Radiographic evaluation

Radiographic evaluation is among the first studies ordered in patients with a suspected rheumatologic disorder. In the current digital era, conventional analog-based radiographs have been largely replaced by computed radiography. Images are usually displayed on workstations with high-resolution monitors within the context of a picture archiving system (PACS). Digital radiographs are of high spatial resolution but relatively poor soft tissue contrast. These images are amenable to a variety of image processing schemes, resulting in enhanced definition of the cortical surfaces and cancellous bone, which may be of value in displaying subtle erosions.

It is important to recognize that radiographs are projection images. To detect an abnormality, it may be necessary to view a joint or other structure at a specific angle. For instance, subtle erosions may only be apparent when viewed tangentially as opposed to en face. It is therefore necessary to have specific image protocols in order to optimally display the joint, cortical surface, or soft tissue structure. Most radiographic evaluations contain at least two orthogonal projections. The addition of an oblique view or other specialized projection may be necessary to address a specific clinical question.

The nature and distribution of joint space narrowing, presence of osteopenia, new bone formation, soft tissue swelling, soft tissue calcification, chondrocalcinosis, presence and nature of erosions, and assessment for joint malalignment may allow a specific diagnosis and help determine the severity of disease (Fig. 258-1). For instance, the presence of a juxta-articular erosion extending over an adjacent area of slightly hyperdense soft tissue swelling in the setting of normal bone mineralization with maintenance of the adjacent joint space is diagnostic of gout, in contrast to RA noted earlier. The seronegative arthritides, such as psoriatic arthritis, have a characteristic appearance in the small joints of the hand and feet, including a predilection for distal joints, asymmetry, and appositional new bone formation.

Table 258-1 summarizes some of the features of several of the more common diseases that may be encountered in clinical practice.

Finally, radiographs provide a direct means for needle localization during percutaneous procedures, predominantly joint injections, aspirations, and some biopsies. These are generally performed while imaging in real time (fluoroscopy) using short bursts of low-intensity x-rays enhanced through an image intensifier. Injection of joints under fluoroscopic guidance provides a convenient means to ensure intra-articular deposition of therapeutic agent or for diagnostic aspiration. Intra-articular location is verified by injection of a small amount of a standard iodinated contrast material. Arthrography using fluoroscopic guidance can be used as a primary diagnostic tool, but this application has largely been replaced by intra-articular injection of contrast followed by computed tomography (CT) or MRI.

For some procedures, CT may be preferable, depending on the location of the abnormality. The principal disadvantages of fluoroscopy relate to the use of ionizing radiation and poor soft tissue contrast. The latter becomes important with needle placements near neurovascular structures that may be potentially compromised by poor position. CT allows greater control over needle placement at the cost of greater levels of radiation exposure. Ultrasonography has replaced fluoroscopy and CT for a large number of percutaneous procedures. MRI provides another method to perform a variety of procedures without the necessity of ionizing radiation. These options will be discussed in greater detail below.

Historically, rheumatic disorders have been well characterized by conventional imaging. In as much as these disorders often manifest in characteristic distributions and present with specific alterations in the appendicular or axial skeleton and adjacent soft tissues, radiographic evaluation has been sufficient to both characterize the abnormalities as well as provide a relatively small number of differential possibilities as to the specific disease. The most well-studied example is rheumatoid arthritis (RA) in which symmetric involvement of the metacarpophalangeal joints, uniform joint space narrowing, periarticular osteopenia, and juxta-articular erosions along the "bare areas" are pathognomonic.

