Choosing the Right Diagnostic Imaging Modality in Musculoskeletal Diagnosis

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KEYWORDS

• Diagnostic imaging • Radiology • Radiographs • Magnetic resonance imaging
• Computed tomography • Arthrogram

KEY POINTS

- Routine radiographs are the first imaging modality of nearly all musculoskeletal disorders.
- Magnetic resonance imaging (MRI) is highly sensitive to fractures and soft tissue injuries.
- Computed tomography is superior to MRI for fracture characterization, particularly involving bones of the hand or the hook of the hamate in the wrist.
- Magnetic resonance arthrogram is recommended for intra-articular disorders such as an injury to the triangular fibrocartilage complex in the wrist, the glenoid labrum in the shoulder, or the acetabular labrum of the hip.

INTRODUCTION

Nature of the Problem

Musculoskeletal injuries and pain are a common presenting complaint among patients in primary care and sport medicine offices. Obtaining a detailed history and physical examination is paramount for establishing an accurate diagnosis. Imaging is an important tool to confirm a diagnosis or rule out a competing diagnosis when the history and physical examination are unable to reliably establish the diagnosis. Selecting the most appropriate imaging test is essential to minimize patient risk, expedite diagnosis and treatment of the patient, and limit health care cost.

Definition

Radiological studies each vary in sensitivity and specificity in identifying abnormalities in different structures. Imaging protocols must take into account the specific clinical

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scenario, patient risk and contraindications, and the associated cost of each imaging modality.

Symptom Criteria

Obtaining a careful history and physical examination is necessary to establish the pretest probability of each competing diagnosis for the musculoskeletal disorder. Accurately choosing the preferred radiological study depends on identifying the affected joint(s) and/or surrounding tissue. In addition, it requires an astute clinician to determine whether the abnormalities identified on the radiological studies are related to the patient's symptoms or whether they are incidental findings unrelated to the patients symptoms.

CLINICAL FINDINGS

History

Imaging algorithms depend on patient age, detailed history, and key physical examination findings to establish the pretest probability for a particular musculoskeletal injury. Key points of the history include the quality and specific location of the pain, onset of pain, related trauma, mechanical symptoms, exacerbating and alleviating factors, pain with weight bearing, instability, and pain while sleeping.

Physical Examination

Physical examination is particularly useful for localizing a patient's pain to a specific joint and the musculoskeletal structure(s) that are involved. Important physical examination findings that support intra-articular disorders include joint swelling (effusion), locking, catching, deformity, and limited or painful range of motion. Instability or laxity suggests ligamentous or capsular injury.[1]

IMAGING

Routine Radiographs

Routine radiographs should almost always be performed as the initial imaging modality for musculoskeletal injuries. Although the densities of calcium, soft tissues, fat, and air can be discerned with radiographs, the resolution of osseous anatomy is superior to that of soft tissues. Radiographs often yield a diagnosis or aid in appropriate selection and interpretation of advanced imaging, particularly with magnetic resonance imaging (MRI). A minimum of 2 radiography projections taken at right angles to each other of the body part of interest are necessary for evaluation. A 3-view radiographic evaluation is recommended for distal extremities in the setting of trauma, because prior studies have shown that up to 6.7% of fractures are only detected on the oblique view and would otherwise have been missed.[2] Certain joints require specific views to depict abnormalities on radiographs (discussed later). In addition, fluoroscopic positioned spot views can be used to avoid bony overlap in certain cases. The sensitivity of routine radiographs varies depending on the mineralization of the bone involved, the specific disorders, and the chronicity of the disorders.[3] The indications, relative cost, and relative radiation exposure of routine radiographs are summarized in **Table 1**.[3]

Computed Tomography

Computed tomography (CT) uses a rotating x-ray source that is reformatted to a cross-sectional image using a computer processor. CT is superior to routine radiographs for evaluating the complex structures of the axial skeleton, the osseous structures of the

Table 1
Summary of routine radiography

Indications	Bone injury (fracture, degenerative changes)
Cost ($)	50–300[a]
Risks/contraindications	Mild radiation exposure[b]

[a] Cost varies among hospitals and depending on the specific studies performed.
[b] Radiation exposure depends on the specific projections performed.

foot, ankle, pelvis, shoulder, wrist, and hand.[3] CT is superior to radiography in showing subtle cortical bone injury. Specific CT reformatting techniques are often performed for surgical planning, which is beyond the scope of this article but should be considered when selecting between MRI and CT.[3,4] The indications, relative cost, and relative radiation exposure of CT are summarized in **Table 2**.[3,4]

