear medicine studies.

**MONOARTHROPATHY MAY BE A PRECURSOR OF POLYARTHROPATHY**

Since virtually any arthritis may initially present as a single joint abnormality, pain in a given joint may represent the first manifestation of polyarthritis. In the absence of trauma, patient history and physical examination results will help to determine whether there are additional features (e.g., rash, fever, weight loss, etc.) suggesting a systemic process which may be manifesting as monoarthritis. Other than trauma, infection (especially gonococcal) and crystal arthropathy (predominantly gout and calcium pyrophosphate dihydrate) are the main causes of monoarthritis.

Analysis of aspirated joint fluid is the key to making a diagnosis in most cases, and imaging typically does not add significant information. For further discussion of arthropathy, see Chapter 13.

**IMAGING SHOULD BE TAILORED TO WHICH JOINT IS SYMPTOMATIC**

**IN GENERAL, PLAIN FILM EVALUATION SHOULD PRECEDE USE OF CT, MRI, ARTHROGRAPHY, AND NUCLEAR MEDICINE**

When imaging is used for evaluation of joint pain, plain films are the first step, as these are readily available, relatively cheap, and often straightforward to interpret. It is difficult to generalize regarding imaging recommendations when comparing the different joints in the body, since they are prone to different diseases. More complex (and expensive) imaging studies such as CT and MRI need to be tailored to the joint, symptoms, and suspected disease processes in each case.

**Shoulder**

Evaluation of acute post-traumatic shoulder pain starts with a plain film examination for evaluation of fracture (Figure 1) and dislocation (Figure 2). If the plain film examination shows a complex fracture...
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requiring surgical fixation, CT may be obtained to evaluate the exact anatomy of the fracture, but the decision to order the CT is typically left to the orthopedic surgeon (Figure 3). If the plain film is negative but your suspicion of significant injury is high, order an MR study: the MR study will show both occult fractures (Figure 4) and any significant soft tissue injury (Figure 5).

Evaluation of chronic shoulder pain (either with or without a history of trauma) also starts with plain films. The plain film examination will demonstrate calcific tendinitis (Figure 6), chondrocalcinosis (Figure 7), and degenerative change (Figure 8). Note that as the shoulder is not a weight bearing joint, degenerative changes should raise the suspicion of underlying, causative pathology (e.g., crystal arthropathy, prior fracture, or longstanding full thickness rotator cuff tear). For patients with chronic shoulder pain requiring further evaluation after the plain film, MR is the study of choice. In younger patients, particularly athletes where shoulder instability is an issue, the MR should be done following an arthrogram, since labral tears are much easier to identify and assess following introduction of contrast material into the shoulder joint (Figure 9). For older patients, MR done without contrast material is usually adequate to exclude rotator cuff tear (Figure 10), although some pinhole tears may be difficult to diagnose without intra-articular contrast and some authors advocate intra-articular contrast for all shoulder MR studies3. Regarding full thickness rotator cuff tears, note that many older individuals may have asymptomatic full thickness rotator cuff tears. Sher et al4 demonstrated that for asymptomatic subjects over the age of 60, 28% had partial thickness, and 26% had full thickness tears at magnetic resonance imaging. For patients between 40 and 60 years of age, 24% had partial thickness and 4% full thickness tears, whereas for those under the age of 40, only 4% had partial thickness and none had full thickness tears. A full thickness rotator cuff tear in a patient over 60 years of age may not be the cause of the patient’s shoulder pain.

An additional clinical scenario to consider in shoulder evaluation is that of a patient who has had a prior rotator cuff repair. Rotator cuff repair, capsulorrhaphy, and acromioplasty may incite pain in the shoulder joint which is similar to pain from a torn (or retorn) rotator cuff 3. MR is the usual method of choice for imaging evaluation of patients who have undergone rotator cuff repair. It is of note that such repairs are not necessarily water tight (and therefore will leak contrast at arthrography), but any large gap should certainly cause concern for a rupture.

Figure 1. Humeral fracture in a 38 year old man with shoulder pain following trauma. AP plain film shows a fracture (arrow) through the base of the greater tubercle of the proximal humerus.

Figure 2. Shoulder dislocation in a 17 year old with pain following trauma. AP plain films shows a humeral head dislocation in the typical anterior, inferior location.
Figure 3. Complex shoulder fracture in a 65 year old woman with pain following trauma. A. AP plain film examination shows a “dent” in the superolateral humeral head (arrow), the Hill-Sachs deformity. B. Axial plain film examination shows discontinuity of the glenoid with a medially displaced bone fragment (arrow). C. Axial CT study at the level of the upper glenohumeral joint shows indentation of the humeral head (arrow). D. Axial CT study at the level of the lower glenohumeral joint shows a fracture of the anterior inferior glenoid rib with a medially displaced bone fragment. The imaging features are characteristic of a dislocation of the glenohumeral joint with associated fractures.
Figure 4. Humeral head fracture in a 33 year old man with pain following trauma (fall on ice). A. AP plain film of the shoulder with the patient’s shoulder in internal rotation shows no displaced fracture. B. AP plain film of the shoulder with the patient’s shoulder in external rotation suggests a possible subtle lucency (arrow) suggesting fracture, although the plain film features are not definitive. C. Coronal oblique T1 weighted MR study shows abnormal marrow and a fracture line along the base of the greater tubercle (arrow). D. Coronal oblique T2 weighted image confirms extensive marrow abnormality and a fracture through the base of the greater tubercle (arrow).
Figure 5. Acute rotator cuff tear in a 64 year old woman following trauma. A. AP plain film examination of the shoulder demonstrates no fracture. B. Coronal oblique fat-suppressed T2 weighted image shows a full thickness rotator cuff tear, with fluid along the normal course of the tendon deep to the deltoid muscle and superficial to the humeral head (arrow). C. Sagittal oblique fat-suppressed T2 weighted image demonstrates a large full-thickness rotator cuff tear (arrow) which involves both the supraspinatus and infraspinatus tendons. D. Sagittal oblique fat-suppressed T2 weighted image closer to the midline demonstrates extensive muscle tearing and interstitial increased signal (compatible with edema or hemorrhage) within the infraspinatus muscle (arrows).
Figure 6. Calcific tendinitis in a 48 year old man with shoulder pain. AP plain film exam demonstrates calcification along the distal aspect of the supraspinatus tendon near its insertion on the greater tubercle (arrow).

