Use of MR Imaging in Diagnosing Diabetes-related Pedal Osteomyelitis

Andrea Donovan, MD • Mark E. Schweitzer, MD

The clinical diagnosis of diabetes-related osteomyelitis relies on the identification and characterization of an associated foot ulcer, a method that is often unreliable. Magnetic resonance (MR) imaging is the modality of choice for imaging evaluation of pedal osteomyelitis. Because MR imaging allows the extent of osseous and soft-tissue infection to be mapped preoperatively, its use may limit the extent of resection. At MR imaging, the simplest method to determine whether osteomyelitis is present is to follow the path of an ulcer or sinus tract to the bone and evaluate the signal intensity of the bone marrow. Combined findings of low signal intensity in marrow on T1-weighted images, high signal intensity in marrow on T2-weighted images, and marrow enhancement after the administration of contrast material are indicative of osteomyelitis. Secondary signs of osteomyelitis include periosteal reaction, a subtending skin ulcer, sinus tract, cellulitis, abscess, and a foreign body. The location of a marrow abnormality is a key distinguishing feature of osteomyelitis: Whereas neuroarthropathy most commonly affects the tarsometatarsal and metatarsophalangeal joints, osteomyelitis occurs distal to the tarsometatarsal joint, in the calcaneus and malleoli. In the midfoot, secondary signs of infection help differentiate between neuroarthropathy and a superimposed infection.

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**Introduction**

Diabetes-related foot ulcers and infections are associated with high morbidity and high healthcare costs (1,2). The lifetime risk for development of foot ulcers among diabetic patients is approximately 25% (3), and as many as 50% of patients develop infections (4,5). The diagnosis and management of diabetes-related pedal osteomyelitis are challenging and require a multidisciplinary, team approach (5). Radiologists play an important role in verifying the presence of osteomyelitis and evaluating the extent of infection. Historically, conventional radiography and scintigraphy have been of limited use in diagnosing osteomyelitis. Magnetic resonance (MR) imaging allows preoperative mapping of the extent of infection and thus may help minimize the area of resection (6,7).

Nearly all diabetes-related foot infections result from the contiguous spread of a skin ulcer (8). The risk factors for the development of a foot ulcer include (a) microvascular disease with resultant neuropathy and (b) redistribution of fat away from the sole of the foot. These risk factors act in combination with unrecognized trauma to accelerate superimposed infection and impede healing (9,10).

The clinical diagnosis of diabetes-related osteomyelitis relies on the identification, localization, and characterization of an associated foot ulcer. A probe-to-bone test may be performed, but it often is not reliable (11,12). The reference standard for diagnosing osteomyelitis remains microbiologic analysis after bone biopsy (5). After initial radiography, MR imaging is the modality of choice for the evaluation of pedal osteomyelitis and soft-tissue infection, with sensitivity of 90% and specificity of 83% (13,14).

In this article, we discuss the MR imaging appearance of diabetes-related osteomyelitis, an approach to evaluate the extent of soft-tissue infection, and MR imaging features of neuroarthropathy with and without a superimposed infection.

**MR Imaging Protocol**

The MR imaging examination should be tailored to the patient and the specific clinical concern. We recommend placing markers over shallow ulcers that may not be visible at imaging. However, because ulcers often are covered by bandages, this may not be possible. The field of view includes the area of concern and is usually tailored to the forefoot, midfoot, or hindfoot (15). The use of a large field of view, such as the entire foot or both feet, should be avoided.

Imaging should be performed in at least two planes to best visualize the area of interest. T1-weighted imaging has the highest specificity for the detection of osteomyelitis. In addition, T2-weighted fat-suppressed imaging is recommended to detect changes in bone marrow and adjacent soft tissue; for these sequences, the echo time usually is fixed at 50–65 msec. Because of the curvature of the foot, fat suppression is more uniform with the use of short inversion time inversion recovery (STIR) imaging than with T2-weighted imaging with chemical fat saturation.