MRI

MRI uses a fixed or superconducting magnet that creates a strong magnetic field. This magnetic field causes the protons of hydrogen nuclei to have a similar alignment, which are then excited by a radiofrequency pulse. The absorbed energy is released as an electromagnetic wave that is detected by a receiving coil, processed, and an image is produced. The field strength of the magnet is directly related to image resolution obtained. The field strength is typically between 1.5 T and 3 T, but may be lower in an open MRI scanner. MRI is optimal to evaluate soft tissue, occult fractures, articular cartilage, masses, marrow abnormalities, synovitis, and infectious processes. MRI is the most sensitive modality for detecting fractures and is recommended if there is clinical suspicion for fracture and radiographs are negative.[4] The indications, relative cost, and contraindications of MRI are summarized in **Table 3**.[4]

Ultrasound

Ultrasound uses high-frequency sound waves directed into musculoskeletal structures. Each tissue comprising the musculoskeletal system varies in density and its ability to transmit and reflect sound waves. The reflected sound waves are converted into an image. Similar to MRI, the image quality depends on the frequency and type of the transducer. In addition, clinical expertise with ultrasound varies and can affect the sensitivity and specificity of ultrasound for evaluation of various injuries. Ultrasound may be used to evaluate masses in soft tissues, vasculature, ligaments, tendons, bone, cartilage,

Table 2
Summary of CT

Indications	Fracture, cortical bone injury
Cost ($)	100–200[a]
Risks	Moderate radiation exposure[b]
Contraindications	No absolute contraindications. CT of the lumbar spine, abdomen, and pelvis of the pregnant woman should be avoided when possible

[a] Cost varies among hospitals and depends on the specific studies performed.
[b] Helical CT or CT angiogram produces significantly higher radiation exposure.

Table 3
Summary of MRI

Indications	Soft tissue mass, vascular disease, ligament/tendon injuries, fracture, osteonecrosis, articular disorders, abnormal cartilage, effusion, foreign bodies, guidance for injection
Cost ($)	500–4000[a]
Risks	No radiation exposure to patient
Contraindications[b]	Cardiac pacemaker, cochlear implants, some prosthetic heart valves, bone growth or neurostimulators (TENS), brain aneurysm clips or coils, periorbital metal fragments, some penile prosthesis, older cardiac stents

Abbreviation: TENS, transcutaneous electrical nerve stimulation.
[a] Cost varies widely among hospitals and depends on specific study performed.
[b] Newer implantable devices may be magnetic resonance compatible. Manufacture's recommendations should be consulted on an individual basis.

effusions, and foreign bodies.[3] The indications and relative cost of ultrasound are summarized in **Table 4**.[3]

Bone Scan (Scintigraphy)

Bone scans detect changes in the skeleton's level of bone formation by using an intravenously administered radiopharmaceutical that binds to the hydroxyapatite crystals in the bone matrix proportionately to local blood flow and osteoblastic activity, thus highlighting areas of increased bone turnover and bone perfusion. Therefore, bone scans can detect abnormalities in bone, such as fractures, stress fractures, osteomyelitis, and osteoblastic metastases, before anatomic changes can be detected on radiograph. In addition, bone scans have a higher sensitivity for stress reactions than CT.[5] Although bone scans are highly sensitive for any bone injury that results in bone formation, the specificity is limited. Single-photon emission CT (SPECT) is used in conjunction with planar bone imaging based on the clinical indication or radionuclide uptake pattern to provide a three-dimensional image and improve specificity and sensitivity. Bone scan with SPECT can increase the sensitivity for detecting vertebral bone lesions and distinguish between aggressive and nonaggressive lesions.[5] In addition to osseous disorders, a 3-phase bone scan can detect abnormal sympathetic activity in an extremity, which is often associated with complex regional pain syndrome. A characteristic finding on the planar 3-phase bone scan is diffuse generalized increased uptake of bone agent throughout all the bones of 1 extremity in all 3 phases, which is caused by increased generalized blood flow.[5] The indications, relative cost, and radiation exposure of bone scans are summarized in **Table 5**.[5]

Table 4
Summary of musculoskeletal ultrasound

Indications	Soft tissue mass, vascular disease, ligament/tendon injuries, bone (fracture, osteoporosis), articular disorders, cartilage, effusion, foreign bodies, guidance for injection
Cost ($)	100–300[a]
Risks/contraindications	None

[a] Cost varies among hospitals and depends on the specific study performed.