The development of new therapeutic alternatives for the inflammatory arthritides, so-called disease-modifying antirheumatic drugs (DMARDs), and chondroprotective strategies in the case of osteoarthritis, require methods to diagnose these diseases at an earlier stage, characterize the degree of inflammation, and provide a useful metric to assess therapeutic response. Indeed, it has become necessary to assess for possible joint and soft tissue abnormalities before irreversible tissue damage, the latter often being the case when the radiographic findings are abnormal. Fortunately, the requirement to achieve earlier diagnosis has paralleled advances in imaging. Ultrasonography and magnetic resonance imaging (MRI) have largely supplanted conventional radiographic evaluation in the imaging work-up of patients with suspected rheumatologic disorders and negative radiographs. The term molecular imaging has been applied, particularly in the case of MRI and positron emission tomography (PET), in as much as these modalities reflect local tissue environment or metabolic activity.
**FIGURE 258-1.** Three hands with different diagnoses. A, Gout. Radiograph of the left hand showing multiple dense soft tissue nodules (n) with multiple small erosions affecting the ulnar styloid, triquetrum and fifth ray. A large erosion (arrow) at the fifth distal interphalangeal (DIP) joint demonstrates bone formation extending circumferentially about the adjacent tophaceous deposit typical of an overhanging edge. Bone mineralization and joint spaces are preserved. B, Rheumatoid arthritis. There is ulnar deviation of the second through fifth metacarpophalangeal (MCP) joints with uniform joint space loss involving the MCP joints and the carpus. The DIP joints are spared. Periarticular demineralization is present with small erosions along the radiolateral aspect of the second (arrow) MCP joint. C, Osteoarthritis. Soft tissue swelling affecting the third digit with joint space narrowing and bone production affecting the DIP joints, third and fifth proximal interphalangeal (PIP) joints, basal joint of the thumb, and scaphotrapeziotrapezoid joint. There are subchondral cystic changes at the third PIP joint having an erosive character (arrow). Mineralization is preserved, as are the radiocarpal and MCP joint spaces.

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**TABLE 258-1** DISTINGUISHING RADIOGRAPHIC FEATURES OF SEVERAL COMMON RHEUMATIC DISEASES

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>COMMON SITES</th>
<th>DISTRIBUTION</th>
<th>RADIOGRAPHIC FEATURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rheumatoid arthritis</td>
<td>Hands: MCP, PIP; wrists: intercarpal, DRUJ, ulnar styloid; feet: fifth MTP, cervical spine (atlantoaxial, apophyseal)</td>
<td>Bilateral, symmetric, polyarticular</td>
<td>Periarticular osteopenia, periarticular swelling, subluxations (e.g., ulnar, volar), uniform joint space loss, erosions (bare areas)</td>
</tr>
<tr>
<td>Osteoarthritis (primary)</td>
<td>Hands (DIP), wrists (basal joint, STT), feet (first MTP), hips (superolateral), knees (medial), spine (discs, facet, apophyseal, uncovertebral)</td>
<td>Symmetric, weight-bearing joints</td>
<td>Normal or increased density, nonuniform joint space loss, subchondral sclerosis, cysts, bone formation (osteophytes)</td>
</tr>
<tr>
<td>Panniculitis</td>
<td>Hands (DIP, terminal tufts), feet (IP joints), entheses (calcaneus: planter, posterior), spine, sacroiliac joints</td>
<td>Asymmetric (single ray), polyarticular, segmental (intervertebral, apophyseal)</td>
<td>Normal or increased density, periosteal bone formation, soft tissue swelling, ankylosis (SI joints), thick hyperostosis spine (nonmarginal syndesmophytes), juxta- and periarticular erosions</td>
</tr>
<tr>
<td>Ankylosing spondylitis</td>
<td>Spine, SI joints, fibrous joints (pubic symphysis), entheses (adductor origin), rhizomelic joints (hips, shoulders)</td>
<td>Symmetric, continuous (may affect entire spine-bamboo spine)</td>
<td>Normal or increased density, erosions (spine squaring, shining corner) with superimposed bone formation (ankylosis: SI), thin (marginal) syndesmophytes</td>
</tr>
<tr>
<td>Gout</td>
<td>Feet (first MTP), other damaged joints, elbow, knee, hindfoot</td>
<td>Asymmetric, extensor surfaces (elbow), abnormal joints (e.g., osteoarthritic joints)</td>
<td>Normal joint space, normal or increased density, dense soft tissue nodules (tophi), para-articular and subchondral erosions with bone formation along tophi (overhanging edge)</td>
</tr>
<tr>
<td>Calcium pyrophosphate dihydrate crystal deposition disease</td>
<td>Hands (second, third MCP), wrists (radiocarpal), TFC, knees (lateral compartment and patella-femoral, menisci)</td>
<td>Symmetric, fibrocartilaginous joints</td>
<td>Normal or increased density, hypertrophic bone formation, subchondral or periarticular cysts, chondrocalcinosis (hyaline, fibrocartilage), periarticular, peritendinous, periligamentous calcification</td>
</tr>
<tr>
<td>Infection</td>
<td>Any joint, pyogenic, TB</td>
<td>Monoarticular (mostly), any joint</td>
<td>Pyogenic (osteoporosis; 8–10 days), joint space widened (early), joint space loss (rapid development), soft tissue swelling, erosions (both sides of joint), sequestra, periostitis, TB (joint space and mineralization may be preserved), juxta-articular erosions, spine–disc space loss and end plate erosion</td>
</tr>
</tbody>
</table>

