Chapter 14
Musculoskeletal Radiology

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Because musculoskeletal complaints are common in day-to-day practice, primary care providers should be familiar with the various radiographic studies available. Radiographic studies should be used as an extension of a focused history and physical examination. Typically, radiographs (aka "plain films" or X-rays) should be considered the first line of imaging when a patient has a musculoskeletal complaint. A detailed description of advanced imaging such as magnetic resonance imaging (MRI), computed tomography (CT), nuclear medicine bone scintigraphy (bone scan), ultrasound, and arthrography is beyond the scope of this chapter, and there are many great resources available if advanced imaging is of interest to the reader. This chapter provides guidance for ordering radiographic studies as well as outlining a few pitfalls along the way.

When ordering radiographic studies, keep these general rules in mind:

1. Patients who can be clinically diagnosed with common conditions do not require imaging. However, if the patient does not respond as expected to treatment, radiographs should be considered.
2. Include detailed clinical information for the radiologist when ordering any radiological study. The higher the quality of the clinical information provided, the higher the quality of the interpretation provided. Similarly, the ordering physician should personally review the images, as the ordering provider has more clinical information than the radiologist interpreting the images. If there seems to be a discrepancy, review the images with the radiologist in person whenever possible.

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3. If radiculopathy is a potential diagnosis for the patient's symptoms, consider imaging the site of pain and the possible origin of the pain (i.e., lumbar spine, cervical spine, etc.).
4. If there is isolated bony tenderness that is not located at the insertion site of a tendon or ligament, consider obtaining radiographs.
5. If the radiographs are negative, but the clinical suspicion for serious pathology remains, consider advanced imaging studies (MRI, CT, bone scan, ultrasound, arthrography, etc.). The specific advanced imaging study to be considered depends on the suspected pathology as well as technical factors such as the eligibility of the patient for a specific examination and the location of symptoms, just to name a few.
6. If a fracture is a consideration, but the initial radiographs are negative and there are persistent symptoms for 7–10 days after the injury, consider repeating the radiographs. Seven to ten days after a subtle fracture, sclerosis at the site of healing can be the only sign to confirm an initially occult fracture. This is especially important in the pediatric population and with specific fractures such as a fracture of the scaphoid, which can have long-term implications if the fracture is not identified and allowed to heal appropriately.
7. Radiographs should be performed at the time of presentation in cases of significant trauma.
8. In radiology, having only one view is like having no view. Pathology, especially fractures, is more confidently diagnosed when visible on more than one imaging plane.
9. Be aware that some patients may have a "therapeutic" benefit from negative radiographs. In other words, their symptoms improve because they were told that their radiographs were negative, but they have significant pathology (occult fractures, ligamentous or tendon injury) that is yet to be diagnosed. *Remember, radiographs are not a substitute for a thorough history and physical exam.*

Ordering X-Rays for Specific Body Areas

Cervical Spine

When ordering radiographs in a patient with cervical spine pain, AP and lateral views are initially obtained to evaluate the vertebral alignment, vertebral body heights, intervertebral disc spaces, uncovertebral joints, and zygapophyseal (facet) joints. If radiculopathy is a consideration, right and left lateral oblique views can be added to look at the osseous neural foramina for osseous impingement on the exiting nerve roots. Degenerative disc disease is a common cause of radiculopathy in the cervical spine which is best evaluated by MRI or CT cervical myelography if MRI is contraindicated in the patient. In the setting of patients with trisomy 21, rheumatoid arthritis, or major trauma, an odontoid view should be added to evaluate the atlanto-occipital and atlantoaxial joints.

If major trauma is the presenting complaint (typically to the emergency department), the cervical spine should be stabilized and then imaged before further clinical evaluation is performed. Classically, this was done with cervical spine radiographs (AP, lateral, and odontoid views), but in recent years, CT has become a popular replacement of cervical spine radiographs to evaluate the spine in the setting of trauma as many trauma patients already have a CT of the head, chest, abdomen, and pelvis at the time of presentation.