Table 5
Summary of bone scintigraphy (bone scan)

Indications	Stress fracture, differentiation of osteomyelitis from cellulitis, avascular necrosis or bone infarction, reflex sympathetic dystrophy, peripheral vascular disease, subtle lumbar lesions such as pars defect[a]
Cost ($)	150–650[b]
Risks/contraindications	Minimal radiation exposure to patient, rare allergic reaction to radiopharmaceutical used

[a] Bone scintigraphy with SPECT is recommended to evaluate for pars defect.
[b] Cost varies among hospitals and specific study performed.

DISORDERS

Shoulder Imaging

The complex anatomy of the shoulder joint makes choosing diagnostic imaging tests challenging. The history of trauma, age of the patient, and specific location of pain are among the most important factors for developing a differential diagnosis and selecting the most appropriate imaging studies. In most cases, routine radiographs are an appropriate initial study. Depending on the nature of the trauma and location of pain, specific radiograph views may be necessary for thorough evaluation (Table 6). In the

Table 6
Summary of radiographic shoulder views

View	Indication(s)	Specific Structure(s) Evaluated
Standard AP in ER	Trauma	Greater tuberosity of humerus
Standard AP in IR	Trauma	Lesser tuberosity of humerus
Grashey (true AP)	Limited ROM Instability	Joint congruity Joint space narrowing Humeral head subluxation
Axillary	Dislocation	Dislocation Anterior/posterior glenoid rim (Bankart fracture)
West point axillary	Dislocation	Anteroinferior glenoid rim (Bankart fracture)
Garth view	Dislocation	Inferior glenoid rim (Bankart fracture) Posterior margin of superolateral humeral head (Hill-Sachs deformity)
Stryker notch	Dislocation	Posterolateral humeral head (Hill-Sachs deformity)
Scapular Y view	Dislocations Trauma	Evaluate supraspinatus outlet Dislocation Scapular fracture Assess for dislocation
Supraspinatus outlet	Impingement Limited ROM	Acromion Humeral head subluxation
Zanca view	Trauma	Acromioclavicular joint
Rockwood view	Impingement	Acromion

Routine shoulder series typically includes AP (in neutral, IR, and/or ER), Grashey, axillary, scapular Y. Routine shoulder series may vary slightly by imaging center or institution.[4]

Abbreviations: AP, anteroposterior; ER, external rotation; IR, internal rotation; ROM, range of motion.

Data from Manaster BJ, Roberts CC, Andrews CL, et al. Diagnostic and surgical imaging anatomy: musculoskeletal. Salt Lake City: Amirsys; 2006.

absence of trauma, deformity, or abnormal range of motion, routine radiographs rarely identify clinically significant abnormalities.[6,7]

Ultrasound and MRI have equivalent sensitivity for rotator cuff disorders and dislocations. Selecting between magnetic resonance (MR) and ultrasound for advanced imaging is based on the specific clinical scenario. Ultrasound is less costly, is better tolerated by patients, and is a dynamic examination that can confirm subluxation of the biceps tendon or subacromial impingement. A labral or osseous injury is better detected with an MR arthrogram and MRI, respectively.[8] Specific MR sequences improve the sensitivity of detecting disorders. For example, the long echo time (TE) sequence and fat-suppressed T2-weighted sequence show increased signal in the rotator cuff tendon in the presence of injury. T1-weighted sequences are similarly used to assess marrow signal related to fracture or bone contusion.[4] CT can be used to characterize fractures and for surgical planning. MR arthrogram is the gold standard for evaluation of the glenoid labrum. CT arthrogram is a good alternative to evaluate labral injury in individuals who cannot undergo MRI.[4] Specific indications for each imaging modality are listed in **Table 7**.[4]

Hand and Wrist Imaging

Imaging of acute and chronic hand and wrist pain should begin with routine radiographs. Radiographs with only 2 projections are inadequate for evaluation in most