DIP = distal interphalangeal; DRUJ = distal radial ulnar joint; IP = interphalangeal; MCP = metacarpophalangeal; MTP = metatarsophalangeal; PIP = proximal interphalangeal; SI = sacroiliac; STT = scaphotrapeziotrapezoid; TB = tuberculosis; TFC = triangular fibrocartilage.
COMPUTED TOMOGRAPHY

Computed tomography provides a two-dimensional map of tissue attenuation obtained from external x-ray source(s) located on a rotating gantry, whose radiation is detected by a series of detectors opposite the source. The current generation of CT scanners uses multiple detectors (16, 32, 64, and so on), allowing rapid image acquisition that can be displayed in a single plane in real time (CT-fluoroscopy) or as extremely thin section contiguous or overlapping acquisitions in the axial plane. The acquired images can be reconstructed in multiple planes with equivalent (isotropic) resolution elements (voxels) or as a three-dimensional rendering. Some scanners use dual energy sources, taking advantage of differences in the attenuation characteristics of various tissues at different energies. This has received greatest attention in the setting of gout, enabling a definitive diagnosis as well as depicting tophaceous deposits in anatomic locations not conducive to radiographs or ultrasound.4

Computed tomography allows the best assessment of trabecular and cortical bone, providing an excellent means to assess fractures and erosions, the presence of new bone formation (e.g., fracture callus), and degenerative or inflammatory arthritis. Soft tissue mineralization can likewise be well characterized, providing important information as to its etiology. Joints that are difficult to assess on radiographs, including the sacroiliac, temporomandibular, wrist, and sternoclavicular joints, are well seen on CT (Fig. 258-2).

Computed tomography generally has poor soft tissue contrast. Nevertheless, it is still very useful in performing a number of guided procedures because of its tomographic nature and rapid image acquisition capability. Improved soft tissue contrast can be obtained with use of iodinated contrast material. A number of soft tissue tumors, inflammatory synovitis, and infectious processes display pathologic enhancement after contrast administration. CT can likewise be used to produce angiographic displays (CTA) when used in combination with contrast, providing exquisite detail of central and peripheral vascular disease, including in patients with suspected vasculitis. These agents are typically administered intravenously following well-defined enhancement characteristics. CTA has become the method of choice in evaluating patients with suspected pulmonary embolism. Likewise, contrast agents may be used to improve intra-articular contrast (CT arthrography), currently the method of choice in assessing internal derangement in the postoperative shoulder, knee, and so on and in patients who are unable to undergo MRI (e.g., those with claustrophobia, aneurysm clips, or cardiac pacemakers). Imaging of cartilage and soft tissue abnormalities usually depends on pathologic imbibition of contrast material, indicative of degeneration or tearing. A limitation of this approach resides in the fact that some abnormalities may remain occult. An example is the inability to detect a bursal-sided rotator cuff tear after shoulder CT arthrography.

