CHAPTER **24**

DIAGNOSTIC ULTRASOUND OF THE FOOT AND ANKLE

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Diagnostic ultrasound imaging consists of a recorded echo of sound waves from an object back to a transducer. The images created by the echoes are based on the acoustic impedance mismatches at the interface between objects (Table 1). High acoustic impedance mismatch is produced when the sound waves encounter an object of high mass density. This will produce brighter or hyperechoic images. Low acoustic impedance mismatch is produced when low mass density objects are encountered by the sound waves. These objects appear darker or hypoechoic on ultrasound.

The ultrasound image consists of axial and lateral resolution. The ability to distinguish between the two reflectors situated along the axis of the ultrasonic beam is referred to as axial resolution. This distinguishes the fine details of small parts. The resolution of two point reflectors in a direction perpendicular to the ultrasonic beam is referred to as lateral resolution. It is directly related to the beam width. These two resolutions together create the ultrasound image. The resolution of the ultrasound image is related to the frequency of the transducer. However, as the frequency of the transducer becomes higher, the size of the field of examination decreases. This decreases the area that can be examined at a given moment. A 7.5 MHz or 10 MHz linear array transducer is ideal for foot and ankle imaging.

Artifact can be produced by probe placement, angle, and pressure. Acoustic shadow is the signal void beyond an object producing a high acoustic impedance mismatch. The object leaves an acoustic void by interfering with the transmission of sound waves. Muscles and tendons can vary in their echogenicity when examined at different angles. This effect is referred to as anisotropy. A strict perpendicular approach with the probe to the long axis of the tendon will provide a correct evaluation. No echoes are returned at the lateral margins of a highly curved surface. This phenomenon is called critical angle shadowing. It can be seen in normal and pathologic conditions. Reverberation artifact is caused by metallic or glass objects. The repetitive echoic bands found at intervals equal to the object's thickness diminish with distance from the object creating a "comet's tail" appearance.

Table 1

ACOUSTIC IMPEDANCE OF VARIOUS MATERIALS

Material	Acoustic Impedance
AIR	0.0004
FAT	1.38
WATER	1.54
BLOOD	1.59
MUSCLE	1.71
CORTICAL BONE	7.8

Ultrasound can be used to examine a wide range of pathologies of soft tissues and cortical bone in the foot and ankle. Tendon tears, soft tissue masses, foreign bodies, intermetatarsal neuromas, lesser metatarsalphalangeal joint pathology, plantar fasciitis, and metatarsal stress fractures are all ideal for ultrasound imaging.

FOOT AND ANKLE TENDON PATHOLOGY

Diagnosis of tendon pathology in the foot and ankle typically requires more than clinical findings. The imaging modality of choice for tendon pathology is currently magnetic resonance imaging (MRI). There are several issues with MRI evaluation. The cost, availability, patient comfort, and resolution are all less than optimal. Other limitations of MRI include pregnancy and presence of metallic implants or pacemakers. Other than imaging of the Achilles tendon, ultrasound has been underutilized in the diagnosis of foot and ankle tendon pathology. A recent study by Rockett, et al comparing the reliability of ultrasound compared with MRI in diagnosis of foot and ankle tendon pathology has shown ultrasound to be more accurate and sensitive than MRI.

Normal tendon appears as fine parallel echoic lines on the longitudinal scan (Figure 1) and as an oval or round

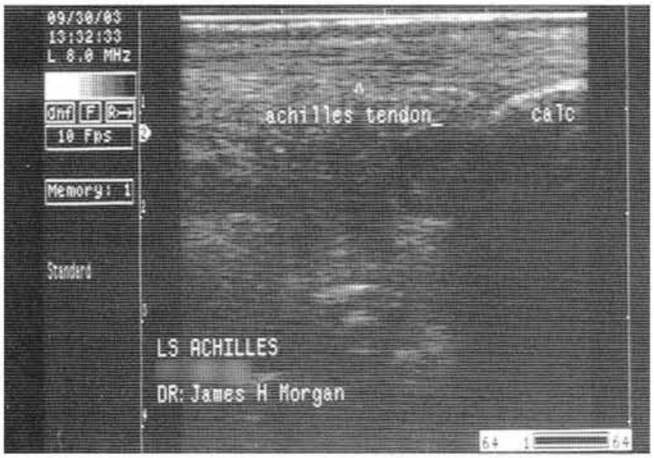

Figure 1. Longitudinal scan of a normal Achilles tendon. Note the homogenous appearance of the parallel echoic lines.