Thoracic Spine

AP and lateral radiographs of the thoracic spine are the initial views of choice in the setting of thoracic spine complaints. There is improved osseous detail on a dedicated AP view of the thoracic spine as compared to an AP chest radiograph. The addition of the swimmer's view, an oblique view centered at the cervicothoracic junction with the humeral heads projected away from the spine, can be beneficial in assessment of the C7, T1, and T2 vertebrae. Radiographs can assess vertebral alignment, vertebral body heights, intervertebral disc spaces, and facet joints. The osseous neural foramina in the thoracic spine are suboptimally evaluated as the ribs typically cause overlap on the lateral view.

Lumbosacral Spine

When imaging the lumbosacral spine, the radiographs typically obtained are AP, lateral, and lateral coned-down L5–S1 views. These views are useful to evaluate vertebral alignment, vertebral body heights, intervertebral disc spaces, facet joints, and sacroiliac joints. The lateral views can be used to assess the osseous neural foramina for osseous impingement on the exiting nerve roots in the setting of radiculopathy.

Right and left lateral oblique views are not routinely obtained when evaluating the lumbar spine for osseous neural foraminal impingement in the setting of radiculopathy because the lateral views are typically sufficient. Degenerative disc disease is a more common cause of radiculopathy in the lumbar spine which is best evaluated by MRI or CT lumbar myelography if MRI is contraindicated in the patient.

Shoulder

Various radiographs of the shoulder used in imaging evaluation include AP with external rotation (anatomical positioning), AP with internal rotation, true AP (Grashey), axillary, scapular Y, and outlet (modified scapular Y) views. There are many other dedicated views of the shoulder which can be used for specific pathology.

Typically, radiographs of the shoulder are useful for assessing the joint for an acute dislocation, signs of prior dislocation such as a Hill-Sachs fracture or a Bankart fracture, an acute fracture, osseous abnormalities related to rotator cuff pathology, or the various arthritides affecting the glenohumeral and acromioclavicular joints.

The first-line imaging of the shoulder in the setting of suspected fracture or dislocation typically includes the AP with external rotation view, AP with internal rotation view, and either a scapular Y or an axillary view. The benefit of the scapular Y view over the axillary view is that the patient does not need to move the joint in the setting of a suspected dislocation whereas the patient will need to abduct the arm to obtain an axillary view. An axillary view or a Grashey view can be added later to better evaluate the glenohumeral joint. An outlet view can be added later to better evaluate the joint for rotator cuff impingement as this view optimally profiles the undersurface of the acromion while aligning the x-ray beam parallel to the supraspinatous tendon as it passes over the humeral head.

Humerus

The primary radiographs of the humerus are the AP with external rotation (anatomical positioning) and AP with internal rotation. As is the case in all imaging studies, the entire structure of interest (in this case, the humerus) must be included on a single film to best evaluate the structure for pathology.

Elbow

Radiographs of the elbow typically include an AP, a lateral with 90° of flexion, and an AP oblique view with external rotation. The AP oblique view is used to evaluate the radial head and decrease overlap of the osseous structures. In children, the many ossification centers of the elbow can be confused with a fracture in the setting of trauma or pain, so consider imaging the opposite elbow for comparison. Table 14.1 and Fig. 14.1 demonstrate the normal ossification centers. In addition, indirect signs may be the only indication that there is a fracture. The "fat pad sign" is an indirect sign of a fracture where the anterior or posterior intra-articular fat is displaced by an acute hemarthrosis that is associated with the fracture. In the setting of an elevated anterior fat pad from an acute hemarthrosis, the elevated fat pad classically looks like the sail of a sailboat, so it may also be referred to as the "sailboat sign."