Figure 7. Chondrocalcinosis and degenerative changes of the glenohumeral joint in a 92 year old woman with shoulder pain. AP shoulder exam demonstrates subtle chondrocalcinosis of the humeral head articular cartilage (arrow), along with joint narrowing, subchondral sclerosis, and osteophytic spurring of the glenohumeral joint.

Figure 8. Degenerative change of the glenohumeral joint in a 47 year old man with shoulder pain who had a remote prior fracture of the humerus.

Figure 9. Labral tear/loose body in a 19 year old with repeated shoulder dislocations. MR arthrogram shows a large filling defect in the inferior recess (arrow).

Figure 10. Full thickness rotator cuff tear in a 57 year old man with chronic pain and shoulder weakness. Coronal oblique fat-suppressed T2 weighted MR study shows a full-thickness defect in the supraspinatus tendon with retraction of the torn tendon margins (arrows).
Elbow

In patients with acute elbow pain following trauma, plain films should be obtained first. These will demonstrate not only cortical discontinuity but also the presence of a displaced fat pad, which is an indication of a joint effusion (Figure 11). In the setting of acute trauma, such an effusion typically represents a secondary finding indicating a nondisplaced radial head fracture. If the plain films show no fracture or effusion, MR may be of benefit, particularly if there are clinical features of a biceps tendon rupture (Figure 12) or other musculotendinous injury (Figure 13).

In patients with chronic elbow pain, imaging is usually not helpful. Exceptions include evaluation of throwing athletes (particularly baseball pitchers) where MR-arthrography of the elbow joint may be of benefit to diagnose radial collateral ligament tears (Figure 14). MR of the elbow may also be of benefit to diagnose loose bodies within an effusion (Figure 15) and neurologic abnormalities centered at the elbow joint, where the ulnar nerve passes in close proximity to the distal dorsal medial humerus (Figure 16). Finally, while it is largely a clinical diagnosis, MR of the elbow can be helpful in confirming abnormalities of the origins of the common extensor and flexor tendons. A painful common tendon origin is called epicondylitis (a misnomer considering that the epicondyle is part of the humerus and is not inflamed). A painful lateral (extensor) tendon origin is also known as “tennis elbow”, and a painful medial (flexor) tendon origin “golfer’s elbow”. MR will demonstrate abnormal signal of the tendon origins.

Figure 11. Radial fracture in a 51 year old woman who had pain following trauma. A. Lateral plain film of the elbow shows displacement of the fat pad from the anterior aspect of the distal humerus (arrow). B. Oblique plain film shows a subtle fracture through the radial neck (arrow). Elbow effusions following trauma are typically secondary to marrow and hemorrhage in the joint from a fracture.
Figure 12. Biceps tendon rupture in a 47 year old man who had acute pain in the elbow following a lifting injury. A. Axial T1 weighted MR image demonstrates a swollen distal biceps tendon (arrow). B. Axial T1 weighted MR image slightly more distal in the arm demonstrates rapid tapering and an irregular appearance of the biceps tendon (arrow), particularly along its deep aspect. C. Axial T1 weighted MR image slightly more distally shows that the biceps tendon is absent (arrow) compatible with tearing and proximal retraction. D. Sagittal proton density MR image shows the tear through the distal biceps tendon (arrow) with retraction of the torn tendon margin.
Figure 13. Pronator teres muscle tear in a 58 year old woman with pain following a golfing injury. A. Axial T2 weighted MR image demonstrates abnormal signal (arrow) in the pronator teres muscle. B. Coronal T2 weighted MR image shows a small focal hematoma (arrow) of the pronator teres muscle.

Figure 14. Intact ulnar collateral ligament in an 18 year old male pitcher with ulnar sided elbow pain. A. Arthrogram shows contrast material in the joint (arrow). B. Coronal T1 fat-suppressed image shows contrast material in the elbow joint, along with an intact ulnar collateral ligament (arrow). Note that the proximal aspect of the ligament was also intact and attached normally to the humerus but was out of the plane of section on this image.
Figure 15. Loose body in the elbow joint in a 54 year old man with elbow pain. A. Lateral plain film shows an osseous fragment (arrow) projecting anterior to the distal humerus. B. Sagittal fat suppressed T2 weighted image demonstrates a joint effusion and the osseous fragment surrounded by elbow joint effusion fluid (arrow).

Figure 16. Ulnar nerve neuritis in a 50 year old woman with cubital tunnel syndrome. Axial fat-suppressed T2 weighted image shows abnormal increased signal in the ulnar nerve (arrow).

Wrist

As with the shoulder and elbow, plain films are the initial study of choice following acute injury of the distal forearm or wrist. Wrist trauma is relatively frequent because falls on an outstretched hand cause fractures of the distal radius (Figure 17) or carpal bones, either singly (Figure 18) or as a complex combination of lunate or perilunate dislocation (Figure 19). Fractures of the scaphoid are relatively common since this bone spans both the proximal and distal carpal rows. Regarding scaphoid fractures, plain films may be initially negative, in which case follow-up study following 10-14 days of immobilization, or immediate MRI, are beneficial. Scaphoid fractures – particularly through the proximal aspect – may go on to nonunion with avascular necrosis of the proximal portion of the bone secondary to the vascular supply (which enters the bone distally) being cut off by the fracture. As in other joint injuries, when plain films are negative and there is a high suspicion of fracture, either CT (Figure 20) or MR may be required to diagnose a fracture which is occult on plain film examination. MR may also demonstrate soft tissue injuries which cause pain but are not seen on plain films (Figure 21).

