Various imaging modalities are used in the diagnosis of rearfoot pathology. This article reviews standard and advanced imaging techniques for a number of common disorders affecting the rearfoot, including plantar fasciitis, Achilles tendon pathology, fractures, arthritides, coalitions, and tumors. Various diagnostic imaging modalities such as routine radiography, radionuclide bone scanning, computed tomography, and magnetic resonance imaging are discussed. (J Am Podiatr Med Assoc 89(6): 292-301, 1999)

**Plantar Fasciitis**

Inflammatory conditions of the plantar fascia most commonly affect the medial calcaneal tubercle and may or may not be associated with radiographic evidence of a calcaneal spur (ie, an enthesophyte). Anatomic studies have suggested that the precise site of a calcaneal spur is not at the origin of the plantar fascia, but rather at the origin of the flexor digitorum brevis on the calcaneus. Although magnetic resonance imaging (MRI) is not typically necessary to assess these conditions, this form of imaging demonstrates increased signal intensity on T2-weighted images and decreased signal intensity on T1-weighted images in the plantar fascia (Fig. 1). On T2-weighted images, increased signal intensity may be seen in the perifascial region; this increased signal represents edema.

**Achilles Tendon Pathology**

Pathologic processes that occur in the Achilles tendon include chronic tendinitis and complete and partial tendon tears. Ossification and calcification occur 2 to 3 cm proximal to the insertion of the tendon, in an area of limited vascularity. On plain film radiographs, the Achilles tendon can easily be seen posterior to Kager’s triangle. Kager’s triangle is a hypodense, fat-filled triangle that is bordered by the Achilles tendon posteriorly, by the deep flexor tendons anteriorly, and by the superior aspect of the calcaneus inferiorly. Kager’s triangle is not visible on radiographs if the Achilles tendon is ruptured. On axial MR images, the normal Achilles tendon appears as a sharply demarcated, black, hypointense structure without high intratendinous signal intensity. Magnetic resonance imaging is an excellent tool for diagnosing and staging tendinitis. Transaxial images of the lower third of the leg will show a focally enlarged tendon with low-to-intermediate signal intensity on T1-weighted sequences and high signal intensity on T2-weighted sequences (Fig. 2).

Type 1 tears are described as a partial disruption of the tendon fibers resulting in bulbous thickening and a fusiform Achilles tendon. At this stage, nodules can be palpated clinically. Vertical splits in the tendon cause tendon hypertrophy, which appears as increased signal intensity on T2-weighted images in a speckled or linear pattern (Fig. 3A). Type 2 tears are also partial in nature. The tendon is attenuated and the tear can often be palpated clinically. Type 3 tears are a complete disruption of the tendon. The tendon ends often retract and appear as “mop ends.” With type 3 tendon tears, the sagittal image demonstrates the proximal portion of the tendon and there is a dramatic increase in signal intensity at the level of the rupture, indicating, in acute tears, hematoma and loss of tendon continuity. Distally, there is a normal low signal demonstrating the tendon inserting on the...
calcaneus (Fig. 3B). If MRI is delayed and a hematoma is replaced by scar tissue, a moderate signal intensity (gray in appearance) will be interspersed in the gap. This makes the diagnosis of the extent of the rupture more challenging.

Tarsal Coalitions

Calcaneonavicular and talocalcaneal coalitions account for about 90% of all tarsal coalitions. Developmental calcaneonavicular coalitions are slightly more common than talocalcaneal coalitions. These unions are either osseous, fibrous, or cartilaginous. Coalitions may result from infection, trauma, articular disorders, or surgery. The cause of developmental tarsal coalitions is a lack of differentiation or segmentation of primitive mesenchyma, which has been demonstrated in fetal dissections. Calcaneonavicular coalitions are most easily seen on medial oblique plain film radiographs, on which the calcaneus appears to extend into the navicular (“anteater nose” sign). This can also be seen on MR

Figure 1. Sagittal short tau inversion recovery (TR/TE, 5830/30, inversion time 150 msec) MR image shows thickening at the origin of the plantar fascia with increased intrafascial intensity.