Table 7
Summary of indications for common imaging modalities

Imaging Modality	Shoulder Structures/Disorders Detected
Routine radiographs	Dislocations (acromioclavicular and glenohumeral) Fractures (proximal humerus, clavicle, and scapula) Osseous finding associated with rotator cuff disorders Glenohumeral osteoarthritis Acromioclavicular joint arthritis Sternoclavicular joint arthritis
Musculoskeletal ultrasound	Joint effusion Rotator cuff injury (tendinopathy, tear) Biceps tendon injury (dislocation/subluxation, tendinopathy, tear) Muscle atrophy/denervation
MRI	Rotator cuff injury (tendinopathy, tear) Avascular necrosis Biceps tendon injury (tendinopathy/tear) Inflammatory processes Tumors Muscle atrophy/denervation Fracture
CT	Characterize fractures/evaluate bone contours Dislocations Assess for bone tumor Characterize glenoid and humeral head anatomy Soft tissue calcifications
MR arthrography	Labral injury (gold standard for diagnosis) Glenohumeral ligament injuries
CT arthrography	Anterior and posterior labrum Joint capsule

cases. A 3-view radiograph consisting of a posteroanterior, lateral, and oblique view is recommended for wrist and hand trauma, particularly if the joint is involved. Some trauma protocols include a fourth projection that is a posteroanterior view, with the wrist in ulnar deviation. Specialized views may be indicated for certain clinical scenarios. A scaphoid view should be added to the 3-view wrist radiograph to improve sensitivity for a scaphoid fracture. The hook of the hamate is best visualized with the addition of a carpal tunnel view.[9]

Imaging the wrist with high-resolution MR may be indicated when there is clinical concern for a radiographically occult carpal fracture, soft tissue injury, mass, bone marrow abnormalities, synovitis, or an infectious process.[3,4,10] Radiological studies have found that approximately half of symptomatic wrists imaged with MR detected abnormalities that have resulted in a change in working diagnosis, and 46% showed findings that resulted in a change in management.[11] However, when evaluating for a suspected hook of the hamate fracture, CT is recommended if radiographs are negative. Injuries involving the transcarpal ligaments, triangular fibrocartilage complex (TFCC), and/or articular cartilage are best detected with MR arthrography. The sensitivity of MR arthrography is less than that of direct visualization with arthroscopy, so, in cases when the injury is amenable to arthroscopic treatment, advanced imaging may not be indicated.[4,10–12]

In the presence of trauma, tenderness directly over the scaphoid (the anatomic snuffbox) necessitates imaging to evaluate for a scaphoid fracture. Routine radiographs are often insensitive for nondisplaced scaphoid fractures until osteoblastic activity can result in radiographic change, around 10 to 14 days following injury.[10] Initial imaging with routine wrist radiographs should include a scaphoid view. Wrist immobilization and follow-up radiographs are recommended after 2 weeks if clinical concern for fracture remains. If immediate diagnosis is necessary, an MRI may be performed directly after initial radiographs are negative to confirm or exclude a scaphoid fracture. The false-negative rate of scaphoid fracture on follow-up radiograph is as high as 9%.[13] The pooled sensitivity for scaphoid fracture is similar that for MRI (96%), CT (93%) and bone scan (97%), whereas the specificity is inferior for bone scan (89%) compared with MRI (99%) and CT (99%).[14] If clinical suspicion remains high for scaphoid fracture despite negative radiographs, MRI is recommended to confirm or exclude fracture.[15]

Hip and Pelvis Imaging

The complexity of the hip and pelvic anatomy, as well as radicular symptoms potentially originating from spinal disorders, can make diagnosing hip and pelvic pain challenging. Imaging can be useful for establishing the diagnosis. Clinical correlation is important to determine whether the imaging abnormalities detected are related to the patient's pain.

Routine radiographs are the initial imaging study to evaluate nearly all acute and chronic hip and/or pelvic disorders. An anteroposterior (AP) view of the pelvis should include both hips to detect asymmetry. A lateral view detects osseous abnormalities of the femoral head and neck. MRI is highly sensitive and specific for osseous and articular hip injuries, as well as soft tissues injuries of the hip and pelvis, and is the recommended imaging modality in most cases after a radiograph is negative.[4,13,15] Exceptions include evaluation for labral injury, osteoid osteoma, and snapping hip syndrome, which are best detected on MR arthrogram, CT, and ultrasound, respectively.[13,15] Radiographs are insensitive for nondisplaced femoral neck fractures, particularly in an osteoporotic patient. If there is a history of fall, clinical concern for insufficiency fractures, or recent trauma in a patient with hip pain, MRI is recommended before allowing the patient to bear weight on the affected leg.