**Figure 1.** Sagittal T1-weighted (a), T2-weighted (b), and gadolinium-enhanced T1-weighted fat-suppressed (c) MR images show that the marrow in the tip of the great toe (arrowhead) has low signal intensity on the T1-weighted image; has high signal intensity on the T2-weighted image; and enhances after the administration of contrast material, findings indicative of osteomyelitis.
Figure 2. Osteitis in a patient who underwent transmetatarsal amputation. Sagittal T1-weighted (a) and T2-weighted fat-suppressed (b) MR images obtained at the level of the great toe show a large soft-tissue defect at the stump. Marrow (arrow) is hyperintense on the T2-weighted image, but no corresponding marrow abnormality is seen on the T1-weighted image. This combination of findings is indicative of reactive marrow edema due to osteitis, not osteomyelitis.

However, because of the increased availability of newer magnets and faster gradients, the use of STIR sequences is becoming less common. For toe ulcers, a short-axis view (aligned perpendicular to the toes) provides excellent visualization of the ulcer and its relationship to underlying osseous structures. Midfoot neuropathic disease and hindfoot calcaneal ulcers are best depicted in the sagittal plane. Medial or lateral ulceration in the hindfoot is best depicted in the axial and coronal planes.

Contrast material–enhanced imaging is useful for the evaluation of soft-tissue complications such as sinus tracts, abscesses, and necrosis, and it provides invaluable information for preoperative planning of limited limb resection. It should be performed with a turbo gradient-echo sequence because of the speed and uniformity of fat suppression that sequence provides. After turbo gradient-echo imaging, we usually obtain at least four additional views: one image in each plane and an additional delayed image in the key plane. Obtaining this delayed image is particularly important because the slow blood flow in diabetic patients may lead to false-negative findings due to a lack of enhancement. Caution should be exercised in patients with renal failure because of the potential for gadolinium-induced nephrogenic systemic fibrosis (16–18). The American College of Radiology recommends that gadolinium-based contrast material not be administered to patients with a severely reduced glomerular filtration rate (<30 mL/min/1.73 m²) (19).

**MR Imaging**

**Findings of Osteomyelitis**

The simplest method to determine whether osteomyelitis is present is to track the ulcer or sinus tract down to bone at MR imaging and evaluate the signal intensity of marrow: Noticeably low signal intensity on T1-weighted images is a primary sign of osteomyelitis (20) (Fig 1). There are several secondary signs, such as periosteal reaction, that may help confirm the diagnosis. At MR imaging, the calcified periosteum appears as a low-signal-intensity line that is separated from underlying bone by a high-signal-intensity layer of fluid or pus. Periosteal reaction usually is seen in the metatarsal bones and malleoli. Osteomyelitis also is likely if soft-tissue findings such as a subtending skin ulcer, sinus tract, cellulitis, abscess, or, less commonly, a foreign body are present (21,22).

In cases in which the bone marrow is hyperintense on T2-weighted images but is not hypointense on corresponding T1-weighted images, osteitis is more likely than osteomyelitis, even when bone marrow enhancement is present (Fig 2). Osteitis is a reactive change resulting from either an adjacent soft-tissue infection or a cortical (nonmedullary) infection. Edema patterns may be peculiar. In the metatarsal bones, edema tends to spread distally, some distance from the tarsometatarsal...
joint, a pattern that is more common in Charcot arthropathy than in infection.

Postoperative imaging of the foot in diabetic patients is becoming increasingly common. The criteria for diagnosing osteomyelitis at the site of amputation are the same as those for patients who have not undergone amputation (Fig 3) (15). However, in patients who undergo débridement instead of amputation, associated postoperative edema may occur at the surgical site and should not be mistaken for osteomyelitis. Surprisingly, most patients who undergo amputation have little postoperative bone marrow edema.

Secondary Signs of Osteomyelitis

Skin Callus
Skin callus formation is perhaps the earliest sign of diabetic pedal osteomyelitis and may only be preceded by redistribution of fat away from the plantar aspect of the foot. Altered biomechanics and friction from ill-fitting footwear lead to callus formation due to pressure at weight-bearing sites. At the forefoot, callus formation occurs beneath the first and fifth metatarsal heads and at the tip of the great toe. At the midfoot, callus formation occurs beneath the cuboid bone in patients with neuropathic disease and rocker-bottom deformity (23). At the hindfoot, most calluses occur at the heel (22).

At MR imaging, a skin callus appears as a focal infiltration or mass within subcutaneous fat, with low signal intensity on T1-weighted images and low to intermediate signal intensity on T2-weighted images (Fig 4). After the administration of contrast material, callus enhancement may be mistaken for a soft-tissue infection; a typical location and lack of adjacent soft-tissue change should help distinguish callus formation from infection.