The radiation dose from CT can be high, especially when using the newer scanners. This is most significant when one is looking to minimize exposure, such as in children, requiring protocols specifically designed for the pediatric population. Intravenous (IV) use of iodinated contrast agents are contraindicated in patients with impaired renal function or history of allergic reaction. Nonionic agents can diminish the associated risks but still should be used with caution.

ULTRASONOGRAPHY

Ultrasound imaging takes advantage of the near uniform speed of sound and predictable attenuation characteristics of sound propagation in soft tissue. In general, anatomic images derive from specular surfaces whose dimensions exceed the ultrasound wavelength; inherent noise (speckle) within the image derives from small scatterers, smaller than the resolution element of the transducer. Modern ultrasound equipment contains various methods to reduce speckle in the image, resulting in a more anatomic rendition of the soft tissues. Rapid image acquisition and processing enables ultrasonography to be performed in real time (=30 frames per second). Ultrasonography is also conducive to evaluation of blood flow from which estimates of flow velocity can be obtained through the Doppler equation. Doppler information is typically reported by either continuously estimating velocity at a specific depth (spectral Doppler) or through a color encoded two-dimensional map (color or power Doppler).

There is great appeal for using ultrasonography in patients with rheumatic disorders. There is no ionizing radiation, and it is real time, inexpensive, relatively portable, and well tolerated. Historically, however, ultrasonography has played only a limited role in the diagnostic assessment and treatment of patients with suspected musculoskeletal abnormalities, being used to differentiate fluid-filled from solid masses. The detection of a Baker cyst in the knee or the presence of a joint effusion constituted two major applications. There has also been limited application of ultrasonography to perform image-guided aspirations and biopsies. Within the United States, in particular, the development of MRI further limited the musculoskeletal applications of ultrasonography.

With the development of linear high-frequency small parts transducers; new imaging capabilities of ultrasound scanners; and the evolution of a new class of compact, portable (laptop) ultrasound units that have excellent image quality, the role of ultrasonography has dramatically changed in recent years.5,6 These new applications have paralleled the development of new classes of DMARDs for which diagnosis of inflammatory synovitis prior to joint destruction is optimal.

The current generation of ultrasound scanners enables examination of the small joints of the hands and feet, allowing early detection of synovitis (Fig. 258-3). Typically, a 10-MHz or higher frequency linear transducer is used. The displacement of the joint capsule by hypoechoic (dark) soft tissue that displays vascularity on Doppler imaging or is incompressible with direct pressure by the transducer is characteristic, allowing differentiation of synovitis from an effusion. In addition to the detection of synovitis, ultrasonography has been shown to be more sensitive than conventional radiographs in the detection of erosions. Erosions appear as discrete irregular discontinuities...
in the normally smooth hyperechoic (bright), reflecting cortical surfaces, often seen in continuity with adjacent inflammatory soft tissue. There is some variation in the appearance of synovitis among various arthritides. The distribution, presence, or lack of symmetry and other concomitant findings may be necessary to obtain a specific diagnosis.

The level of vascularity on color-flow imaging can reflect active inflammation, correlating with clinical and biochemical parameters. A parametric image encoding either mean Doppler shift (color Doppler) or amplitude (power Doppler) is typically used as a standard Doppler map. Both maps can be used to detect abnormal levels of vascularity. Whereas power Doppler provides an indirect measure of the number of moving scatterers within the region being scanned, color Doppler provides a velocity map, and therefore is more subject to artifact (angle dependence and sampling errors). When combined with color-flow imaging, the activity of the synovitis can be estimated. Ultrasound contrast agents can depict capillary flow, resulting in significantly improved detection sensitivity of synovial inflammation, and are used extensively in Europe. They constitute microbubble agents encased in a lipid or polysaccharide shell that can be instilled as either bolus or constant infusion, with the shell being metabolized in the liver and the gas exhaled in the lungs. These agents have biological half-lives on the order of minutes and are best suited to examining target joints. Contrast agents have received Food and Drug Administration approval for cardiovascular applications and therefore can only be used off label for the assessment of synovitis.