Plain films are also the best first step in the evaluation of chronic wrist pain, and may
demonstrate carpometacarpal (CMC) joint arthritis of the thumb (Figure 22). Plain films also may show variations of carpal anatomy including the ulnar-plus variant, where the ulna is significantly longer than the radius and which may be associated with ulnar abutment, and ulnar-minus variant (Figure 23), where the ulna is significantly shorter than the radius, which may be associated with avascular necrosis of the lunate. Plain films can also demonstrate secondary signs of De Quervain’s tenosynovitis (of the short extensor and abductor tendons of the thumb) (Figure 24) as well as scapholunate advanced collapse (SLAC) wrist, or degenerative changes secondary to chronic scapholunate ligament tearing with proximal migration of the capitate bone (Figure 25). MR in patients with chronic wrist pain may demonstrate an otherwise occult ganglion of the scapholunate ligament (Figure 26). MR is usually supplemented by arthrography to demonstrate triangular fibrocartilage and interosseous ligament tears (Figure 27). Similar to the case of shoulder rotator cuff tears (see above), the significance of wrist triangular fibrocartilage or interosseous ligaments tears in the middle aged and elderly is questionable.

Figure 17. Radial styloid fracture in 48 year old woman with wrist pain following trauma. A. AP view of the wrist shows a subtle lucency along the base of the radial styloid (arrow). B. Lateral exam better shows the fracture as a lucency (arrow) and associated cortical interruption along the dorsal, distal radius.
Figure 18. Pisiform fracture in an 18 year old man with pain following a fall on an outstretched arm. A. AP view of the wrist demonstrates a subtle lucency (arrow) through the pisiform bone. B. Lateral plain film examination confirms a fracture extending through the pisiform (arrows).

Figure 19. Perilunate dislocation in an 80 year old man with wrist pain following trauma. A. AP exam shows abnormal alignment of the lunate (arrow). B. Lateral exam shows anterior dislocation of the lunate which has been rotated ninety degrees from its normal orientation (arrows).
Figure 20. Distal radial fracture in a 79 year old woman with pain following trauma who has known rheumatoid arthritis. A. AP plain film shows chronic changes secondary to rheumatoid arthritis (including osteopenia and diffuse joint space loss) without obvious fracture. B. Lateral plain film examination shows possible interruption of the dorsal distal radial cortex (arrow). C. Axial CT study shows a fracture line extending to the articular surface (arrow). D. Sagittal reformatted CT shows an intra-articular fracture (arrow).
Figure 21. Bone contusion and tenosynovitis of the adductor pollicis longus tendon in a 56 year old woman with direct trauma to the lateral aspect of her wrist. A. Axial fat-suppressed T2 weighted image shows increased signal intensity in the distal, lateral radius (arrow) compatible with bone contusion. B. Axial fat-suppressed T2-weighted image slightly more distal shows fluid surrounding the adductor pollicis longus tendon (arrow) compatible with tenosynovitis.

Figure 22. Thumb carpometacarpal joint osteoarthritis in a 69 year old with chronic pain along the base of the thumb. Oblique plain film exam shows joint space narrowing and osteophytic spurring along the thumb CMC joint.

Figure 23. Ulnar minus variant with secondary degenerative changes in a 62 year old woman with chronic wrist pain. AP plain film examination shows that the ulna is considerably shorter than the radius, articulates abnormally with the distal radius, and that there is extensive secondary osteoarthritis along the distal radio-ulnar joint (arrow).
Figure 24. Secondary boney changes in De Quervain’s tenosynovitis in a 56 year old with chronic radial sided wrist pain. AP plain film examination shows irregular periostitis along the base of the radial styloid (arrow).

Figure 25. Scapholunate advanced collapse (SLAC) wrist in a 67 year old man with chronic wrist pain. AP plain film exam shows widening of the scapholunate interval (white arrows) and proximal migration of the capitate with elimination of the joint between the capitate and lunate (black arrow), along with degenerative changes between the scaphoid and radius.

Figure 26. Ganglion cyst in a 16 year old volleyball player with chronic wrist pain. Axial fat-suppressed T2 weighted image shows a small mass which demonstrates marked T2 increased signal intensity along the dorsum of the carpus (arrow).
Figure 27. Scapho-lunate ligament rupture in a 52 year old with chronic ulnar sided wrist pain. A. Wrist arthrography during the early part of the injection with the needle along the radial aspect of the joint and contrast material pooling mostly along the radial side of the wrist. Note the lack of contrast material in the mid-carpal joints. B. Wrist arthrography later during injection, with contrast extending between the lunate and triquetrum (white arrow) into the mid-carpal joint (black arrow), diagnostic of a lunato-triquetral interosseous ligament disruption.

Hand

X-rays of the hands may be obtained following trauma, as the phalanges are the most frequently fractured bones in the body and x-rays can show fractures (Figure 28), dislocations, retained foreign bodies, as well as combinations of these abnormalities. CT may be helpful in the specific instance of intra-articular fractures through the base of the ring and small finger metacarpals, as the anatomy of the carpal-metacarpal junction on the ulnar side of the hand is complex with multiple overlapping structures making assessment of fracture position difficult. MR may be helpful to diagnose and distinguish between two types of thumb injury: the gamekeeper’s thumb and the Stener lesion. In explanation: the ulnar collateral ligament (UCL) is an important stabilizer of the thumb metacarpophalangeal (MCP) joint. Chronic repetitive injury (said to occur from wringing the necks of game birds in England) or acute post-traumatic injury (most frequently against a planted ski-pole) may sprain or rupture this ligament. If the ligament is ruptured but nondisplaced (Figure 29) it may heal as long as it is held in position. This is the classic gamekeeper’s thumb. There is an adductor aponeurosis which usually covers the superficial aspect of the MCP UCL. If this aponeurosis is also torn and the UCL displaced superficial to the aponeurosis, the injury is said to be a Stener lesion, which generally requires operative intervention for repair. Failure to diagnose UCL injuries may lead to debilitating, painful laxity of the thumb MCP joint.