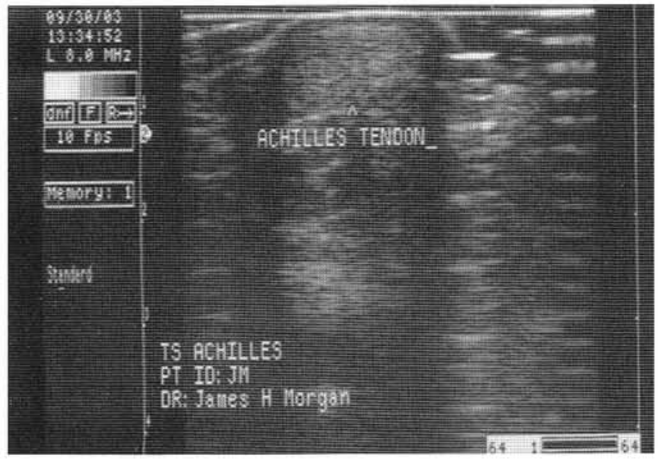

Figure 2. Transverse scan of a normal Achilles tendon seen as an oval collection of echoic dots.

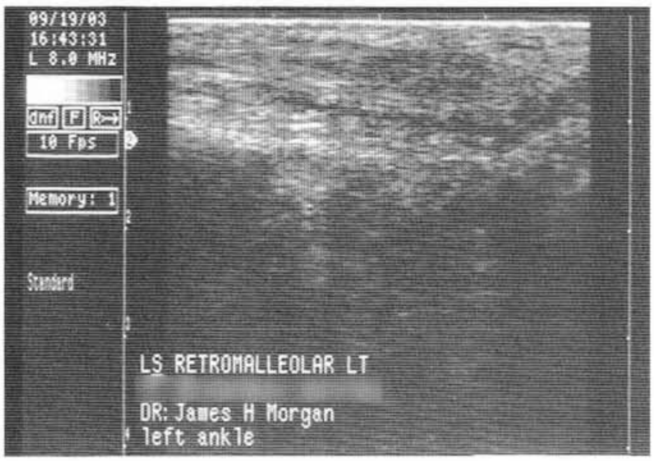

Figure 3. Longitudinal scan of an intrasubstance tear of the peroneus brevis tendon represented by a hypoechoic region within the echoic parallel lines.

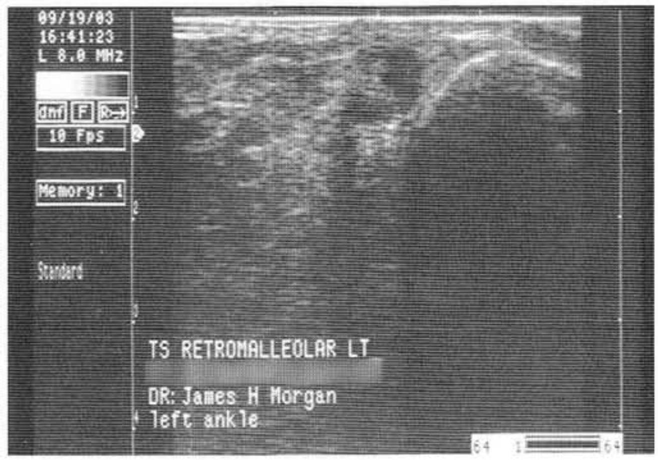

Figure 4. Transverse scan of the peroneal tendons demonstrating an intrasubstance tear with tenosynovitis involving the peroneus brevis tendon. Note the irregular margins of the oval tendon surrounded by an increased hypoechoic synovial fluid.