Articular and fibrocartilage have characteristic appearances on ultrasonography. Whereas the former appears as a thin hypoechoic band paralleling the articular surface, fibrocartilage appears hyperechoic. Chondrocalcinosis appears as discrete hyperechoic foci with the substance of the cartilage, in which case its presence is suggestive of calcium pyrophosphate deposition disease. Calcification along the margin of the articular cartilage gives rise to the double-line sign seen in gout.

Tendons and muscles have characteristic appearances on ultrasonography. The presence of tendinosis, tendon tears, muscle edema or inflammation, atrophy, and tears can be diagnosed. Ultrasonography is very sensitive, although not specific, for the detection of small amounts of calcification or ossification. It is an excellent method to assess for calcific peritendinitis and to provide guidance for treatment. Abnormal fluid distention of synovial lined structures can be assessed and treated under ultrasound guidance. Ultrasonography is an excellent modality to provide image guidance for therapeutic aspiration and injection of small and large joints, tendon sheaths, and cysts (e.g., bursae, ganglion, paralabral cysts, hematomas, abscesses, etc.). The real-time capability of ultrasonography is useful to demonstrate the presence of subluxations or painful snapping, to document the distribution of injected material, and to assess adhesions. Ultrasonography is considered the method of choice to detect foreign bodies.

Nerves also have a characteristic appearance on ultrasonography. In cross-section, a nerve often has a “cluster of grapes” appearance, with nerve fascicles appearing hypoechoic and surrounded by hyperechoic endo- and epineural fat. In long axis, nerves display a characteristic tram-track appearance. Ultrasonography has been shown to be useful in the diagnosis and treatment of carpal tunnel syndrome and cubital tunnel syndrome. It is an excellent modality to assess for the presence of posttraumatic or postsurgical and inter-digital neuromas and to provide image guidance for treatment, including therapeutic injections and ablative therapy.

Although ultrasonography is well suited to the evaluation of superficial structures, it is less well suited to deep structures. Frequency and penetration are reciprocally related: the higher the frequency, the better the axonal resolution but poorer the degree of penetration. A 15-MHz linear transducer would work well in the hand but not in the hip. Examination of a hip might require a 5-MHz transducer and curved transducer geometry with reduced image quality. Excessive abdominal fat can further limit acoustic penetration and distort the ultrasound beam, limiting image quality. Diagnostic ultrasonography does not penetrate bone, resulting in limited acoustic access to joint structures. In some instances, soft tissue contrast can be poor. An inexperienced scanner may find ligaments and tendinous insertions difficult to differentiate from adjacent fibrofatty structures.

**MAGNETIC RESONANCE IMAGING**

The natural abundance of hydrogen in biological systems and an inherent property of hydrogen, called spin, form the basis of conventional MRI. When placed in a strong magnetic field, protons tend to align themselves along the direction of the field. Magnetic field strengths are specified as Tesla and can be variable between clinical scanners. The majority of scanners in clinical usage vary between 1.0 and 3 Tesla. Application of a radiofrequency (RF) pulse to the system of protons induces the spins to rotate away from the direction of the field, during which time they precess about the direction of the magnetic field at a characteristic frequency, called the Larmor frequency. When the RF pulse is turned off, the spins relax toward their initial state determined by two tissue-dependent relaxation times, T1 and T2, which vary with field strength. T1 (also known as the spin-lattice relaxation) and T2 (or the transverse relaxation time) along with proton density are the principal determinants of signal intensity. The image can emphasize either the T1 or T2 characteristics of the tissue, impacting tissue contrast. Different tissues have varying appearance often based of levels of fat and water content, reflected by their inherent T1 and T2 relaxation times. Tissue morphology is often characterized by their appearance on T1-weighted or proton density images: tendon, muscle, fat, marrow, cortical bone, articular, and fibrocartilage have characteristic appearances. Many pathologic states, alternatively, are characterized by increased mobile water or effective T2 lengthening. Examples include soft tissue edema, inflammatory infiltrates, and neoplasm (Fig. 258-5). Images that emphasize T2 contrast are therefore helpful to display most pathologic states. Selective maps of T2 have been used to characterize the state of articular cartilage in early degenerative disease. Other cartilage specific properties that relate to water content, glycosaminoglycan (GAG) content, and integrity of collagen architecture can be assessed using T2 and other parametric maps that can be derived from the MR data (Fig. 258-6).