Figure 28. Proximal phalanx fracture in an 8 year old girl with pain following trauma. Oblique plain film examination demonstrates a minimally displaced Salter-Harris Type II fracture through the proximal, ulnar aspect of the proximal phalanx of the small finger (arrow).
Evaluation of chronic hand pain relies primarily on a clinical assessment of whether the pain is actually monoarticular or polyarticular, since the hand is frequently involved in polyarthropathy. Chapter 13 addresses the situation when the symptoms indeed involve multiple joints. If only one joint is involved, this may represent carpometacarpal (CMC) joint strain or arthritis of the thumb CMC, which can be differentiated with plain film examination (Figure 22). Plain films are also helpful in evaluation of pain secondary to gout which has involved only a single joint (Figure 30). MR is rarely used for the evaluation of chronic hand pain unless there is a strong suspicion of tenosynovitis (particularly infectious) or retained foreign body.

Figure 29. Gamekeeper’s thumb in a 16 year old male with pain following trauma (football injury). A. AP plain film examination of the thumb demonstrates an abnormal fragment of bone projecting along the ulnar aspect of the joint (arrow). B. Coronal fat-suppressed proton density MR shows discontinuity of the ulnar collateral ligament (arrow) of the thumb MCP joint. C. Coronal fat-suppressed proton density image shows increased signal intensity compatible with contusion along the proximal, ulnar aspect of the proximal phalanx of the thumb (arrow). D. Coronal fat-suppressed proton density MR image shows that the overlying aponeurosis is intact (arrow).
Figure 30. Gouty tophus in a 59 year old woman with acute thumb pain but no injury. AP plain film of the thumb shows calcified tophus in the soft tissues adjacent to the thumb interphalangeal joint (arrows).

Figure 31. Proximal femur fracture in a 75 year old with pain following trauma. A. AP plain film of the hip shows a fracture through the base of the femoral neck (arrow) with associated shortening of the femur. B. Axial view of the hip shows anterior angulation of the fracture apex (arrow).

Hip

X-ray examination is the study of choice for evaluation of the acutely traumatized hip. Plain films will typically demonstrate fractures (Figure 31) and dislocations. In cases where the plain films are negative but persistent severe pain causes a high level of suspicion for fracture, either CT or MR may be performed. CT may be a better alternative when there is substantial trauma as in an MVA (Figure 32), whereas MR is actually more sensitive to subtle fractures (Figure 33), and will detect soft tissue injuries not seen on plain films (Figure 34).
Figure 32. Acetabular fracture not visible on plain film but seen on CT in a 38 year old with pain following trauma. A. AP plain film examination of the hip shows no abnormality. The patient had persistent severe pain and therefore a CT was performed. B. Axial CT of the hip shows a fracture through the anterior column of the acetabulum (arrow).

Figure 33. Hip fracture seen on MR in a 94 year old man with persistent pain following trauma. A. AP plain film of the hip shows no fracture. B. Coronal T1 weighted MR study shows a fracture line through the femoral neck (arrow).
Figure 34. Gluteus medius muscle tear in a 75 year old woman with chronic hip pain. Coronal STIR image demonstrates abnormal increased signal in the left gluteus medius muscle (arrow) compatible with a muscle tear.

The first step in evaluation of chronic hip pain is also x-ray examination, which may demonstrate such causative abnormalities as osteoarthritis (Figure 35), CPPD, or gout (Figure 36). Plain films may demonstrate some processes which require further evaluation with MR, such as rapidly destructive osteoarthritis (Figure 37) or avascular necrosis (Figure 38). If plain films are unremarkable in patients with chronic hip pain, MR may demonstrate osteoarthritis (Figure 39) or avascular necrosis which is either subtle or not appreciated on plain film examination. In patients with symptoms of an acetabular labral tear (clicking or locking of the hip joint) MR arthrography is helpful to evaluate the internal structures of the joint including the labrum.

Patients with prostheses and following fracture fixation should also first undergo x-ray examination to evaluate possible dislocation (Figure 40), hardware complication (Figure 41), and dystrophic calcification (Figure 42). Such films are typically ordered at 1 year, 3 years, and 5 years (and then at 5 year intervals) by the operating orthopedic surgeon\textsuperscript{10}. Painful prostheses which show no plain film abnormalities but for which there is suspicion of an infection can be aspirated; if imaging is required, the best course is performance of a nuclear medicine bone scan examination, followed by indium-labeled WBC evaluation: the combination of the two studies can help distinguish normal post-operative prosthesis changes from loosening and loosening from infection\textsuperscript{10}.

X-ray guidance is typically used for hip intra-articular injections of either lidocaine (for diagnosis) or steroids (for treatment) or combinations of the two, as injection without radiographic guidance is insufficiently accurate.

Figure 35. Osteoarthritis of the left hip in a 35 year old with chronic hip pain. AP plain film exam shows joint narrowing and subchondral sclerosis.
Figure 36. Gout of the right hip in a 70 year old man with chronic hip pain. A. Plain film examination shows calcification along the margin of the femoral head (white arrow). There is erosion with an overhanging edge along the lateral acetabulum (black arrow). B. Hip arthrogram shows contrast along the synovial extension adjacent to the acetabulum through a narrow connection along the femoral head (arrow).