MR arthrogram involves undergoing an intra-articular hip injection of gadolinium before performing MRI, which improves the sensitivity for labral injury up to 90%.[13] Diagnostic and therapeutic joint injections can be performed at the time of an MR arthrogram to provide clinical information regarding the patient's pain generator. If the detected abnormalities on MR are the source of pain, the patient should experience pain relief following the injection.

Ultrasound is the recommended imaging modality for evaluating snapping hip syndrome, because both static and dynamic imaging can be obtained. CT may be performed to better characterize osseous abnormalities such as osteoid osteoma, and may be used in preoperative planning.[13,14]

Knee Imaging

Radiographs of the knee are commonly performed for evaluation of traumatic and atraumatic knee pain, but are often negative. To decrease the number of unnecessary radiographs, numerous criteria guidelines have been created with the objective of guiding appropriate use of radiographs for acute knee injury. The most widely cited criteria are the Ottawa Knee Rules (**Box 1**).[16–18] Numerous validation studies have found that these guidelines are 100% sensitive for detecting knee fractures and decrease the radiograph rate by 28% to 35%, depending on the specific study.[14,16,17,19] Radiography is not sensitive for meniscal or ligamentous injury. Physical examination is important to establish the pretest probability for internal derangement (disruption of the meniscus, ligaments, and/or osteochondral injury). When clinical suspicion is high for meniscal or ligamentous injury, MRI is the best modality to detect such injuries. Imaging should be performed judiciously, because asymptomatic abnormalities, particularly to the meniscus, are frequently detected on MRI.[20]

Radiographic criteria for detecting osteoarthritis were established in the 1950s and include osteophytes, sclerosis, joint space narrowing, and subchondral cystic bone.[21] Current practice relies more on joint space narrowing, which is more sensitive with a weight-bearing AP view or a weight-bearing AP view with flexion. MRI is a more sensitive modality for early osteoarthritic changes. The usefulness of imaging for detection of osteoarthritis is not clear because the severity of joint degeneration on imaging infrequently correlates with pain.[22]

Foot and Ankle Imaging

In the setting of acute trauma to the foot or ankle, 3-view radiographs should be performed if the patient experiences tenderness over the navicular, base of the fifth metatarsal, medial or lateral malleolus (see **Box 1**), or if the patient does not meet the

Box 1
Ottawa Knee Rules for radiography in the setting of acute knee injury

Age greater than or equal to 55 years

Palpable tenderness over head of fibula

Isolated patellar tenderness

Unable to flex knee to 90°

Unable to bear weight immediately and in emergency department (4 steps)

Radiographic examination is recommended for acute knee injuries in patients with 1 or more of these criteria.

inclusion criteria for the Ottawa Rules.[15,23] These rules have been validated for adults and children and have a sensitivity of 99%.[15] However, the exclusion criteria of cases in which the Ottawa Rules should not be applied are extensive and include penetrating trauma, skin wound, polytrauma, neurologic abnormality involving the foot, pregnancy, underlying bone disease, return visit, or presenting with radiographs more than 10 days old.[23] An acute forefoot injury concerning for a Lisfranc injury should always be imaged. Three-view radiographs may be performed as the initial imaging and should include a weight-bearing AP view. Advanced imaging is often necessary even if radiographs are normal when clinical suspicion is high for this injury. MR can detect a ligamentous injury as well as a fracture. If a fracture is identified, CT is often used by orthopedic surgeons to characterize fractures for preoperative planning. Ligamentous injuries to the ankle are common and do not necessitate imaging in most cases.

In the setting of chronic ankle or foot pain, radiographs are typically the appropriate initial study. Routine radiographs of the foot should always include AP and lateral views. Oblique and occasionally specialized views are indicated depending on the clinical presentation. Advanced imaging is often recommended if radiographs are not diagnostic. Selection of MR, CT, bone scan, or ultrasound depends on the specific clinical presentation.