The widely used contrast for MRI studies is a neutral, hydrophilic salt of the gadolinium chelate, gadolinium diethylenetriamine-penta-acetic acid (Gd-DTPA). Gadolinium can be injected intravenously or directly into the joint. IV injection (indirect magnetic resonance arthrography) carries the contrast in the vascular system to areas of hyperemia and inflammation (Fig. 258-7). It can be used for assessment of synovial activity in inflammatory joint diseases. Gadolinium is taken up in inflamed synovium and is able to demonstrate thickened pannus. The slope of the early time-signal intensity curve provides a measure of tissue perfusion and can quantify inflammatory activity. Contrast material excreted into the synovial fluid provides excellent depiction of intra-articular structures and can be used in lieu of arthrographic
FIGURE 258-4. Ultrasound-guided therapy in the first metatarsophalangeal (MTP) joint of a patient with pain and swelling. A, Longitudinal gray scale image of the dorsal recess of the first MTP joint. Fluid and soft tissue distend the joint capsule (arrows). The metatarsal (m) and proximal phalanx (p) are labeled. Note that a thin hypoechoic (dark) band parallels the surface of the metatarsal head, corresponding to the overlying articular cartilage. B, Increased vascularity (red color hues) demonstrated on power Doppler imaging within the dorsal recess reflects the level of disease activity. C, Transverse gray scale ultrasound image shows a needle (N) within the distended dorsal recess from which several drops of synovial fluid were aspirated followed by therapeutic injection. D, Postinjection transverse ultrasonography depicts low level echoes (small echogenic foci within dorsal recess) and microbubbles (arrows) within the distended joint capsule from injected material. Whereas microbubbles aggregate along the nondependent portion of the distended joint capsule, injected material tends to settle to the deep portion of the recess.

FIGURE 258-5. Magnetic resonance image of the right wrist in a female patient with advanced rheumatoid arthritis. A, Proton density coronal image shows loss of normally bright marrow signal within the scaphoid and lunate bones (arrows). The proximal scaphoid is eroded, and the lunate appears deformed and translocated and volarly tilted (not shown), giving rise to its triangular appearance. The distal ulna (u) is poorly visualized because of a large erosion. Intermediate-intensity material (appears dark gray) within the carpus and distal radioulnar joint is difficult to separate from the distal ulna, lunate, and scaphoid. The triquetrum (t), hamate (h), trapezial (tr1) and trapezoid (tr2), capitate (c), and radius (r) are labeled. B, Fluid-sensitive coronal image emphasizing T2 relaxation demonstrates increased signal intensity (bright) within the inflammatory pannus, compatible with increase in mobile water associated with inflammation. Increased signal intensity is evident within the lunate, scaphoid, and distal ulna, including focal areas within the distal row of carpal bones, corresponding to small erosions. Diffuse increased signal within the distal radius likely reflects reactive marrow edema (asterisk).
direct techniques. In glycosaminoglycan (GAG)-depleted cartilage, there can be delayed uptake of contrast into the cartilage, which would normally be inhibited by the negatively charged GAG molecules.

Patients with renal disease who receive IV injection of gadolinium can develop nephrogenic systemic fibrosis (NSF). (Also see the section Nephrogenic Systemic Fibrosis in Chapter 267.) When the kidney cannot sufficiently clear out the gadolinium, it produces fibrosis of many tissues, including the skin, muscle, heart, nerves, and pleura. To date, NSF has been seen only in patients who have been given IV gadolinium with acute or chronic renal insufficiency. The changes in the skin with NSF are usually bilateral and symmetrical, primarily involving the extremities and the trunk. These changes can mimic systemic sclerosis but, unlike that disease, the face is usually spared. If renal function improves, the skin lesions may stabilize or get better, although in some patients, the process progresses, affecting mobility and causing severe pain.