Figure 37. Rapidly destructive osteoarthritis of the right hip in an 80 year old woman with progressive hip pain. A. AP plain film at the onset of hip pain shows mild joint narrowing (arrow). B. AP plain film obtained six months later (with steadily increasing pain) shows marked progression of joint space narrowing (arrow). C. Coronal T1 weighted image shows extensive abnormal decreased signal intensity through the femoral neck and acetabulum (arrows). D. Coronal T2 weighted image shows abnormal increased signal intensity through the femoral head, neck, and acetabulum (arrows).
Figure 38. Avascular necrosis of the hips in a 38 year old man with chronic hip pain. A. AP view of the pelvis shows abnormal increased density (arrows) in both femoral heads. B. Coronal T1 weighted MR image demonstrates extensive decreased signal intensity (arrows) in the subchondral aspects of both femoral heads. Note mixed signal intensity at the interface between the normal signal intensity in the femoral necks and the decreased signal intensity in the heads. C. Coronal STIR image demonstrates mixed signal intensity in the femoral heads (arrows).
Figure 39. Early degenerative change seen on an MR study in a 50 year old woman with chronic hip pain. A. AP plain film of the hip shows no significant joint space narrowing, subchondral sclerosis, osteophytic spurring, or subchondral cyst formation. B. Coronal T1 weighted image demonstrates abnormal decreased signal intensity in the acetabulum (arrow). C. Coronal fat-suppressed proton density image demonstrates abnormal increased signal intensity in the acetabulum. D. Sagittal STIR image confirms abnormal signal intensity in the acetabulum.
Figure 40. Dislocated hip prosthesis in an 87 year old with pain and hip deformity. A. AP plain film of the hip shows the femoral prosthesis displaced superolateral to the acetabulum (arrow). B. AP plain film of the hip following reduction demonstrates correct positioning of the prosthesis.

Figure 41. Complication of fixation device in an 82 year old woman s/p ORIF. A. AP plain film of the hip demonstrates the fixation device with an intramedullary rod and interlocking blade-plate with the tip of the blade-plate device projecting inside the femoral head (arrow). B. AP plain film shows migration of the helical blade plate through the femoral head cortex. Such migration is generally prevented in these devices because the device can “back out” of the medullary rod. In this case, the position of the device prevented “backing out” because the sliding, interlocking helical blade plate was covered by the margin of the femoral shaft (black arrow).
Knee

As in other joints, x-ray examination is the first step in imaging the traumatized knee. Knee films may show and fully characterize the fracture, so that no further examination is necessary (Figure 43). Plain films may demonstrate a severe fracture that needs further evaluation with CT for surgical planning (Figure 44). Plain films may show a fracture that has a known associated significant ligamentous or other soft tissue injury, with an MR required for further evaluation (Figures 45 and 46). On the other hand, the plain films may show a nonspecific effusion, which suggests possible internal derangement and likely requires further work-up with MRI as well (Figure 47). If the plain films are negative and the patient has significant pain and/or instability, MR should be performed. MR has the ability to accurately characterize a wide range of injuries which may show no significant plain film findings, including: anterior cruciate ligament contusion and rupture (Figure 47); posterior cruciate ligament rupture (Figure 45); collateral ligament rupture (Figure 47); posterolateral corner injury; transient dislocation of the patella (Figure 46); radiographically occult fractures (Figure 48); bone contusions; muscle tears (Figure 49); cartilage injuries; and meniscal tears (Figure 50). A negative MR effectively excludes significant osseous, cartilaginous, ligamentous, and tendinous injury.

Figure 42. Dystrophic ossification in a 72 year old woman following hip prosthesis placement. A. Frog-lateral plain film of the hip following hip prosthesis placement demonstrates a normal post-operative appearance of the components and native bone and soft tissues. B. Frog-lateral plain film of the hip three months later demonstrates heterotopic bone formation along the hip joint margin (arrows).

Figure 43. Tibial fracture in a 66 year old man with pain following trauma. AP plain film exam shows a parasagittal fracture through the lateral tibial plateau (arrow).
Figure 44. Tibial fracture in a 67 year old woman with knee pain following trauma. 

A. AP “notch” plain film of the knee shows a fracture along the lateral aspect of the tibial plateau (arrow). 

B. Lateral plain film of the knee shows an ill-defined density projecting at the level of the proximal tibia (arrow). Note the associated joint effusion superior to the patella (double arrow). 