Chronic friction also may result in adventitial bursa formation at the same pressure points as those of callus formation. Adventitial bursitis appears as a thin, flattened fluid collection over an osseous prominence (Fig 5). On contrast-enhanced images, preservation of adjacent subcutaneous fat helps differentiate adventitial bursitis from an abscess.

Ulcer
In general, the locations of ulcers are similar to those of calluses because ulcers are a result of callus breakdown. However, in the neuropathic foot, midfoot ulcers commonly occur without preceding callus formation. In addition, dorsal toe ulcers occur with flexion deformities of the toes and without initial callus formation.
Several factors contribute to the breakdown of a callus, including dry skin related to autonomic dysfunction, altered weight bearing resulting from motor neuropathy, and persistent friction at pressure points (24). Ulcers result from cumulative mechanical trauma, and their distribution varies according to the patient’s gait, type of footwear, and level of activity. Forefoot and midfoot ulcers typically are superficial and occur in ambulatory patients. By contrast, in nonambulatory patients, ulcers occur at the calcaneus and lateral malleolus and are broad and deep because of chronic pressure on the externally rotated foot (22).

MR imaging may help differentiate an ulcer from a callus. Ulcers typically appear as focal skin interruptions with elevated margins and associated soft-tissue defects (Fig 6). Unlike calluses, ulcers appear hyperintense with intense
appear round if viewed in cross section and may be mistaken for an abscess. Familiarity with typical ulcer locations and sinus tract features is critical in the evaluation of osteomyelitis. On occasion, deep fluid collections may attempt to decompress externally. It is helpful to imagine such “pointed” fluid collections as ulcers in reverse.

**Sinus Tract**

If a sinus tract is present, an ulcer may extend to the level of the adjacent osseous prominence. On contrast-enhanced images, sinus tracts display a “tram-track” pattern of enhancement (Fig 7) (20,21). Sinus tracts should be evaluated in all imaging planes. A meandering sinus tract may appear as a soft-tissue defect with peripheral enhancement on T2-weighted images, a finding indicative of granulation tissue at the base of the ulcer. Care must be taken with granulated ulcers that do not have visible soft-tissue defects because the likelihood of a deep infection is similar to that with an open ulcer.

**Cellulitis**

As an ulcer extends into the soft tissue, it may progress to a more advanced infection such as cellulitis, a phlegmon, or an abscess. In the presence of cellulitis, the skin is warm and appears red and swollen, an appearance that also may be seen in the acute, or early, phase of neuropathic disease (10). In addition, diffuse, noninfectious

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**Figure 7.** Calcaneal ulcers and sinus tract associated with osteomyelitis. (a-c) Coronal T1-weighted (a), T2-weighted fat-suppressed (b), and gadolinium-enhanced T1-weighted fat-suppressed (c) MR images show two calcaneal ulcers: One is at the plantar surface, recognizable by the presence of skin discontinuity, and the other is more medial with an elevated margin (black arrowhead). Enhancing phlegmonous soft tissue also is seen deep to the plantar ulcer (white arrowheads). Arrow = calcaneus. (d) Axial gadolinium-enhanced T1-weighted fat-suppressed MR image shows a sinus tract with rimlike enhancement that extends to the calcaneus (black arrows). The sinus tract was visible only after the administration of contrast material. The medial ulcer (arrowhead) also is more apparent than in a–c. Marrow edema in the calcaneus is indicative of osteomyelitis (white arrow).
soft-tissue swelling is common in the foot and ankle in patients with diabetes. Osteomyelitis is unlikely in patients with isolated soft-tissue swelling and no skin ulcers. The role of imaging in evaluating soft-tissue swelling is to determine whether neuropathic disease is present and assess the extent of soft-tissue infection (25–27). Soft-tissue swelling is more important as a secondary sign of infection than when it occurs in isolation.

At MR imaging, skin thickening and edema are seen in both soft-tissue edema and cellulitis, and reticulation of fat is more prominent, with intermediate signal intensity on T1-weighted images and high signal intensity on T2-weighted images (28). Contrast enhancement is a distinguishing feature of cellulitis and is not seen in diabetes-related edema or neuropathic disease (25). However, the extent of enhancement depends to some degree on the delay in image acquisition.