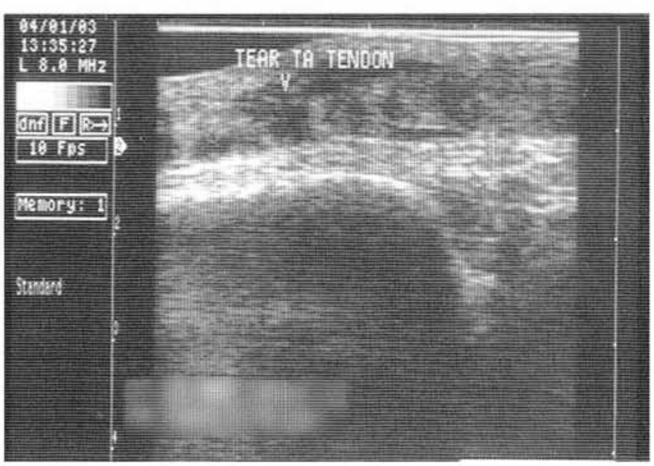

Figure 5. Longitudinal scan demonstrating a complete rupture of the tibialis anterior tendon. Note the increased hypoechoic region surrounding and disrupting the echoic parallel lines.

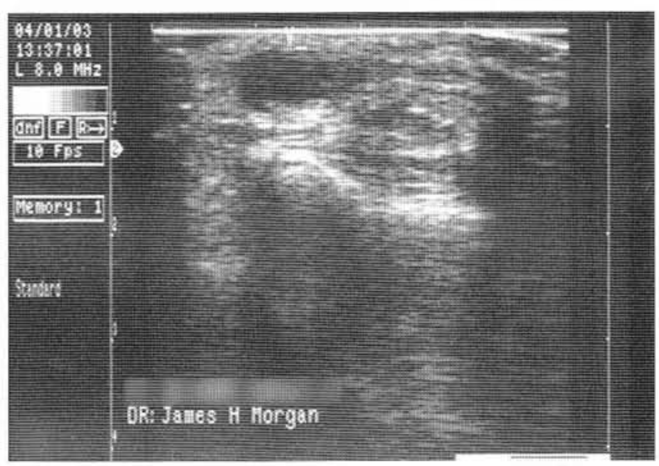

Figure 6. Transverse scan of the complete rupture. There is a complete absence of the tendon which is replaced by hemorrhage seen as an oval hypoechoic region.

grouping of echoic dots on the transverse scan (Figure 2). Surrounding the echoic lines are slightly less echoic lines which represent the tendon sheaths. Separating the tendon and the sheath is a small amount of hypoechoic fluid.

Pathologic tendon on the longitudinal images shows a fusiform thickening of the tendon at the location of the tear. There is disruption of the fine echoic lines of the tendon with hypoechoic regions within the fusiform thickening (Figure 3). A moderate to large amount of hypoechoic fluid is typically seen surrounding the tendon and distending the tendon sheath. Echogenic and hyperechoic material can also be seen outside the tendon representing tendon debris.

The transverse scan is the key to diagnosis of intrasubstance tears (Figure 4). Typically, disruption of the echoic architecture of the tendon is seen. Hypoechoic lines extending from the periphery into the tendon substance represents intrasubstance tears. These vary in size and shape depending on the size or length of the tear. The tendon is seen surrounded by varying amounts of hypoechoic fluid and echoic debris.

On both longitudinal and transverse scans, complete rupture of a tendon would show total disruption of the fine echoic parallel lines with a hypoechoic gap between the ruptured tendon ends (Figures 5, 6). Absence of the gliding mechanism would be absent on active movement of the tendon. This real-time capability of high-resolution ultrasound is perhaps its greatest advantage over the static MRI scan.

The author has found ultrasonography to be useful when evaluating calcific tendinosis of the Achilles and retrocalcaneal exostosis. The longitudinal and transverse scans demonstrate the extent as well as the location of the calcifications (Figures 7, 8). This will provide better preoperative planning on whether or not the insertion of the tendon will be violated.

SOFT TISSUE MASSES

Ultrasound evaluation of soft tissue masses has received little attention. The size, shape, depth, extension, and homogeneity of the mass can be well defined by ultrasound. When a mass has an extremely mixed echogenicity, has deep extension into the tissues, or is highly vascular, an MRI evaluation should be ordered.

Ganglions and lipomas are two types of masses that have well-defined ultrasonographic appearance. A ganglion appears as an anechoic mass (Figure 9). It may be round, oval, or lobulated in shape. Extension into a joint or tendon can often be seen. The echogenicity of a lipoma will vary based on the water and fat content. Typically, a lipoma will be isoechoic or hyperechoic to the surrounding subcutaneous fat (Figures 10, 11). The mass will be fully compressible and return to its original size and shape after compression. Other soft tissue lesions that can be identified with ultrasound include aneurysms, abscesses, plantar fibromas, neurilemmomas, and neurofibromas (Figures 12-14).