The radiocapitellar relationship is important to note when assessing the elbow. On the lateral view, the anterior humeral line and the radiocapitellar line are used to assess the elbow joint alignment. The anterior humeral line is a line drawn along the anterior cortex of the distal humeral metaphysis which should pass through the middle third of the capitellum (Fig. 14.2). If the anterior humeral line passes in the

Table 14.1 Approximate age of ossification

Site	Age in years
Capitellum	1
Radial head	3
Medial epicondyle	5
Trochlea	7
Olecranon	9
Lateral epicondyle	11

Fig. 14.1 Left elbow AP oblique with external rotation in a 15-year-old demonstrating the fused elbow ossification centers. *C* capitellum, *R* radial head, *M* medial epicondyle, *T* trochlea, *O* olecranon, *L* lateral epicondyle

anterior third of the capitellum or anterior to the capitellum, then the capitellum is too posterior, indicating a distal humeral fracture. The radiocapitellar line is a line drawn through the radial neck which should pass through the capitellum (Fig. 14.3). If the radiocapitellar line does not pass through the capitellum, then there is a radiocapitellar dislocation.

Fig. 14.2 Lateral view of the elbow with a normal *anterior humeral line*. The anterior humeral line is a line drawn along the anterior cortex of the distal humeral metaphysis which should pass through the middle third of the capitellum

Fig. 14.3 Lateral view of the elbow with a normal *radiocapitellar line*. The radiocapitellar line is a line drawn through the radial neck which should pass through the capitellum

Radius and Ulna

The primary radiographs of the radius and ulna are the AP and lateral views. For sufficient evaluation, the elbow and wrist should also be visible because there are important fractures that include dislocation components. A Monteggia fracture-dislocation is a fracture of the ulna shaft with an associated dislocation of the radial head. A Galeazzi fracture-dislocation is a fracture of the radius with a dislocation of the distal radioulnar joint.

Another common fracture is a Colles' fracture. A Colles' fracture is a fracture of the distal metaphysis of the radius associated with dorsal angulation and displacement of the distal radius typically seen in the older population or women with osteoporosis. In addition to inclusion of the elbow and wrist joints, care must be taken to avoid pronation or supination between views as either of these changes in position will change the orientation of the osseous structures and potentially obscure pathology.

Wrist

Radiographs of the wrist should include the carpal bones as well as the metacarpals, distal radius, and distal ulna. AP, lateral, and oblique views of the wrist are the standard views obtained. In the setting of suspected fracture of a specific bone, particularly the scaphoid, dedicated views of the specific bone can be requested to improve evaluation.

The carpal alignment can be assessed by evaluating the three carpal arcs on the AP view. If there is disruption of the carpal arcs, then a fracture or ligamentous injury is suggested. The first arc traces the proximal convexities of the scaphoid, lunate, and triquetrum. The second arc traces the distal concave surface of the scaphoid, lunate, and triquetrum. The third arc traces the main proximal curvatures of the capitate and hamate. See Fig. 14.4 which demonstrates the normal carpal arcs. In addition to the carpal arcs, specific ligamentous injuries can be suggested on the AP view. In the setting of a scapholunate ligament injury, then there can be widening of the scapholunate joint. In the setting of a fracture of the ulnar styloid, then there may be injury to the triangular fibrocartilage (TFCC). If a ligamentous injury is suspected, MRI should be considered.

The most common wrist dislocations are the perilunate and lunate dislocations which can be assessed on the lateral view. Figure 14.5 demonstrates the normal lateral wrist alignment. If the capitate is centered over the radius with the lunate tilted towards the palmar surface, then there is a lunate dislocation. If the lunate is centered over the distal radius with the capitate located dorsally, then there is a perilunate dislocation.

Hand

To evaluate the hand, AP, lateral, and oblique radiographs are typically obtained. If individual phalangeal injuries are suspected, then dedicated radiographs of the designated phalanx should be ordered. The phalanges can be designated by name or number. Using the numbering system, the thumb is designated the first digit, the index finger is designated the second digit, and so on.

Fig. 14.4 AP view of the wrist with normal carpal alignment demonstrating the three carpal arcs. *Arc 1* traces the proximal convexities of the scaphoid, lunate, and triquetrum. *Arc 2* traces the distal concave surfaces of the scaphoid, lunate, and triquetrum. *Arc 3* traces the main proximal curvatures of the capitate and hamate

Pelvis and Hip

In the setting of a patient with a history of trauma and pain during weight bearing, images of both the pelvis and hip should be considered. Radiographs of the pelvis and hip starts with an AP view of the pelvis. After the pelvis has been imaged, AP and frog leg lateral views of the affected hip should be obtained. Weight-bearing AP views of the hip or pelvis can be subsequently considered if the initial images are negative. Keep in mind that hip pain can be referred from the lumbar spine or from extra-articular causes.

