Looking Within: Foot and Ankle Imaging

by Steven D. Needell, M.D.

Arriving at an accurate diagnosis of foot and ankle disorders requires expertise in clinical evaluation and knowledge of the anatomy and pathology of the lower extremity. In addition to routine history and physical, it is often useful to obtain an imaging study to confirm a suspected diagnosis, as well as to exclude the possibility of other causes which may have a similar presentation. The most common screening modality is routine radiography (x-rays), but not infrequently other imaging studies are required to obtain an accurate diagnosis and to allow appropriate treatment planning. Discussed below are imaging modalities used to evaluate foot and ankle disorders. A case presentation of a diabetic patient with osteomyelitis (bone infection) of the toe provides representative images.

X-rays

Conventional x-rays are the most common imaging exam for evaluating foot and ankle disorders. X-rays machines are readily available and exams are quick and relatively simple to perform. The denser an object is, the whiter it appears on an x-ray. Since bones are very dense, they are easily seen, but soft tissue abnormalities are not easily detected. X-rays excel at identifying fractures, arthritis, and bone tumors, but are not particularly useful in evaluating tendon and ligament injuries, masses, and infection.

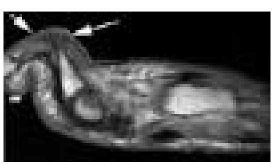
X-ray of the toes in a diabetic patient with a deep skin wound, performed to evaluate for spread of infection to underlying bone. Bone destruction from infection can take up to two weeks to be detected by x-rays, and since bones overlap one other, it is often difficult to see each bone in its entirety. On these x-rays, the bones are well seen and show no abnormality to suggest infection (osteomyelitis).

Nuclear Medicine

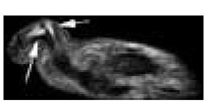
A tiny amount of radioactive material is injected through a vein and a special camera hooked up to a sensitive radiation detector (similar to a sophisticated Geiger counter) is used to acquire images of the body. For foot and ankle imaging, the most common nuclear medicine study ordered is a "bone scan". The injected radiotracer is bound to a molecule that seeks out areas of high bone turnover. Increased radioactivity is detected at fractures, bone infections, and active arthritis. Bone scans are very sensitive tests and are able to detect bone abnormalities weeks before they are visible on conventional x-rays. A "triple-phase bone scan" obtains images at three different times during a four-hour period to allow differentiation between soft tissue infection (cellulitis) and bone infection (osteomyelitis). Since some patients who are suspected of having an infection may also have fracture or arthritis, this test may pose a diagnostic dilemma. It is therefore essential that x-rays are available when the test is being interpreted to assist in making an accurate diagnosis. Another nuclear medicine test which is used to evaluate for infection is called a "white blood cell" (WBC or Ceretec) scan. This test reveals abnormalities related to the presence of large numbers of white blood cells, and is therefore fairly specific in diagnosing infection. Nuclear medicine tests are commonly used to diagnose bone infection, but MRI is becoming increasingly popular because of its ability to provide superior spatial resolution and anatomic depiction.

Nuclear Medicine Bone Scan performed to evaluate for bone infection (same patient as above). Both feet are imaged in this example. Note increased activity (red arrow) at the second toe indicating an area of abnormal bone. While this test supports the diagnosis of infection, it is difficult to precisely describe the extent of involvement.

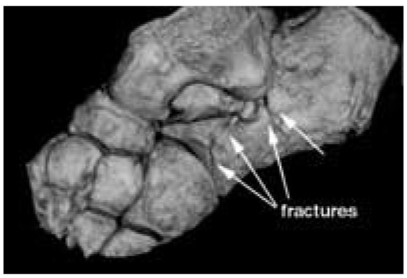
Magnetic Resonance Imaging (MRI)
MRI has become the most robust imaging tool for diagnostic problem solving in the foot and ankle. MRI uses sophisticated computer technology coupled to powerful magnets to detect water and fat molecules, producing detailed, high resolution images of structures that until the last decade, were impossible to image. MRI is the most sensitive test available for establishing whether an abnormality exists in the bone, soft tissues, tendons, or ligaments. MRI is capable of not only detecting an anatomic abnormaility, but excels at characterizing masses and evaluating the extent of soft tissue injury. Its ability to identify the type of tissue in a mass can indicate the likelihood of whether it is benign (not cancer) or aggressive (cancer, infection). Images are obtained in multiple cross sectional planes and different sequences are chosen to best characterize anatomy and abnormalities. Because of the strong magnetic field, patients with pacemakers and other implanted electronic devices are unable to have MRI.



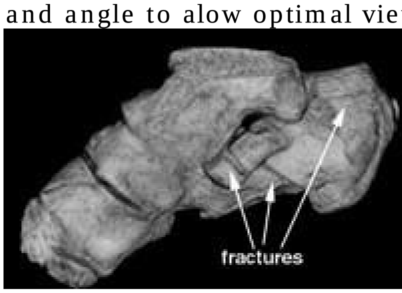
In this T1W MRI image, normal bone marrow in the toe is white and the abnormal marrow (arrows) is dark. Note how each thin section image provides exquisite anatomic detail of bone, fat, muscles, and tendons.MRI protocols typically include several different imaging planes and sequences to allow accurate characterization of abnormalities. This fat-supressed T2W MRI image depicts normal bone marrow as dark and abnormal marrow as white (arrows). The MRI was able to assist the surgeon by demonstrating which part of the toe was infected and which part could be saved.



Computed Tomography (CT Scan)
CT uses x-rays and a sophisticated computer to provide cross-sectional images. Where conventional x-rays superimpose overlying structures on top of one another, CT acquires thin (between 1 and 10mm) cross-sectional slices, allowing detailed evaluation of anatomy. For this reason, CT is the best exam for precisely determining the extent of a complicated fracture. Other uses for CT scans of the foot and ankle are to evaluate for fusion of joints (tarsal coalition), to quantitate the degree and location of arthritis at a joint, and for localization of a foreign body. While soft tissues are also visible, CT is not as capable at characterizing soft tissue abnormalities as MRI. Advanced computer post-processing allows CT images to be reconstructed in any plane, and can even create a three dimensional image, which is epecially useful for surgical planning (FIGURE). Helical (or spiral) CT scanners are able to acquire images much more quickly than conventional CT scanners, and provide the best image reconstructions. Three dimensional reformations generally require a helical (spiral) CT scanner and a dedicated computer workstation.



3D CT reformation of complicated calcaneus (heel) fracture shows involvement of multiple joints which were not apparant on regular X-rays. Additional 3D CT images of the hindfoot in the same patient. The images can be be rotated in any direction and angle to alow optimal viewing of the fracture sites.



Ultrasound
In the United States, ultrasound has not attained widespread popularity for evaluating foot and ankle disorders. In experienced hands, ultrasound is able to detect tendon abnormalities and masses, and has become a first line imaging modality for evaluation of sports medicine injuries abroad. In the USA, MRI is more popular as it is widely available, less user-dependent, and able to provide superior anatomic information. The most common use for podiatric ultrasound in the USA is for detection of foreign bodies and to assist biopsy of masses.

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Imaging of the Diabetic Foot and Its Complications