Fluid in soft tissue tends to localize along fascial planes and may mimic a fluid collection. It is important to understand that the dependent location of fluid during the MR imaging examination, when the patient is supine, is not necessarily the same as that during the activities of daily living.

The presence of soft-tissue mass effect or a phlegmon may indicate osteomyelitis. Phlegmonous soft tissue replaces subcutaneous fat and is ill defined, with low signal intensity on T1-weighted images and intermediate to high (though not as high as that of fluid) signal intensity on T2-weighted images (Fig 7). On contrast-enhanced images, a phlegmon usually displays vague enhancement instead of the discrete rimlike enhancement that is characteristic of an abscess.

**Abscess**

Abscesses are uncommon in patients with diabetes; however, when they occur they have signal intensity of fluid with peripheral rimlike enhancement on contrast-enhanced MR images (Fig 8).

Most abscesses are small and may be obscured
by adjacent soft-tissue edema if contrast material is not administered (25). Thus, the routine use of contrast material is recommended because it aids in abscess identification and enables assessment of the extent of soft-tissue infection. In a small foot, the abscess may be so close to the skin that the rim of enhancement is not visible, an appearance that can be misleading. The presence of an abscess precludes nonsurgical management, which is possible only in cases of uncomplicated osteomyelitis.

Foreign Body

Foreign bodies may be seen in diabetic patients with sensory neuropathy or after they undergo surgery. A careful search for a foreign body should be performed in patients with a soft-tissue infection and no adjacent ulcer. A foreign body usually has low signal intensity on both T1- and T2-weighted MR images, and blooming artifact may be seen on gradient-echo images (15). A surrounding rim of enhancement is indicative of a granulomatous reaction and should not be mistaken for an abscess (26). The signal intensity on

**Figure 9.** Foreign body granuloma. Short-axis T2-weighted (a) and gadolinium-enhanced T1-weighted (b) MR images obtained with fat suppression show a planar fluid collection with peripheral rimlike enhancement (black arrows) and round areas (white arrows) that are hypointense on the T2-weighted image with extensive surrounding enhancement medial and lateral to the fluid collection, a finding indicative of foreign bodies and adjacent reactive hyperemia. A small focus of blooming artifact also is seen (arrowhead in b).

**Figure 10.** Gas gangrene in a patient with crepitation of the foot and signs of infection. (a) T2-weighted fat-suppressed MR image shows low-signal-intensity foci of blooming artifact (arrows) along the flexor tendon sheath, findings indicative of extensive soft-tissue gas. The sheath is distended by fluid. (b) Long-axis T1-weighted MR image shows an ulcer over the great toe (arrowhead) and the distended flexor tendon sheath (arrows). It is unlikely that gas entered from the ulcer. Findings are suggestive of wet gangrene and infection.
T2-weighted images helps distinguish a foreign body from an abscess: An abscess has the signal intensity of fluid, and a foreign body does not (Fig 9). Foreign bodies usually are located under the metatarsal heads.

Gangrene
End-organ ischemia may lead to gangrene in diabetic patients. In most cases, gangrene is diagnosed clinically, and advanced imaging is unnecessary. Noninfected devitalized tissue is referred to as dry gangrene, whereas the term wet gangrene refers to gangrenous tissue with superimposed infection.

Contrast-enhanced MR imaging may be performed to delineate areas of soft-tissue devascularization. On contrast-enhanced MR images, gangrene is depicted as a nonenhancing area of devitalized tissue that is sharply demarcated from surrounding viable tissue. The periphery of the devitalized tissue may demonstrate reactive hyperemia and enhancement (29). The delay in image acquisition after the injection of contrast material should be carefully timed because it substantially affects image interpretation.

Wet gangrene may demonstrate soft-tissue gas at MR imaging. Air can be difficult to visualize at MR imaging because it spreads along the fascial planes, in which tissue contrast is similar to that of air. Gradient-echo sequences are most sensitive for depicting small foci of blooming artifact, findings indicative of air (Fig 10). Care should be taken to differentiate soft-tissue gas related to gangrene from that related to a skin ulcer that serves as a portal for air to enter soft tissues. Gangrene usually is associated with nonenhancing devitalized tissue and demonstrates more extensive soft-tissue gas than that seen surrounding an ulcer (30).