Femur

Upper leg complaints may be due to pathology of the hip, femur, knee, or lumbar spine. When the appropriate history and physical examination indicates the femur as the pathological source, AP and lateral views of the femur can be added to images of the hip or less commonly images of the knee.

Fig. 14.5 Lateral view of the wrist with normal alignment of the distal radius (*R*), lunate (*L*), and capitate (*C*)

Knee

Radiographs of the knee typically include an AP, lateral, and sunrise view. The initial views are typically obtained supine, but weight-bearing AP and PA can be subsequently obtained to further evaluate the medial and lateral compartments. The AP view primarily is used to evaluate the medial and lateral femoral compartments. The lateral view helps determine if a joint effusion is present. The sunrise view is used to primarily evaluate the patellofemoral compartment.

Certain fractures of the knee noted on plain films are highly suggestive of internal derangement requiring MRI for further evaluation. A Segond fracture is an avulsion fracture of the lateral tibial condyle associated with anterior cruciate ligament (ACL) disruption (75–100 %), medial meniscus tears (66–75 %), avulsion of the fibular collateral ligament (a ligamentous structure that makes up the lateral collateral ligament complex or LCL), avulsion of the fibular attachment of the long head of the biceps femoris, and potentially a lateral capsular ligament injury. A reverse Segond fracture is an avulsion fracture of the tibial component of the tibial collateral ligament (also known as the medial collateral ligament or MCL) which is associated with posterior cruciate ligament (PCL) disruption and medial meniscus tears.

Tibia and Fibula

The tibia and fibula are evaluated with AP and lateral radiographs in the supine position. As with other long bone radiographs, inclusion of the adjacent joints (knee and ankle) while imaging the entire structure of interest, the tibia and fibula in this case, is the standard of practice. An important fracture to recognize is a tibial plateau fracture which is a commonly encountered fracture in the setting of motor vehicle collisions or in older women with osteoporosis. Tibial plateau fractures can be associated with internal derangement of the knee. Another important fracture to recognize in the pediatric population is the toddler's fracture which is a nondisplaced spiral fracture of the distal third to distal half of the tibia in the setting of low-energy trauma.

In addition to evaluating the osseous structures for fracture, determining the relationship between the osseous structures can be a clue to underlying interosseous ligament injury (such as in a Maisonneuve fracture) or distal syndesmosis injury (injury to the anterior and/or posterior tibiofibular ligaments that occurs in a so-called high ankle sprain). To confirm the suspicion of a ligamentous injury, MRI should be performed.

Ankle

The ankle is best evaluated with AP, lateral, and ankle mortise radiographs. In addition to evaluating for fracture, the ankle mortise is the primary structure to evaluate with dedicated ankle radiographs. Malalignment of the ankle mortise indicates underlying ligamentous injury requiring further evaluation with MRI. Subtle sclerosis of the talar dome can be a clue to an old cartilaginous defect that may be unstable and continue to cause pain. If talar dome injury is suggested, then MRI should be considered to determine stability. The lateral view of the ankle can be used to evaluate the joint for an effusion or for osseous coalition which may limit range of motion or cause pain.

Foot

To evaluate the foot, AP, lateral, and oblique radiographs are typically obtained. If individual phalangeal injuries are suspected, then dedicated radiographs of the designated phalanx should be ordered. Like the hand, the phalanges can be designated by name or number, but numbering is preferred. Using the numbering system, the great toe is designated as the first digit and numbering continues laterally.

The Lisfranc fracture-dislocation is a well-known injury to the midfoot occurring in athletes, in the setting of major trauma, or in the diabetic neuropathic joint (Charcot's foot). The Lisfranc joint involves the articulation of the bases of the first three metatarsals with the three cuneiforms as well as the bases of the fourth and fifth metatarsals with the cuboid. The Lisfranc ligament attaches the medial cuneiform with the base of the second metatarsal on the plantar aspect of the foot. Injury resulting in dislocation of the midfoot joints or fracture of the midfoot osseous structures indicated a Lisfranc fracture-dislocation. In the setting of suspected Lisfranc fracture-dislocation, MRI should be considered to determine the extent of the injury and for operative planning.