C. Axial CT study shows a “hole” in the tibial plateau with rotation of the cortex out of its usual position (arrow). 

D. Sagittal reformatted CT study shows the tibial plateau fracture and documents the extent of depression and separation of fragments along the articular surface, as well as the number of fragments and their orientation (arrow).
Figure 45. Fracture with associated soft tissue injury (posterior cruciate ligament avulsion) in a 49 year old man with pain following trauma. A. AP “notch” view of the knee shows a relatively subtle lucency in the mid portion of the tibial plateau. B. Coronal fat-suppressed proton density MR image shows a bone fragment of the tibial plateau (arrow) surrounded by a wide band of abnormal signal intensity. C. Sagittal proton density MR image shows separation of the posterior cruciate ligament from its insertion along the proximal, posterior tibia (white arrows). Note the abnormal thickening of the mid-portion of the posterior cruciate ligament compatible with tear (black arrow). D. Sagittal fat-suppressed T2 weighted image demonstrates abnormal signal intensity along the insertion of the posterior cruciate ligament (arrows).
Figure 46. Patellar fracture from transient lateral patellar dislocation in a 22 year old woman with pain following trauma. 
A. Plain film axial (also known as a “sunrise”) view demonstrates a fragment of bone along the medial patellar facet (arrow). 
B. Axial fat-suppressed proton density MR image shows the fracture (single arrow) along with abnormal increased signal intensity through the fracture fragment. In addition, there is extensive abnormal signal along the anterior, lateral aspect of the lateral femoral condyle (double arrows) from the associated contusion secondary to the transiently dislocated patella. 
C. Coronal fat-suppressed T2 weighted image also demonstrates the contusion along the anterior lateral femoral condyle (arrow). Note that this contusion is in a different location than that seen with an acute ACL tear. 
D. Sagittal fat-suppressed T2 weighted image demonstrates a fluid level in a knee joint effusion (arrow), indicating hemorrhage from the recent fracture.
Figure 47. Knee effusion with associated ACL and MCL tears in a 33 year old man with knee pain. A. Lateral plain film shows fullness in the suprapatellar bursa (arrows), nearly always indicating a knee joint effusion. B. Sagittal fat-suppressed T2 weighted image demonstrates discontinuity of the anterior cruciate ligament (ACL) (arrow) secondary to an ACL tear.
C. Coronal fat-suppressed proton density image demonstrates a tear of the proximal medial collateral ligament (MCL) (single arrow) along with abnormal increased signal in the lateral femoral condyle (double arrow) from bone marrow contusion.
D. Sagittal fat-suppressed proton density image demonstrates so-called “kissing contusions” (arrows) of the lateral femoral condyle and posterior tibial plateau created by the pivot-shift injury which caused the patient’s ACL and MCL tears.
Figure 48. Radiographically occult fracture in a 62 year old man with pain following trauma. A. AP plain film of the knee shows no abnormality. B. Lateral plain film of the knee demonstrates fullness of the suprapatellar bursa (arrows), usually indicating a knee joint effusion. In the setting of acute trauma, this could indicate either a radiographically occult fracture, internal derangement (for example, a torn anterior cruciate ligament), or both. C. Coronal proton density MR image shows a combination of fracture (arrow) and contusion through the lateral tibial plateau. D. Sagittal fat-suppressed T2 weighted image demonstrates extensive increased signal intensity through the lateral tibial plateau (arrow) compatible with contusion.
Figure 49. Popliteal muscle tear in a 48 year old man with pain following trauma. A. Axial fat-suppressed T2 weighted image shows abnormal signal and swelling of the popliteus muscle (arrow), compatible with a strain (partial thickness musculotendinous tear). B. Sagittal fat-suppressed T2 weighted MR imaging also demonstrates abnormal signal and swelling of the popliteus muscle (arrow).

Figure 50. Meniscal tear and tibial contusion in a 68 year old woman with knee pain following trauma. Coronal fat-suppressed T2 weighted image shows both a tear of the dorsal root of the medial meniscus (single arrow) and a contusion of the lateral tibial plateau (double arrow).

Chronic knee pain should also be first imaged with x-rays, which may demonstrate causative osteoarthritis (Figure 5, Chapter 13, page 186) or chondrocalcinosis characteristic of CPPD crystal deposition disease (Figure 3, Chapter 13, page 185). Note that CPPD causes not only chondrocalcinosis, but often preferential degenerative changes of the patellofemoral articulation\textsuperscript{11}. When further imaging of the knee joint is required because the plain film does not demonstrate a reasonable explanation, MR may be performed. MR of the knee in chronic pain may demonstrate meniscal tears (Figure 51), loose bodies (Figure 52) or such infrequently seen entities as spontaneous osteonecrosis of the knee (SPONK) (Figure 53) and symptomatic bipartite patella (Figure 54). Beware of obtaining an MR without a plain film, because it is often difficult or impossible to see chondrocalcinosis on MR and a knee MR may be incorrectly interpreted as showing osteoarthritis and meniscal degenerative change rather than CPPD crystal deposition disease (Figure 55).

The considerations that apply to hip prostheses and hardware apply to the knee as well: follow-up films will typically be obtained by the operating orthopedic surgeon, with sequential plain film evaluation serving as the primary method of detecting hardware loosening or fracture, with a combined bone/WBC nuclear medicine study required to evaluate for possible infection.
Figure 51. Meniscal tear in a 63 year old man with chronic knee pain. A. Coronal fat-suppressed proton density MR image shows a focal abnormality along the posterior horn of the medial meniscus (arrow). B. Sagittal fat-suppressed T2 weighted image (arrow) shows increased signal intensity extending through the meniscus from the femoral side to the tibial side (arrow), compatible with a full thickness meniscal tear.

Figure 52. Loose body in the knee joint in a 56 year old woman with knee pain. A. Sagittal fat-suppressed T2 weighted image demonstrates an abnormality in the suprapatellar bursa (arrow). The lesion demonstrates mixed signal intensity compatible with an osseous fragment (with both cortical bone and bone marrow), and is surrounded by high signal intensity fluid. B. Axial fat-suppressed proton density image demonstrates another lesion along the lateral aspect of the joint (arrow). Note osteophytic spurring along the patellofemoral joint margins.
Figure 53. Spontaneous osteonecrosis of the knee (SPONK) in a 66 year old woman with chronic knee pain. A. Coronal proton density MR image shows focal signal abnormality along the medial femoral condyle (arrows). B. Coronal fat-suppressed T2 weighted image demonstrates extensive abnormal signal through the medial femoral condyle. Note the serpentine “double line” along the articular surface (arrow), characteristic of osteonecrosis. C. Sagittal proton density image shows the anterior to posterior extent of the osteonecrosis (arrow). D. Sagittal fat-suppressed T2 weighted image also demonstrates the “double line” of osteonecrosis paralleling the articular margin of the condyle (arrow).
Figure 54. Symptomatic bipartite patella in a 41 year old woman with chronic knee pain. A. Coronal T1 weighted MR image demonstrates a cleavage plane between the body of the patella and a superolateral ossification center (arrow). Such an appearance is a relatively frequently seen (and usually asymptomatic) normal variation. B. Coronal fat-suppressed proton density image demonstrates increased signal intensity (arrow) along the interface between the patella and accessory ossification center. In asymptomatic patients, this interface will demonstrate decreased, not increased (as in this case), signal intensity. C. Frontal view nuclear medicine bone scan shows intense increased radiotracer uptake of the patella (arrow). D. Lateral view nuclear medicine bone scan confirms that the intense activity is in the patella (arrow) and not in the underlying femur.
Figure 55. Chondrocalcinosis in a 71 year old woman with chronic knee pain, not seen on MR. A. Coronal proton density image shows mildly increased signal intensity in the menisci (arrows). B. Coronal fat-suppressed T2 weighted image also demonstrates increased signal intensity in the menisci (arrows). C. AP plain film examination shows extensive chondrocalcinosis (arrows).