Injection of dilute gadolinium into the joint (direct magnetic resonance arthrography) is helpful for outlining structures to determine whether there is morphologic damage. Injection is usually performed either under fluoroscopic or ultrasound guidance. This technique is particularly effective for visualization of small structures such as the labrum of the hip or shoulder if there is no joint effusion. It is also helpful for demonstrating breakdown of soft tissue structures that normally prevent communication between joint compartments such as the rotator cuff, triangular fibrocartilage of the wrist, and ligaments in the various joints. Newer techniques that enable image acquisition in near real time as well as the development of MR-compatible needles now permit a variety of percutaneous procedures to be performed directly under MR guidance.

**SCINTIGRAPHY**

Scintigraphy by its nature represents physiologic imaging because it derives from labeling physiologically occurring substances with a gamma-emitting radionuclide and uses detectors in the form of gamma cameras arranged in a planar or circumferential configuration to determine the distribution of radionuclide within the tissue. Scintigraphy can provide a global assessment of abnormal tracer uptake or can be performed using a targeted approach (Fig. 258-8). Images often provide high tissue contrast but are of relatively poor spatial resolution. Commonly used agents vary from tagged red blood cells to assess blood flow; agents that reflect bone metabolism (technetium-99m methylene diphosphonate [Tc-MDP]); agents that reflect glucose metabolism (18-fluorine deoxy-glucose [18-FDG]), in the case of PET; and agents that concentrate at sites of inflammation, such as autologous white blood cells labeled with 111In (Indium) and 67Ga-citrate (gallium). Clinical applications include detection of a variety of malignancies, osteomyelitis, vascular graft infection, multifocal infectious disease, inflammatory diseases such as RA, vasculitis, inflammatory bowel disease, sarcoidosis, fever of unknown origin, and infection of joint prostheses.

Traditional nuclear medicine involves use of single gamma photon emissions as a product of nuclear decay. The information can be displayed using planar imaging through a single (or multiple) pinhole camera or displayed tomographically in a manner similar to CT (single-photon emission computed tomography [SPECT]). Bone scintigraphy uses Tc-MDP as the radioactive tracer. The isotope goes to areas of high bone turnover and vascular flow as well as areas of calcium or bone deposition. Three-phase bone scans are obtained at different intervals after injection, reflecting the early vascular phase, the intermediate blood pool phase, and the late phase. Each phase allows for further characterization of the disease process. Abnormal tracer uptake is seen in areas of inflammation, infection, neoplasm, osteonecrosis, and fracture. The scan is most useful to identify the location of lesions within the skeleton but is nonspecific.

Positron emission tomography scans use the appearance of two simultaneously produced 511-KEV gamma rays after annihilation of a positron and electron pair to localize the distribution of radionuclide. The
FIGURE 258-8. Rectilinear bone scan in a patient with back pain. Anterior (A) and posterior (B) delayed images of the axial and appendicular skeleton demonstrate increased tracer uptake in the region of the sacral ala, left ankle, and right midfoot (arrows). Follow-up radiographs confirmed the presence of bilateral sacral ala fractures. Note that the central pooling of tracer in the expected location of the urinary bladder is normal. Bone scans provide a sensitive but nonspecific method to evaluate the appendicular and axial skeletal. Increased uptake in the feet in this patient was attributed to degenerative change.