Advanced Imaging

MRI, CT, bone scan, ultrasound, and arthrography typically are not ordered as the initial study in musculoskeletal complaints. Before ordering advanced imaging, the clinician should obtain a focused history and physical examination and the initial radiographic studies outlined above. If the initial radiographic studies are negative or further imaging is suggested by the interpreting radiologist, then the clinician could consider ordering advanced imaging.

MRI is primary used to evaluate the soft tissues such as muscles, ligaments, tendons, and cartilage. MRI also allows for the evaluation of bone marrow-related pathology. MR arthrography can be utilized to better evaluate labral pathology in the shoulder or hip or ligament/tendon pathology in the wrist, elbow, or ankle. In addition, if osteomyelitis is a consideration, contrast can be added for improved evaluation. MRI can be used to evaluate osseous structures for radiographically occult stress fractures. MRI has the added benefit of not involving ionizing radiation. But, some patients are not candidates for MRI due to pacemaker/defibrillator placement, cochlear implants, certain aneurysm clips, and many other medical devices. In addition, the table weight limits and the bore diameter of the machine can be limiting factors for some patients. Some patients require sedation to complete an MRI because of the anxiety associated with the examination due to both noise and claustrophobia. Lastly, if the patient is unable to remain still for the length of the imaging sequences, motion can degrade the images and limit interpretation by the radiologist.

CT is typically used in major trauma as an initial study in the emergency department (with the exception of evaluation of the extremities). CT can also be used for further evaluation of the pattern of a known fracture or to determine if displacement is present. If initial radiographs are determined to be equivocal for fracture, CT can be obtained to clarify the presence or absence of fracture. CT arthrography is occasionally used in patients who do not qualify for MRI arthrography and provides similar information to the clinician.

Bone scans can be used to evaluate osseous structures for radiographically occult stress fractures. In additional, bone scans are also useful in evaluating osseous structures for the presence of osteomyelitis. A bone scan is a useful tool when the clinician is trying to determine if osseous metastases are present in the setting of malignancy. Although one must keep in mind that photopenic osseous metastasis, such as in the setting of multiple myeloma, are not well identified on bone scans.

Ultrasound can be used to determine if a joint effusion, tendon injury, or hernia is present. Targeted musculoskeletal ultrasound depends on experienced and reliable technologists to provide the appropriate images to the radiologist or clinician. If there is ever a question of what structures are being imaged on the still images provided by the technologist, the radiologist or clinician should perform real-time imaging for clarification.

Summary

Radiographs are typically the first line of imaging in musculoskeletal complaints after a focused history and physical examination is performed. Provide as much detailed clinical information as possible to the radiologist to improve the diagnostic accuracy of the interpretation. After ordering an imaging study, be sure to review the images personally. If the interpretation is discordant with your own personal review of the images, then review the images with the radiologist. If a fracture is a diagnostic consideration and pain persists after negative radiographs, a subtle fracture may be found by repeating radiographs in 7–10 days or ordering specialized views. Advanced imaging is typically reserved for a second-line evaluation of musculoskeletal complaints.

Tables 14.2, 14.3, and 14.4 summarize the views that should be ordered for each body area listed in this chapter, as well as some clinical pearls that may be helpful when ordering tests. If the ordering clinician is uncertain of the most helpful views, he or she should consider calling a radiologist for advice.