Ankle

As in the other extremity joints, x-rays represent the first step in imaging the ankle. X-rays will demonstrate fractures (Figure 56) and fracture-dislocations (Figure 57) and will show ankle joint effusions which may be associated with fractures. For patients with negative plain films who have signs or symptoms of a radiographically occult fracture, MR is helpful. MRI of the traumatized ankle joint can demonstrate both fractures and ankle sprains. While imaging documentation of ankle sprains is not typically necessary, differentiation of a “regular” ankle sprain (involving the anterior talofibular, calcaneofibular, and posterior talofibular ligaments) (Figure 58) from a “high” ankle sprain (involving the distal tib-fib ligament) (Figure 59) may be important from a prognostic standpoint, given the necessity for athletes with a high ankle sprain to rehabilitate for longer prior to returning to play than athletes with a routine regular ankle sprain. MR can also detect radiographically occult fractures (Figure 60), and acute tendon ruptures.

For patients with chronic ankle pain, plain films may demonstrate osteoarthritis (Figure 61) or the rare condition of hypertrophic pulmonary osteoarthropathy (Figure 62). Plain films may also demonstrate either direct or indirect evidence of tarsal coalition in patients with painful flatfoot (Figure 63). CT is usually used for further evaluation of suspected tarsal coalition, given the superb bony detail of the complex articulations between the distal tibia and fibula, hindfoot, and midfoot, although MR may also demonstrate coalition (Figure 63). MR is more helpful in such soft tissue abnormalities as hindfoot sprain (Figure 64), tenosynovitis (Figure 65), tendon tears (Figure 66), bursitis (Figure 67) loose bodies within the ankle joint (Figure 68) and peroneus brevis tendon split (Figure 69).
Figure 57. Fracture-dislocation of the ankle in a 46 year old man following a motor vehicle accident. A. AP plain film examination shows gross medial, proximal displacement of the talus. Note fractures of both the medial and lateral malleoli. B. Lateral plain film examination shows malalignment of the talus compared to the tibia, although this view clearly underestimates the true extent of derangement as seen on the frontal view.

Figure 58. Ankle sprain (torn anterior talofibular ligament) in a 16 year old man with pain following trauma. A. Axial fat-suppressed proton density MR image shows a normal, intact distal syndesmotic connection (the distal tib-fib ligament) spanning the anterior aspect of the distal tibia and fibula (arrow). B. Axial fat-suppressed proton density MR image slightly inferior shows an intact posterior talofibular ligament (double white arrow). At the usual position of the anterior talofibular ligament, there is ill defined increased soft tissue density (arrow) without definition of the ligament itself, characteristic of a full thickness anterior talofibular ligament tear.
Figure 59. “High” ankle sprain in a 42 year old man with pain following trauma. A. Axial fat-suppressed proton density MR image shows lack of normal tissue between the distal tibia and fibula (arrow) because of a complete tear of the distal tib-fib syndesmosis. Note the large joint effusion with fluid (high signal intensity) along the anterior and posterior aspects of the talus. B. Axial fat-suppressed proton density MR image shows a normal anterior talofibular ligament (arrow) and posterior talofibular ligament (double arrow).

Figure 60. Radiographically occult fracture in a 28 year old man with pain following trauma. A. Lateral plain film examination of the ankle is normal. B. Sagittal fat-suppressed T2 weighted image demonstrates a fracture line (arrow) through the posterior, distal tibia (the so-called “posterior malleolus”).
Figure 61. Osteoarthritis of the ankle in a 71 year old man with chronic ankle pain. A. Lateral plain film examination shows joint narrowing (arrows), subchondral sclerosis, and osteophytic spurring along the ankle joint. B. AP plain film also demonstrates joint narrowing, subchondral sclerosis, and osteophytic spurring (arrows). Note the large cyst in the medial malleolus.

Figure 62. Hypertrophic pulmonary osteoarthropathy in a 74 year old woman with chronic ankle pain and lung cancer. A. Mortise view of the right ankle demonstrates diffuse periostitis along the distal fibula and tibia (arrows). The contralateral ankle (not shown) showed similar findings. B. Nuclear medicine bone scan shows diffuse increased radiotracer localization through both feet and ankles, including along the cortical margins of the distal tibia and fibula bilaterally (arrows). Chest CT (not shown) showed a large lung mass that proved to be cancer.
Figure 63. Subtalar coalition in a 32 year old woman with chronic ankle pain.  
A. Lateral plain film examination shows subtle increased density (arrow) along the margin of the subtalar joint.  
B. Coronal T1-weighted MR image demonstrates fusion across the medial subtalar joint (arrows) with a broad band of decreased signal intensity compatible with adjacent reactive change.  
C. Sagittal T1-weighted MR image through the level of the medial subtalar joint shows extensive spur formation along the joint margins (arrows).  
D. Coronal fat-suppressed T2 weighted image demonstrates increased signal intensity along the joint margins (arrows), compatible with reactive change.
Figure 64. Hindfoot sprain in a 57 year old woman with remote trauma and chronic ankle pain. A. Sagittal proton density image demonstrates decreased signal intensity in the space between the talus and calcaneus (arrows), which is usually occupied by well-defined ligaments and fatty tissue. B. Sagittal fat-suppressed T2 weighted image demonstrates increased signal intensity in the space between the talus and calcaneus (arrow) as well as in the marrow along the adjacent talus and calcaneus.