Septic Arthritis
When septic arthritis occurs in the feet of diabetic patients, it most often is secondary to an adjacent soft-tissue infection (22,31). Although there is a slightly increased incidence of hematogenous septic arthritis among patients with diabetes than in the general population, most cases of diabetes-related septic arthritis are transmitted by inoculation.

Septic arthritis most often involves joints that are adjacent to a callus or ulcer. It is common in the interphalangeal joints when dorsal ulceration is present, the metatarsophalangeal joints when lateral ulceration is present, the first and fifth metatarsophalangeal joints, the midfoot when neuropathy is present, and the ankle and subtalar joints when malleolar or calcaneal ulceration is present. Septic arthritis in the midfoot is the most challenging to diagnose because its appearance can be nearly identical to that of midfoot neuroarthropathy.

At MR imaging, complex joint effusion is seen in the involved joint, with intense, usually thick, synovial enhancement (Fig 11). Synovial outpouchings also are common. There may be direct communication of joint fluid with an adjacent...
sinus tract. In these cases, joint effusion may appear decompressed and reduced at follow-up imaging despite ongoing septic arthritis. Periarticular edema may be seen in adjacent soft tissue, and a thin rim of reactive edema may be seen in subchondral marrow with marginal erosion (32). It is important to distinguish reactive bone marrow changes that are secondary to septic arthritis from those associated with superimposed osteomyelitis. Proximal extension of subchondral edema beyond the subchondral bone and diffuse, fairly overt hypointense signal in adjacent marrow on T1-weighted images likely are indicative of osteomyelitis (33).

**Tenosynovitis**

Septic tenosynovitis may result from the spread of infection from an adjacent pressure ulcer. Tendons are situated over osseous prominences and are separated from the skin by a thin layer of subcutaneous fat. Although theoretically tendons are a path for proximal spread of infection, this path is uncommon clinically. Septic tenosynovitis most commonly occurs in the peroneal tendons from a lateral malleolus ulcer and in the Achilles tendon from a calcaneal ulcer. In the forefoot, nearly two-thirds of all tendon infections involve the flexor tendons and are a result of plantar forefoot ulceration. Rarely, progression of a soft-tissue infection may lead to tendon destruction (8).

At MR imaging, an area of peritendinous enhancement coursing through an area of cellulitis and adjacent to an infected ulcer may indicate a tendon infection (Fig 12) (34). Tendon thickening, hyperintensity on T2-weighted images, and enhancement may indicate infection, but these findings are nonspecific; they also may be seen with other inflammatory, neoplastic, or posttraumatic conditions (35). A positive correlation has been reported between tendon infection and osteomyelitis, presumably because both are related to progression of an advanced infection (35).

It should be noted that the presence of fluid in a tendon sheath is normal and may be seen in mechanical and traumatic disorders. In addition, fluid in the ankle joint often decompresses into the flexor hallucis longus tendon sheath. However, fluid in the anterior tendons is almost never normal or due to a mechanical disorder.

**Differentiation of Osteomyelitis from Neuroarthropathy**

Neuroarthropathy may mimic osteomyelitis both clinically and at imaging. We are most familiar with the radiographic appearance of the chronic stage of neuroarthropathy. It is in the early stages, when there are no radiographic findings, that neuroarthropathy can mimic osteomyelitis on bone scans, clinically, and on MR images.

In the early stages of neuroarthropathy, soft-tissue edema, fluid collections, effusions, and bone marrow abnormalities are seen at MR imaging (36,37). Periarticular soft-tissue and bone marrow enhancement are seen at contrast-enhanced MR imaging (38). Bone resorption is seen in the subacute, or coalescent, stage of neuroarthropathy. In the chronic, or consolidation, stage, there is no substantial soft-tissue edema or osseous resorption, yet the foot is deformed (39,40). Deformity, osseous fragmentation, and joint effusion may be seen at MR imaging, with little marrow edema (Fig 13). This advanced, quiescent stage of neuroarthropathy does not mimic osteomyelitis clinically, and any signs or symptoms of infection are strongly suggestive of osteomyelitis.