Figure 2. Transverse proton density (TR/TE, 2500/20), spin-echo MR image comparing a normal Achilles tendon (right) with the contralateral Achilles tendon with tendinitis. The left tendon shows thickening of the tendon substance and increased signal intensity.

Figure 3. A, Partial rupture of the Achilles tendon is shown on a sagittal T1-weighted (TR/TE, 600/25) spin-echo MR image. Note the fusiform thickening in a linearly speckled pattern in the tendon. B, Complete rupture of the Achilles tendon. Sagittal T1-weighted (TR/TE, 5000/104) spin-echo MR image reveals loss of tendon continuity (arrows).
images (Fig. 4). Although calcaneonavicular coalitions are easily seen radiographically, the identification of talocalcaneal coalition bars is more challenging. Narrowing and sclerosis of the subtalar joint at the sustentaculum tali indicates middle-facet arthrodesis. A “halo” sign refers to a round rim of sclerosis encircling a portion of the talus, commonly seen in talocalcaneal coalitions. Ball-and-socket ankle joint and talar beaking are also common radiographic features. Calcaneal axial and Harris-Beath views show that the middle facets are jointed, and the posterior facet may look irregular and without definition. Coronal computed tomographic (CT) scans show middle-facet fusion, and partial fusion may also be seen in some cases. Again, this can also be seen on MR images (Fig. 5).

**Calcaneal Fractures**

**Intra-articular Fractures**

Calcaneal fractures account for 60% of all tarsal fractures and 2% of all skeletal fractures. Intra-articular calcaneal fractures characteristically cause a reduction in Böhler’s angle (Fig. 6A), except in cases of nondisplaced vertical fractures of the calcaneal tuberosity. A decrease in Böhler’s angle or an increase in the critical angle of Gissane occurs if the sustentaculum tali is completely separated from the posterior facet and the posterior subtalar joint is depressed. In some cases, only the lateral half of the posterior facet is fractured; in these cases, a “double density” of bone-on-bone is seen on the lateral view and Böhler’s angle is within normal limits. When this happens, the articular surface is seen within the body of the calcaneus and is rotated 90° to the remainder of the subtalar joint.

The most accurate evaluation of calcaneal fractures is accomplished with CT scanning (Fig. 6B). Both feet should be scanned to allow for comparison of the injured and noninjured sides. Contiguous 3-mm-thick slices should be scanned from the level of the navicular to the posterior calcaneus in the semicoronal plane, and from the level of the plantar surface of the foot to the level of the talus in the axial (transverse) plane. Using both plain film radiographs and CT scans allows evaluation of the degree of calcaneal shortening, lateral wall expansion (Fig. 6B), location of the primary fracture line, extent of comminution of the posterior facet, calcaneocuboid displacement, and the position and size of the sustentaculum fragment.

**Calcaneal Stress Fractures**

There are two types of stress fractures: insufficiency fractures and fatigue fractures. The former occurs when a normal stress is applied to abnormal bone, and the latter develops when normal bone undergoes repetitive stress. The calcaneus, navicular, metatarsals,
and distal aspect of the fibula and tibia are the most common sites of lower-extremity stress fractures. The sensitivity of early plain film radiographs for detecting stress fractures can be as low as 15%, and subsequent radiographs may demonstrate findings in only 50% of cases. Faint blurring of the trabeculae, and sclerosis, in the form of a band, may be the only early indicators of stress fractures in cancellous bone. Stress fractures of the calcaneus typically are associated with a vertically oriented sclerotic line parallel to the posterior cortex and perpendicular to the line of trabeculae (Fig. 7A).

A radionuclide bone scan can be useful when clinical suspicion for stress fracture is high and initial radiographs are negative. Magnetic resonance imaging is extremely sensitive to the detection of stress injuries and is more specific than radionuclide bone scanning because of its exquisite spatial resolution. On T1-weighted, spin-echo images, a stress fracture appears as a line of low signal intensity surrounded by an area of slightly higher, but still low, signal intensity. On T2-weighted images, the central fracture line will appear as a region of low signal intensity and the surrounding broader area of edema will appear as high signal intensity (Fig. 7B).