Routine radiographs of the ankle should include AP, lateral, and ankle mortise views. Osteochondral injuries are often not detected on routine radiographs and further imaging with MRI, MR arthrogram, or SPECT/CT may be indicated if clinical suspicion is high.[22] When chronic foot or ankle pain cannot be localized to a particularly structure on examination, MR is usually the recommended modality because it can detect soft tissues as well as osseous abnormalities. Ultrasound is particularly useful for evaluating pain occurring only with particular positions because it allows a dynamic evaluation **Box 2**.[24]

Spine Imaging

Traumatic cervical spine injures

The NEXUS (National Emergency X-Radiography Utilization Study) criteria (midline neck pain or tenderness, neurologic findings, altered mental status, intoxication, and/or distracting injury) have been established and validated to guide selection of patients who require cervical spine imaging for vertebral bone blunt cervical trauma injury with 99% sensitivity and a negative predicted value of 99.8%.[25] Performance of a multidetector-

Box 2
Indications for radiography in the setting of acute foot or ankle injury[a]

Navicular tenderness

Tenderness over base of fifth metatarsal

Tenderness over medial or lateral malleolus

Inability to bear weight

Presence of neuropathy affecting feet

Clinical suspicion for Lisfranc injury[b]

[a] Based on Ottawa Rules and exclusion criteria.

[b] MRI is also an appropriate initial imaging study to detect Lisfranc ligamentous injury and should always follow up a normal radiograph if clinical suspicion is high. CT may be required to characterize fractures detected on radiograph or MRI.

row CT (MDCT) has replaced routine cervical radiographs in patients with a suspicion for cervical spine injury because it can be performed more rapidly and has an increased sensitivity. Recent studies have found that radiographs detect only 36% of cervical spine injuries identified on CT in patients who meet one or more of the NEXUS criteria.[26] Thin-slice, reformatted CT imaging is often necessary, even in the presence of a cervical injury detected by radiography, for complete evaluation of the cervical spine for traumatic injuries, including evaluation for subtle injuries, spinal canal compromise, and fragment positioning. When a burst fracture is identified with radiography, a total spine CT should be performed to assess whether fracture fragments compromise the spinal canal and to evaluate for additional injures.[3] Nonosseous structures such as the spinal cord, nerve roots, and soft tissue are not well visualized on CT and often require MRI for thorough evaluation, if clinically indicated. In addition, MRI may identify posterior ligament injuries on the T2-weighted images that were not detected on CT or radiographs.[3] Ligamentous injuries can be detected with flexion/extension radiograph views of the cervical spine, but with a lower sensitivity than MRI. In addition, in the acute setting, there may be significant cervical muscle splinting resulting in a false-negative test. Flexion/extension films should only be obtained after a comprehensive neurologic examination has been completed to exclude any spinal cord or plexus injury.[15]

Traumatic thoracolumbar spine injuries

Although validated criteria have not been established for imaging of the thoracolumbar spine, criteria similar to the NEXUS criteria have been recommended.[15] As with evaluating the cervical spine, MDCT has replaced conventional radiography for evaluation of osseous disorders of the thoracolumbar spine resulting from a trauma because of its superior sensitivity compared with radiographs.[15] In addition, identification of one spinal fracture increases the likelihood of a subsequent spinal fracture and may justify the need for a total spine CT.[3] When a thoracic spine fracture is identified on radiograph, fragment position and spinal canal compromise may require further evaluation with CT.[3,27] MRI is recommended when there is any clinical concern for injury to the spinal cord, nerve roots, and/or soft tissue, which are not well visualized on CT.[3,15]

Spondylolysis and spondylolisthesis

Radiographs are routinely the initial imaging study performed to evaluate a young athlete with low back pain with clinical concern for spondylolysis. Lateral views detect subluxation (spondylolisthesis), which may occur in the presence of a bilateral pars interarticularis defect. AP and oblique views may identify a pars defect (spondylolysis), but with limited sensitivity. Oblique views are slightly more sensitive than AP views but increase the patient's exposure to radiation and are no longer routine in protocols at many institutes. Bone scintigraphy with SPECT is a highly sensitive imaging test for early spondylolysis and is often recommended when radiographs are normal, particularly in elite athletes.[15,28,29] This test shows increased uptake in a pars defect, which is associated with bone healing. This test does not differentiate between a stress reaction or an overt fracture, which results in a high false-positive rate for diagnosing a pars fracture. A pars defect detected on radiographs that is acute is indistinguishable from one that has healed with a fibrous union.[15] Bone scintigraphy with SPECT is important for differentiating these cases and is positive in the former and negative in the latter. A limited CT (reverse gantry axial plane at the area of increased uptake on the bone scintigraphy) is also commonly performed to characterize the extent of fragmentation, neuroforaminal patency, and the extent of healing when the bone scan is positive.[27] When subluxation is identified, flexion and extension radiographs should be performed to assess stability. If there is a clinical concern for radiculopathy,