FOREIGN BODIES

Ultrasound is an excellent study for visualizing foreign bodies in the foot and ankle. While metallic and leaded glass can be easily visualized on plain film radiograph, radiolucent foreign bodies such as wood are often missed on radiographs. Wood on ultrasound appears as a hyperechoic object sometimes with a hypoechoic halo depending on the presence of air or fluid surrounding the foreign body. Wood will also produce an acoustic shadow. The greatest advantage of ultrasound for detection of foreign bodies is the ability to measure the length, width, depth, and orientation of the object. This information is extremely valuable to the preoperative planning of the incision placement in patients whose portal of entry has already healed. This will allow for a decrease in the overall surgical and anesthesia time as well as a decrease in dissection.

INTERMETATARSAL NEUROMAS AND PLANTAR PLATE RUPTURES

Ultrasound can also be used to diagnose atypical neuromas. In some cases, it is difficult to distinguish between lesser metatarsalphalangeal joint pathology with interdigital neuritis and intermetatarsal neuromas. Other cases may involve neuromas with coexisting neurological conditions. In either of these cases, ultrasound will provide direct visualization of the neuroma and the plantar plate of the lesser metatarsal-phalangeal joints.

The ultrasonographic appearance of a neuroma is a round or ovoid hypoechoic mass with or without hyperechoic material within it (Figures 15, 16). A diameter of 5 mm or greater on ultrasound has been shown be symptomatic and pathologic. Lesser metatarsalphalangeal joint capsulitis appears as anechoic regions in the joint capsular structure. The author has found ultrasound to be highly accurate in diagnosing plantar plate ruptures. An anechoic lesion is noted in the plantar capsular structures on the longitudinal scan (Figure 17). The lesion varies in length during real-time scanning while performing Lachman's test on the involved joint. This finding is absent with pure capsulitis.

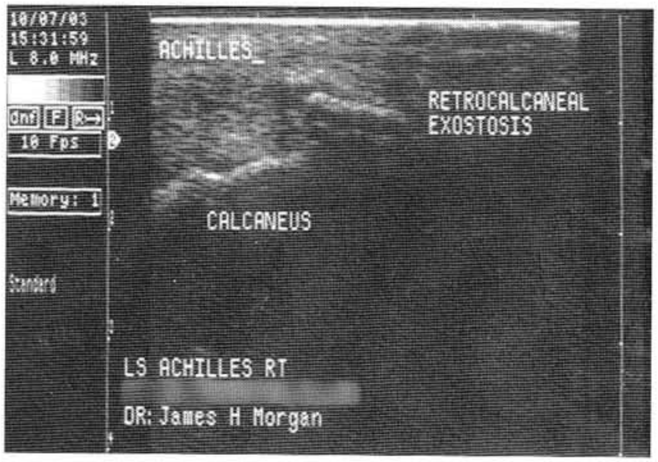

Figure 7. Longitudinal scan of a retrocalcaneal exostosis. This view is valuable in assessing the depth of the spur.

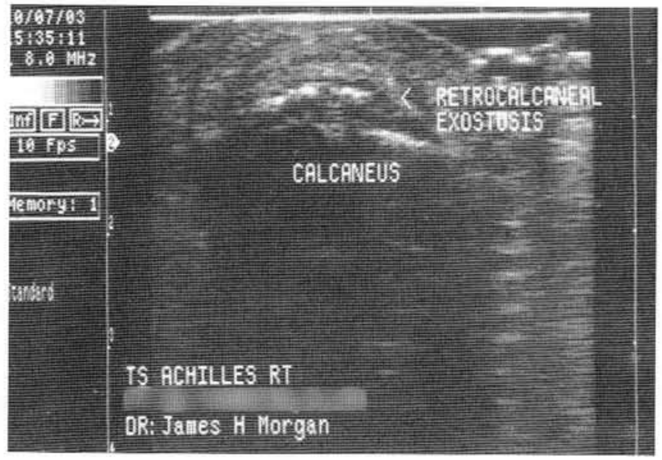

Figure 8. Transverse scan of a retrocalcaneal exostosis. This view shows the extent of the spur from medial to lateral.