**Arthritides**

**Rheumatoid Arthritis**

Radiographic examination is important in diagnosing, staging, and determining the progression of arthritic disease. Throughout the disease process, periarticular soft-tissue swelling, osteopenia, marginal and central bone erosion, joint space narrowing, deformities, and subluxations are seen radiographically. Retrocalcaneal bursitis and Achilles tendinitis are not uncommon findings associated with rheumatoid arthritis. Patients with retrocalcaneal bursitis will show evidence of erosion at the posterosuperior margin of the calcaneus. Well-defined enthesophytes at the origin of the Achilles tendon and plantar fascia are common (Fig. 8). If Achilles tendinitis is severe, there may be an indistinct and enlarged tendinous outline on the lateral radiograph. In the rearfoot, pes planus and retrocalcaneal bursitis are important manifestations of the disease. Lakits et al found that 50% of patients with confirmed rheumatoid arthritis had retrocalcaneal bursitis and erosion of the posterosuperior portion of the calcaneus.

**Seronegative Spondyloarthopathies**

Of the seronegative arthritides, Reiter’s syndrome most commonly affects the rearfoot, whereas psoriatic arthritis has a predilection for both the forefoot and the rearfoot. Ankylosing spondylitis occurs in the calcaneus in 10% to 20% of cases in the early stages and in up to 50% of cases in the later stages of disease. A common radiographic finding in cases of seronegative arthritides is obliteration of the retrocalcaneal recess secondary to synovial fluid accumulation in the retrocalcaneal bursa. Periostitis at the plantar and posterior attachments of the calcaneus is commonly seen.
seen; however, well-defined enthesophytes at the insertion of the Achilles tendon have also been observed. Feather-like osseous excrescences, known as “whiskering” and occurring adjacent to marginal erosions, are a characteristic feature of seronegative spondyloarthropathies (Fig. 9A).

The initial attack of arthritis in patients with Reiter’s syndrome commonly affects the knee, ankle, metatarsophalangeal joint, heel, shoulder, wrist, hip, and lumbar spine, in decreasing order of frequency. The calcaneus is affected in nearly two-thirds of patients with Reiter’s syndrome. Fuzzy, inferior calcaneal spurs at the origin of the plantar fascia are common (Fig. 9B). The calcaneus is most commonly affected at its posterosuperior and plantar margins as a result of retrocalcaneal bursitis and fasciitis. Obliteration of the retrocalcaneal recess at the posterosuperior margin is often the earliest radiographic sign of the disease. This occurs as a result of retrocalcaneal bursitis and Achilles tendinitis.

The calcaneal involvement in cases of Reiter’s syndrome is very similar to that in rheumatoid arthritis. In advanced stages, a well-defined spur is seen. The resulting radiographic appearance may mimic a spur of biomechanical origin. Osseous changes and well-defined spurs at the Achilles tendon insertion occur but are infrequent.

Bone Tumors

Benign tumors of the foot are rare. Between 2,000 and 3,000 malignant bone tumors occur in the United States annually. Typically, primary malignant tumors of bone are larger than benign tumors and their rate of growth is faster. Routine radiographs are generally used to evaluate bone tumors initially. Because radiographic changes occur after 30% to 50% of the bone has been destroyed, bone scanning is sensitive in detecting osseous lesions that are not visible on radiographs.

Osteogenic Sarcoma

Osteosarcoma is the most common primary malignant tumor of bone and is found most commonly in
male teenagers. Eighty percent of cases involve the metaphysis of long bones; approximately 2% of cases are pedal. The radiographic changes documenting osteosarcoma are variable and show both lytic and sclerotic areas (Fig. 10). A poorly defined metaphyseal lesion is a typical radiographic finding. Other radiographic signs may include a Codman’s triangle, a “sunburst” periosteal reaction, or a pathologic fracture.

Bone scanning demonstrates increased focal uptake at the site of a tumor. The main use of MRI with malignant skeletal neoplasms is to stage the disease process prior to treatment. Magnetic resonance imaging is superior to CT scanning in defining both the intraosseous and extraosseous extent of the lesion. A low signal intensity on T1-weighted, spin-echo images and high signal intensity within the tumor itself on T2-weighted, spin-echo images are typical. Although MRI is a sensitive modality, subtalar cortical changes are often better visualized with CT.