Figure 65. Posterior tibial tendon split and tenosynovitis in a 50 year old woman with chronic ankle pain. A. Axial fat-suppressed proton density image at the level of the ankle joint shows fluid along the posterior tibial tendon (white arrow) as well as abnormal increased signal within the tendon (black arrow). B. Sagittal fat-suppressed T2 weighted image demonstrates fluid along the tendon sheath (arrow).
Figure 66. Partial thickness Achilles tendon rupture in a 72 year old man with diabetes and chronic ankle pain. Sagittal proton density MR shows swelling and abnormal increased signal in the distal Achilles tendon (arrow).

Figure 67. Achilles tendinitis and retrocalcaneal bursitis in a 27 year old woman with chronic ankle and heel pain. Sagittal proton density MR shows abnormal increased signal intensity in the calcaneus (black arrow) as well as focal abnormal signal in the fat superior to the posterior tuberosity of the calcaneus (white arrow).

Figure 68. Loose body and degenerative change in a 55 year old woman with chronic ankle pain. Sagittal fat-suppressed proton density image shows a loose body (arrow) floating in effusion fluid anterior to the joint.

Figure 69. Peroneal tendon split in a 69 year old man with chronic ankle pain. Axial proton density image demonstrates the peroneus longus tendon (black arrow) against the posterior aspect of the fibula, with the split portions of the peroneus brevis displaced medially and laterally (white arrows).
Foot

As in the other joints of the body, plain film evaluation is the initial study of choice following acute injury. Radiographs will show fractures (Figure 70) and dislocations. Standing views with comparison to the other side are helpful to evaluate subtle degrees of subluxation at the base of the first and second metatarsal characteristic of a Lisfranc fracture (Figure 71), an injury which may lead to devastating long-term disability if missed. If plain films are unremarkable and the suspicion of fracture is high, CT may be helpful showing fractures of the overlapping bones within the midfoot (Figure 72).

Evaluation of chronic foot pain also begins with a plain film examination, which may document clinically obvious hallux valgus and cock-up toe deformity (Figure 73). Plain films may also diagnose stress fractures of the metatarsals (Figure 74), osteonecrosis of the head of the second metatarsal (also known as Freiberg’s infraction), osteoarthritis (Figure 75), or gout (Figure 76). Diabetics frequently have foot problems secondary to peripheral neuropathy and vascular disease. Plain film examination is the first step in diagnosis of diabetics with foot symptoms. The neuropathy may lead to a denervation arthropathy of the midfoot known as a Charcot joint which is typically not particularly painful but results in swelling, warmth, and deformity including flatfoot (Figure 77). The vascular disease often leads to infection, and plain films may show osteomyelitis (Figure 78) but if infection is suspected MR is often performed regardless of the plain film results, both to diagnose the infection and to document its extent (Figure 79). Infection of the foot may also occur secondary to open wounds, particularly when associated with embedded foreign bodies.

Figure 70. Fracture of the proximal aspect of the small toe metatarsal in a 57 year old man with acute foot pain following trauma. A. Oblique plain film of the foot demonstrates fracture lucency (arrow) through the base of the small toe metatarsal. B. Lateral examination also demonstrates the fracture lucency (arrow) along the base of the small toe metatarsal.
Figure 71. Lisfranc fracture in a 22 year old woman with acute foot pain following trauma. A. Oblique plain film examination of the foot demonstrates abnormal separation of the medial cuneiform and base of the second metatarsal (arrows). B. Sagittal reformatted CT study shows a small fracture fragment off of the second metatarsal base (arrow), compatible with avulsion of the plantar tarsal-metatarsal ligament.

Figure 72. Occult (on plain films) cuneiform fracture in a 22 year old man with foot pain following trauma. A. Oblique plain film of the foot is normal. B. Axial CT examination shows a fracture through the medial cuneiform (arrow).
Figure 73. Both hallux valgus and cock-up toe deformities deformity in an 80 year old woman with chronic foot pain. A. AP view of the foot shows hallux valgus deformity of the great toe metatarsal-phalangeal joint as well as malalignment of the second and third toe MTP joints (arrows). B. Lateral examination shows extension of the metacarpal-phalangeal joints and flexion of the PIP joints of the second and third toes (arrows) also known as cock-up toe.

Figure 74. Stress fracture in a 56 year old with ongoing foot pain after taking a new job. AP plain film of the foot shows periostitis along the shaft of the second toe metatarsal (arrow), indicating a stress fracture.

Figure 75. Great toe metatarsal-phalangeal degenerative change (hallux rigidis) in a 66 year old woman with chronic medial forefoot pain. AP plain film of the foot shows joint narrowing (arrows), subchondral sclerosis, and osteophytic spurring.
Figure 76. Gout with calcified soft tissue tophus in an 85 year old man with chronic medial forefoot pain. AP plain film of the foot shows calcified soft tissue (arrow) as well as swelling along the medial aspect of the great toe metatarsal-phalangeal joint.

Figure 77. Charcot joint in a 68 year old with flat foot deformity and diabetes. A. AP view of the foot demonstrates joint narrowing and osteophytic spurring at the tarsal-metatarsal junction (arrows). B. Lateral examination shows pes planus and osteophytic spurring along the dorsum of the foot (arrow).

Figure 78. Osteomyelitis and septic arthritis seen on plain film examination in a 42 year old diabetic man. Detail from AP plain film exam of the foot shows periostitis along the third toe metatarsal and proximal phalanx (white arrows) and destruction of the metatarsal head (black arrow).
SUMMARY

This relatively long chapter has covered imaging of single joints. Acutely injured joints should generally undergo plain film evaluation if there is any suspicion of fracture. Further evaluation of acutely injured joints and evaluation of chronically painful joints depends on which joint is involved and to a certain extent on the disease process that the primary care provider feels is most likely to be causing the patient’s symptoms, as noted in the above sections.

REFERENCES