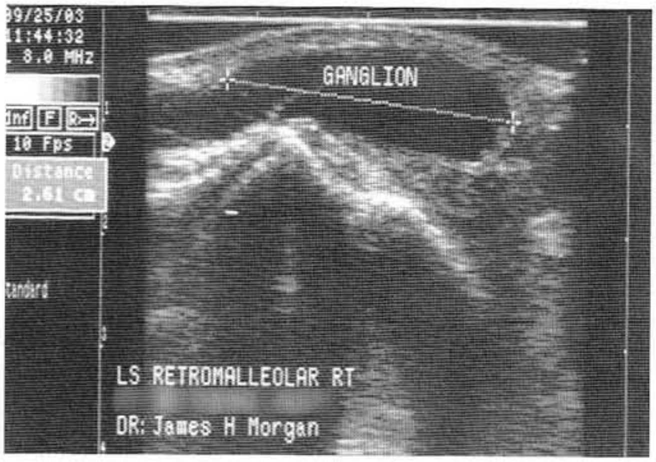

Figure 9. Longitudinal scan of a ganglion cyst. Note the hypoechoic oval lobulated mass.

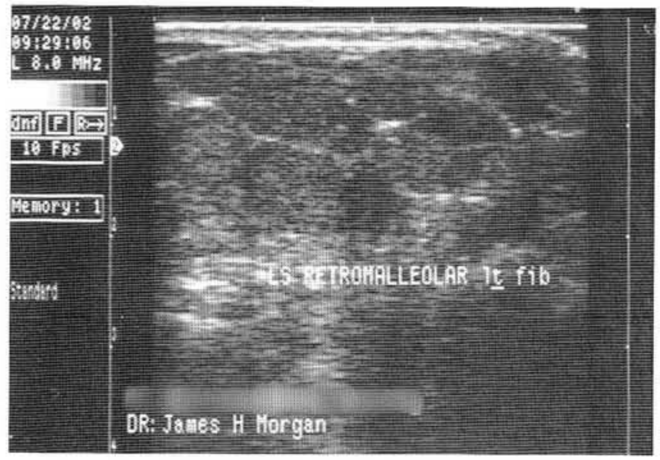

Figure 10. Longitudinal scan of a lipoma located anterior to the lateral malleolus. The mass is isoechoic to the subcutaneous tissue. Note the hyperechoic lattice-like pattern of the mass.

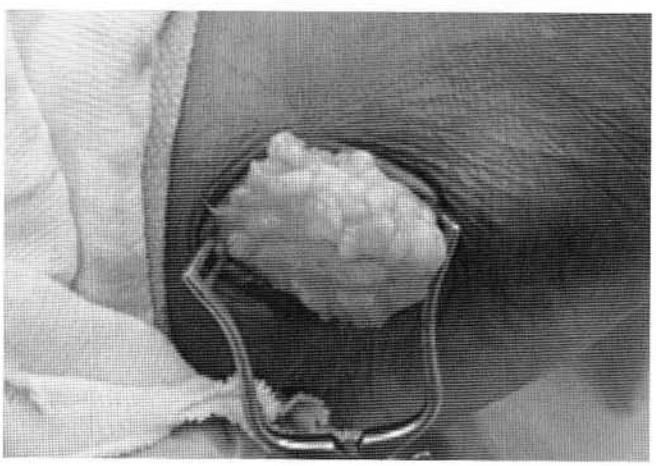

Figure 11. Intraoperative photo of the lipoma.

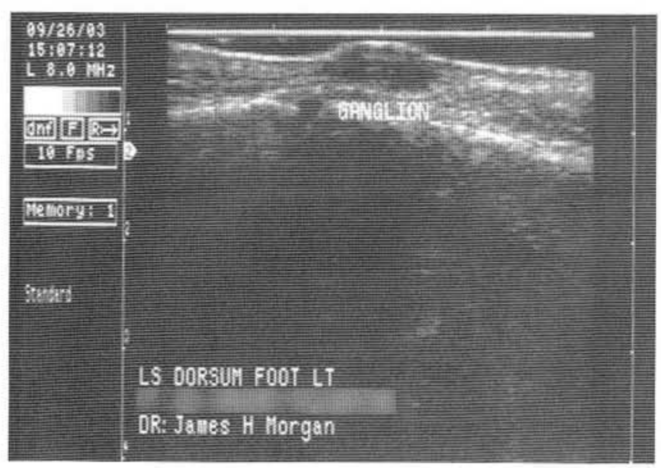

Figure 12. Longitudinal scan of a neurofibroma. The mass appears as an oval hypoechoic region with fine echoic parallel lines.