Intraosseous Lipoma

Intraosseous lipoma may or may not be a true primary benign neoplasm of bone. This lesion has an incidence of 1 in 1,000 and occurs most commonly in the metaphysis of long tubular bones; the calcaneus is involved in 15% of cases. On standard radiographs, intraosseous lipomas are well defined with marginal sclerosis, a radiolucent center, and often a central nidus of calcification. Intraosseous lipomas and simple bone cysts occur frequently in the anterior third of the calcaneus, an area known as the neutral triangle (Fig. 11A). On MR images, the lesion demonstrates a signal intensity identical to that of fat, with lower signal intensity in the central nidus (Fig. 11B).

Simple Bone Cyst

Simple bone cysts—also called solitary or unicameral bone cysts—are common lesions that occur most often in males between the ages of 4 and 65 years. The cysts are benign and tend to recur if the lesion is large.
and multiloculated and if the patient is a boy under the age of 10 years. In 52% of the cases, the patient is older than 17 years, and the cyst occurs in either the ilium or the calcaneus. Only 3% of all simple bone cysts arise in the neutral triangle of the calcaneus.

The lesion is typically defined, radiolucent, and centrally located with a thin rim of cortex (Fig. 12A). Simple bone cysts are very similar in their radiographic appearance to aneurysmal bone cysts. However, the main differential diagnostic consideration in the calcaneus is an intraosseous lipoma. Computed tomography and MRI can be used to visualize the full extent of the lesion and, rarely, may show fluid levels within the lesion (Fig. 12B).

**Aneurysmal Bone Cyst**

Aneurysmal bone cysts, first described by Jaffee and Lichtenstein in 1942, are benign lesions of bone and are the only bone lesions named for their radiographic appearance. Typically occurring by the third decade of life, aneurysmal bone cysts are expansile, non-neoplastic lesions with thin walls and blood-filled cavities, and they commonly have a “soap bubble” appearance. Up to 4% of all aneurysmal bone cysts occur in the feet, most commonly in the calcaneus. Casadei and associates reported that 84% of aneurysmal bone cysts in the foot localized to the body of the calcaneus (Fig. 13A). On radiographs, aneurysmal

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**Figure 11.** A, Lateral radiograph reveals two calcified foci of an intraosseous lipoma located in a radiolucent area of the anterior third of the calcaneus. B, Sagittal T1-weighted (TR/TE, 566/15) spin-echo MR image shows the intraosseous lipoma with a signal intensity matching that of subcutaneous fat (arrows). Fluid is also seen in the lesion. Note one area of ossification. (Courtesy of T. Armbuster, MD, Fort Wayne, Indiana.)

**Figure 12.** A, The well-defined lucent area of a simple bone cyst is easily seen on a radiograph. B, Coronal CT image of a simple bone cyst of the calcaneus (arrow).
bone cysts are eccentric in long bones and central in short, tubular bones. The expansile nature of these cysts often makes the cortex thinned, and a loss of trabeculation with numerous fibrous septa can be seen radiographically. The T2-weighted MR images show fluid-fluid levels with low-signal-intensity septa and high-signal-intensity fluid (Fig. 13B). Fluid levels can be detected in giant cell tumors, chondroblastomas, and telangiectatic osteosarcomas, but they are more frequently observed in aneurysmal bone cysts and are clearly seen on CT images (Fig. 13C).

Osteochondroma

Osteochondroma is the most common benign neoplasm of bone. Osteochondromas occur in the physis and consist of two elements, bone and cartilage. The lesion is usually a sessile or pedunculated lesion with a hyaline cartilaginous cap and varying degrees of calcification. Fifty percent of osteochondromas occur in the lower extremity. These lesions are typically located in the physis and grow away from the joint because of the effect of the pull of the tendon. Malignant transformation is most likely in those lesions whose caps remain cartilaginous and whose cap thickness exceeds 1 to 2 cm. A radiographic appearance of continuity between the marrow and the cortex of the outgrowth and the parent bone is important for accurate diagnosis (Fig. 14).

Summary

This article has presented an overview of imaging of the rearfoot. Both standard and advanced imaging
modalities are useful in the diagnosis of a wide range of rearfoot disorders. The reader is encouraged to consult other sources for more detailed descriptions of the techniques presented.

References