Osteomyelitis develops, almost exclusively, by the contiguous spread of infection from skin ulceration at predictable sites, whereas neuroarthropathy is primarily articular. These features may help distinguish neuroarthropathy from osteomyelitis at MR imaging (22). The presence of a bone marrow abnormality with no adjacent ulceration, as well as periarticular disease, is indicative of neuroarthropathy. The most useful distinguishing feature of osteomyelitis is its loca-
Figure 13. Neuroarthropathy. Sagittal T1-weighted (a) and T2-weighted fat-suppressed (b) MR images show a rocker-bottom deformity and midfoot fragmentation. A joint effusion extends from the tarsometatarsal joint to the plantar soft tissues (black arrows), but subcutaneous fat superficial to the joint effusion (bracket) is maintained. Subchondral marrow edema at the calcaneocuboid joint (white arrow) is a result of neuroarthropathy. These findings are characteristic of synovial outpouching and effusion associated with neuroarthropathy and are similar to those of abscess; the absence of a skin ulcer and the lack of a typical location should help differentiate the two.

Figure 14. Osteomyelitis in a patient with neuroarthropathy. Sagittal T1-weighted (a) and T2-weighted fat-suppressed (b) MR images show a rocker-bottom deformity and a large plantar ulcer that extends to the cuboid bone (arrowheads). Marrow edema (black arrows) also is seen, with low signal intensity on the T1-weighted image and high signal intensity on the T2-weighted image, findings indicative of osteomyelitis. Note the midfoot fragmentation and disorganization (white arrow).

Neuroarthropathy most commonly affects the tarsometatarsal and metatarsophalangeal joints, whereas osteomyelitis occurs distal to the tarsometatarsal joint in the calcaneus and malleoli. The midfoot presents the greatest diagnostic difficulty, but secondary signs of infection such as direct spread from an ulcer over a rocker-bottom deformity and the presence of a sinus tract are indicative of osteomyelitis.

Osteomyelitis in Neuroarthropathy
The presence of neuroarthropathy may limit the specificity of MR imaging for the detection of a superimposed infection. However, patients with neuroarthropathy and an ulcer that extends to the bone are more likely to also have osteomyelitis than are patients with no preexisting neuroarthropathy (Fig 14). In these patients, MR imaging is performed to evaluate the extent of disease rather than make a diagnosis (35).

Contrast-enhanced MR imaging is recommended for assessing the extent of soft-tissue disease (13). Several imaging features may be useful for distinguishing neuroarthropathy with
superimposed osteomyelitis from that without osteomyelitis (41). The soft-tissue features commonly associated with a superimposed joint infection include the absence of adjacent subcutaneous fat signal intensity and the presence of adjacent soft-tissue fluid collections that are larger than those typically seen in uninfected neuropathic joints. Sinus tracts also are common in patients with a superimposed infection and often lead to a paradoxical decrease in the size of fluid collections at follow-up imaging. Soft-tissue abnormalities that are not helpful in differentiating neuropathic disease with a superimposed infection from that without infection include skin ulceration, soft-tissue enhancement, and rimlike enhancement of fluid collections that are adjacent to joints. The presence of subchondral cysts or intraarticular bodies may help exclude superimposed osteomyelitis in patients with neuroarthropathy. The disappearance of either of these two findings at follow-up imaging is indicative of a superimposed osteomyelitis (42).

Bone marrow changes associated with superimposed osteomyelitis commonly are diffuse. In con-
Bone marrow involvement in neuroarthropathy is limited to periarticular locations because the pathologic process is joint centered. We have found that the “ghost sign” helps distinguish acute neuropathy from neuroarthropathy with a superimposed infection. The ghost sign indicates that a superimposed infection is present, and the absence of the ghost sign excludes the presence of a superimposed infection. Bones that “disappear” on T1-weighted MR images and “reappear” (become morphologically more distinct) on T2-weighted images or after the administration of contrast material (the ghost sign) likely have superimposed osteomyelitis (Fig 15). In the uninfected neuroarthropathic foot, the ghost sign is absent because the bones are truly “dissolved” and destroyed.

**Summary**

Diabetic pedal osteomyelitis arises from the contiguous spread of an ulcer to soft tissue. MR imaging is the modality of choice for the assessment of osteomyelitis and associated soft-tissue complications. It is also used to guide patient management. On T1-weighted images, low signal intensity in marrow adjacent to an ulcer or a sinus tract is a primary sign of osteomyelitis. The location of the marrow abnormality is a key distinguishing feature of osteomyelitis. In the midfoot, secondary signs of infection may help differentiate neuroarthropathy from a superimposed infection.

**References**


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