FIGURE 258-7. Functional magnetic resonance image. A, Parametric image derived from fitting a two-compartment model of soft tissue and synovial enhancement after intravenous administration of contrast material. Three parameters extracted from the time-intensity curves are displayed as parametric images: \( K_{\text{trans}} \) (left) provides a measure of contrast exchange into the extravascular soft tissues; \( V_e \) (center) and \( V_p \) (right) reflect the relative distribution volumes for the extravascular space and plasma, respectively. The arrows depict a region of increased synovial volume and enhancement at the second MCP joint. Increased values of \( K_{\text{trans}} \) and \( V_e \) illustrate increased vascular permeability at the site of inflammation. (Printed with permission of Dr. Luis Beltran.) B, Sagittal T2 map of the knee in which relative T2 relaxation is color encoded, showing regions of higher cartilage T2 values at the femoral condyle and tibial plateau. This reflects alterations in cartilage collagen architecture and water content and possibly early osteoarthritis. (Printed with permission of Dr. Gregory Chang.)
near-simultaneous detection of the photons (coincidence counting) provides an estimate of source tracer concentration. Newer PET scanners are often used in combination with either CT or MRI to achieve improved spatial registration, allow accurate estimates of soft tissue attenuation, provide high-quality anatomic images, and quantify metabolic activity. Combined PET-CT or PET-MRI provides high-resolution images of abnormal metabolic activity and may ultimately provide the most definitive maps of inflammatory activity in patients with rheumatic disease. Early results to date have been promising and are expected to provide sensitive evaluation of the response to DMARDs in patients with inflammatory arthritis.
4. A patient has shoulder pain and gives a history of prior dislocation. There is an equivocal abnormality on the humeral head on radiographic evaluation. Which additional study should be considered?
A. Ultrasonography to rule out a rotator cuff tear
B. Noncontrast computed tomography
C. Additional specialized radiographs to evaluate the scapula
D. Direct MR arthrography
E. Nuclear scintigraphy

Answer: D Although ultrasonography could evaluate the rotator cuff, it does not provide adequate assessment of the capsular labral complex. Cross-sectional imaging with intra-articular contrast would best accomplish this. MR arthrography would be optimal. Direct arthrography has been the method of choice in assessing the glenoid labrum, surrounding ligaments, and capsule. CT arthrography is of value, particularly in the postoperative shoulder, and provides indirect imaging of internal structures by coating them with contrast material. Noncontrast CT would be very limited in assessing the labroligamentous complex, even in the presence of a joint effusion caused by poor soft tissue contrast.

5. A patient with early rheumatoid arthritis is being considered for placement on a DMARD. All of the imaging studies below could assess the level of disease activity and response to therapy except
A. 18FDG scan.
B. radiographs of the hands and wrists.
C. gray-scale ultrasonography with power Doppler.
D. MRI with gadolinium.
E. parametric MR imaging of distribution volumes of contrast in the extravascular space.

Answer: B Radiographic findings in rheumatoid arthritis usually occur when there has already been irreversible joint damage. Ideally, therapy would be instituted on a radiographically negative patient. The remaining examinations can provide sensitive evaluation of disease activity before the development of either bone or cartilage erosion.

2. A patient presents with radial-sided wrist pain that extends proximally into the forearm. What imaging test(s) would assess possible etiologies?
A. Radiographs alone should be adequate
B. MRI
C. Ultrasonography
D. B and C are correct
E. A and B are correct

Answer: D The clinical history suggests DeQuervain’s tenosynovitis. Radiographs would allow assessment of the osseous structures but not the adjacent tendons. Although MRI would provide the most complete examination of the radial-sided structures, ultrasonography is well suited to evaluating the soft tissues, including the first dorsal compartment tendons. One also could perform ultrasound-guided therapy at the time of diagnosis.

3. A patient is suspected of having sacroiliitis. What imaging study would be appropriate to initially evaluate the patient?
A. Radiographs of the SI joints
B. Computed tomography
C. Nuclear scintigraphy (bone scan)
D. MRI
E. Ultrasonography

Answer: A Dedicated radiographic views of the sacroiliac joints should be the first study ordered to assess for possible erosions and may be sufficient to establish the diagnosis. Computed tomography would provide a more sensitive evaluation for subtle erosions as well as the adjacent soft tissues, particularly with the addition of intravenous contrast. Computed tomography provides an ideal method to perform guided therapy or aspiration. A bone scan would provide a sensitive evaluation of the SI joints but findings would be likewise abnormal for trauma, inflammatory, or degenerative etiologies. A bone scan would allow a global assessment of the axial and appendicular skeleton to determine whether other sites are potentially affected. MRI allows the best assessment of the bone, adjacent marrow space, and soft tissues.