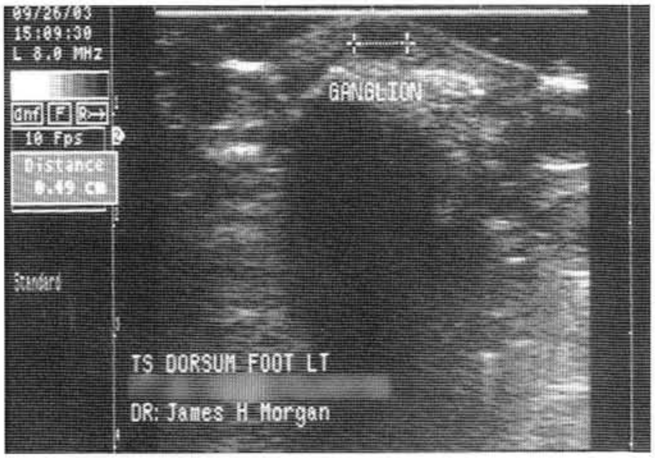

Figure 13. Transverse scan of a neurofibroma. Note the round hypoechoic mass with echoic dots.

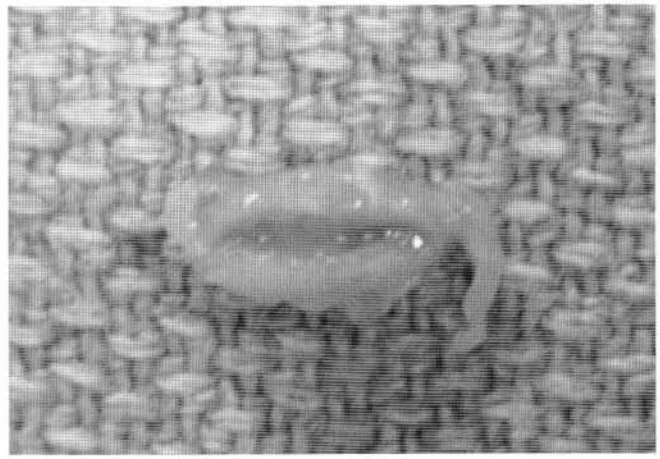

Figure 14. Intraoperative photo of the neurofibroma.

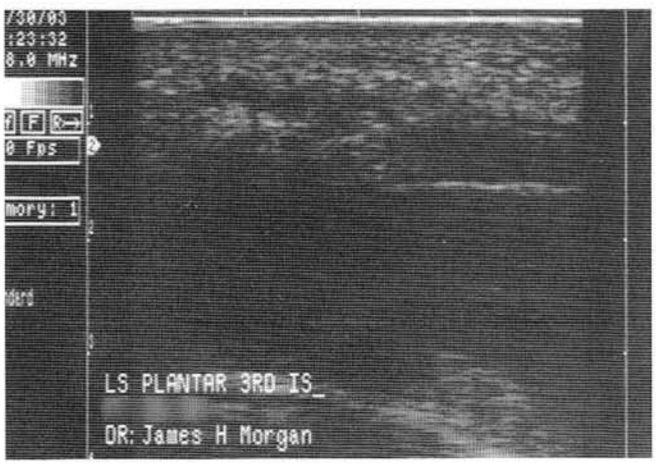

Figure 15. Longitudinal scan of an intermetatarsal neuroma. Note the hyperechoic fine parallel lines surrounded with anechoic regions deep and superficial.