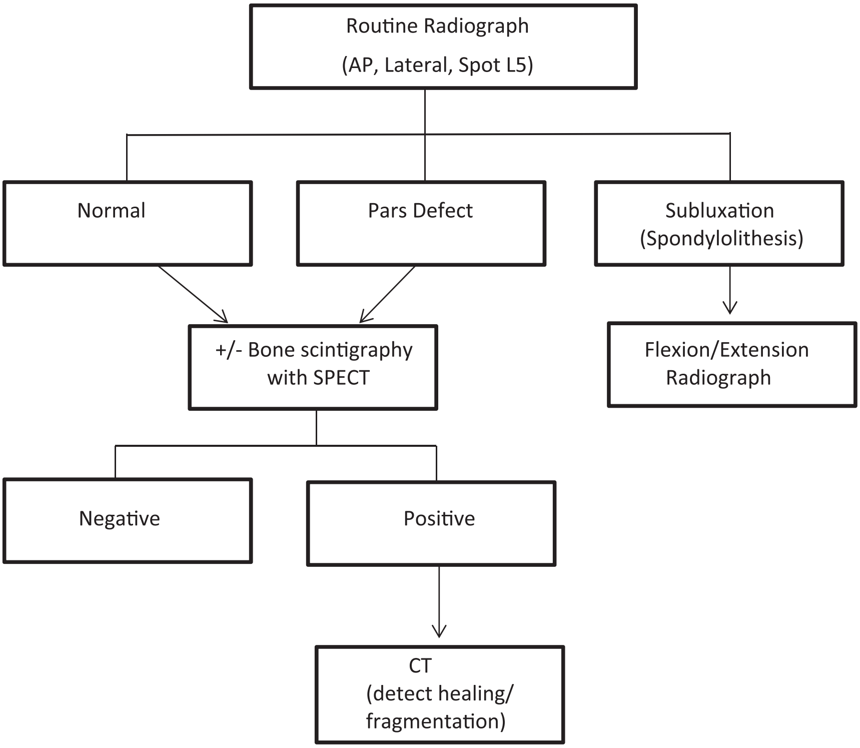

Fig. 1. Algorithms for evaluating spondylolysis in a young athlete. AP, anteroposterior; CT, computed tomography; SPECT, single-photon emission computed tomography.

MRI is recommended to evaluate neural involvement. MRI (particularly T2-weighted fat-saturated images) may also detect edema, reactive marrow changes, and synovitis. Some recent studies suggest that MRI has equivalent sensitivity to CT for detecting a pars fracture (Fig. 1).[27,28]

Atraumatic spine disorders

Spinal disorders with insidious onset and/or those without a history of trauma are initially evaluated with routine radiographs. Radiographs detect osseous changes

Table 8
Radiograph views for evaluating spinal disorders

Anatomic Region	Indication	Radiography Views
Cervical spine	Trauma/routine	AP, lateral, AP odontoid, both obliques (including C7–T1 level on both)
	Instability	Flexion/extension
Thoracolumbar spine	Routine	AP, lateral
	Scoliosis	Lateral bending
	Pars defect	AP, lateral, spot L5, both obliques[a]

[a] Oblique views for pars defect is no longer universally performed because of increased radiation dose with modestly increased sensitivity for fracture compared with performing AP and lateral views only.

including osteophyte formation, loss of lordosis, and facet degeneration. Intervertebral disc disorders can be indirectly detected with loss of disc height; however, MRI is usually necessary to evaluate for neuroforaminal stenosis, disc herniation, mass, and/or infection. CT myelography is also used to evaluate for disc herniation, particularly for surgical planning, or when MRI is contraindicated **Table 8**.[3]

SUMMARY

Diagnostic imaging can be a valuable tool when used in conjunction with a thorough history and physical examination for establishing a diagnosis and treatment plan. Radiographs are the initial imaging modality in most cases of musculoskeletal injury or pain. MRI is often the recommended imaging in the setting of a normal radiograph for most injuries. CT is the optimal imaging study for traumatic injury to the hands or the hook of the hamate. Ultrasound can be used to detect myotendinous injuries, ligamentous injuries, fractures, and masses. MR arthrography is recommended for evaluation of specific intra-articular soft tissue structures such as the TFCC in the wrist, glenoid labrum in the shoulder, and the acetabular labrum in the hip. Additional imaging algorithms and the usefulness of imaging studies can be found in the American College of Radiology Appropriateness Criteria.[15]

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