Table 14.2 The spine

Body area	Views	Clinical pearls
Cervical	AP, lateral, right and left lateral oblique, and odontoid	In the setting of acute trauma, first stabilize the patient prior to imaging Consider adding oblique views in the setting of radiculopathy (remember, MRI better evaluates the various causes of radiculopathy) Add odontoid in trisomy 21, rheumatoid arthritis, or major trauma
Thoracic	AP, lateral, and swimmer's	Osseous neural foramina are suboptimally evaluated due to rib overlap on the lateral view Consider adding the swimmer's view to better assess the cervicothoracic junction
Lumbar	AP, lateral, and lateral coned-down L5–S1	Oblique views are typically not needed as the lateral views can be used to assess the osseous neural foramina in the setting of radiculopathy As in cervical radiculopathy, MRI better evaluates the various causes of lumbar radiculopathy

Table 14.3 Lower extremity

Body area	Views	Clinical pearls
Pelvis	AP	Consider imaging the hip with the pelvis in the setting of trauma and pain A weight-bearing AP view can be considered if the initial view is negative
Hip	AP, frog leg lateral	A weight-bearing AP view can be considered if the initial view is negative Keep in mind that hip pain can be referred from the lumbar spine or from extra-articular causes
Femur	AP, lateral	If the femur is thought to be the source of pathology, the views can be added to images of the hip or less commonly images of the knee
Knee	AP, lateral, sunrise, weight-bearing AP, weight-bearing PA	Use the AP view to evaluate the medial and lateral femoral compartments Use the lateral view to determine if a joint effusion is present Use the sunrise view to evaluate the patellofemoral compartment Segond and reverse Segond fractures indicate internal derangement of the knee
Tibia and fibula	AP, lateral	Include the knee and ankle joints Important fractures of the tibia and fibula include the tibial plateau fracture, toddler's fracture, and Maisonneuve fracture
Ankle	AP, lateral, ankle mortise	The ankle mortise is the primary structure to evaluate with dedicated ankle radiographs Malalignment of the ankle mortise indicates underlying ligamentous injury Subtle sclerosis of the talar dome can be a clue to an old cartilaginous defect that may be unstable Use the lateral view to evaluate the joint for an effusion or for osseous coalition
Foot	AP, lateral, oblique	Use all three views to look for fractures and osseous alignment The Lisfranc fracture-dislocation is an important injury to the midfoot that requires surgical stabilization
Phalanges	Designate dedicated views	Phalanges can be designated by name or number, but numbering is preferred Using the numbering system, the great toe is designate as the first digit and numbering continues laterally

Table 14.4 Upper extremity

Body area	Views	Clinical pearls
Shoulder	AP with external rotation, AP with internal rotation, true AP, axillary, scapular Y, and outlet	Scapular Y view does not require the patient to move the joint Axillary view requires abduction of the arm Axillary or true AP view evaluates the glenohumeral joint Outlet view evaluates the joint for rotator cuff impingement
Humerus	AP with external rotation, AP with internal rotation	The entire length of the humerus should be included on each view

(continued)

Table 14.4 (continued)

Body area	Views	Clinical pearls
Elbow	AP, lateral in 90° of flexion, and AP oblique with external rotation	In children, consider imaging the opposite elbow due to the many ossification centers Look for indirect signs of fracture, i.e., "fat pad sign" or "sailboat sign" Use the lateral view to measure the anterior humeral line and the radiocapitellar line to assess the radiocapitellar relationship on Use the oblique view to evaluate the radial head
Radius and ulna	AP, lateral	Include the elbow and wrist joints Avoid pronation or supination between images Important fractures of the radius and ulna include the Monteggia fracture-dislocation, Galeazzi fracture-dislocation, and Colles' fracture
Wrist	AP, lateral, oblique	If there is a suspected fracture of a specific bone, particularly the scaphoid, dedicated views of the bone can be obtained Evaluate the three carpal arcs on the AP view Evaluate the relationship of the distal radius, lunate, and capitate on the lateral view
Hand	AP, lateral, oblique	Use all three views to look for fractures and osseous alignment
Phalanges	Designate dedicated views	Phalanges can be designated by name or number, but numbering is preferred Using the numbering system, the thumb is designated the first digit, the index finger is designated the second digit, and so on

Suggested Readings

1. Manaster BJ, May DA, Disler DG. Musculoskeletal Imaging: the requisites. 4th ed. Philadelphia: Elsevier Saunders; 2013.
2. Helms CA. Fundamentals of skeletal radiology. 4th ed. Philadelphia: Elsevier Saunders; 2014.