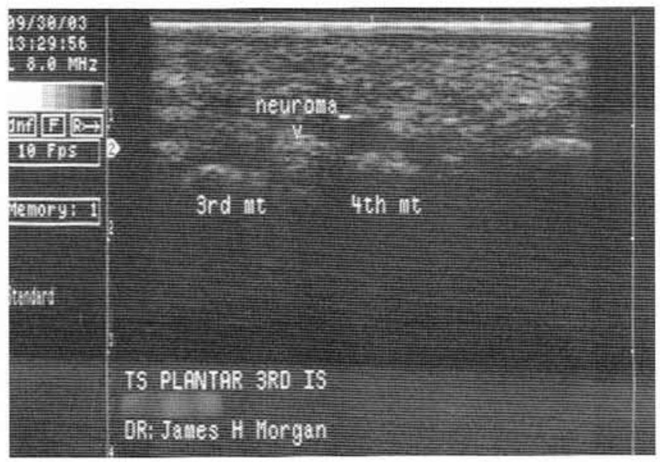

Figure 16. Transverse scan of an intermetatarsal neuroma.

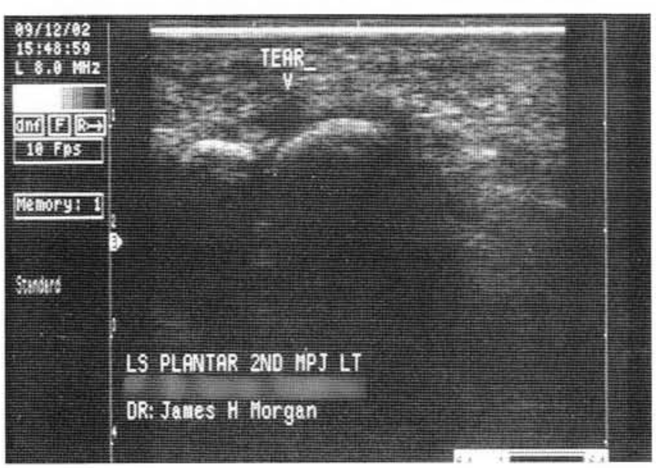

Figure 17. Longitudinal scan of a metatarsal phalangeal joint demonstrating a plantar plate rupture. Note the anechoic region proximal to the phalangeal base.

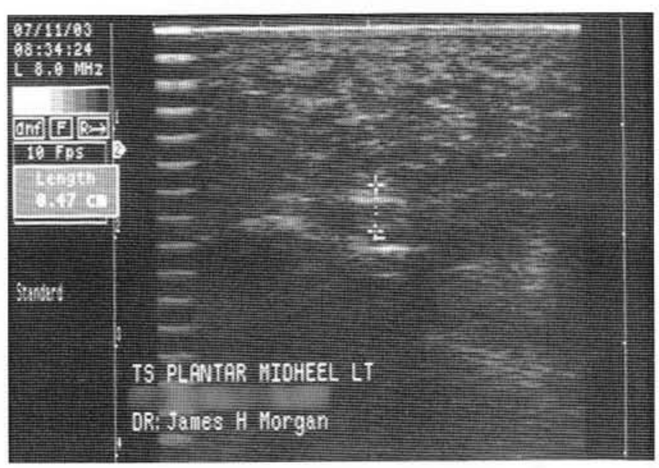

Figure 18. Longitudinal scan of the plantar fascia measuring 0.47 cm which is consistent with plantar fasciitis.

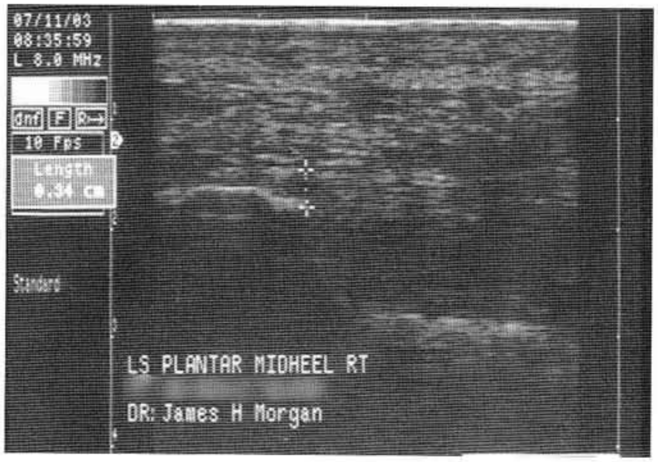

Figure 19. Longitudinal scan of the contralateral plantar fascia measuring 0.34 cm.

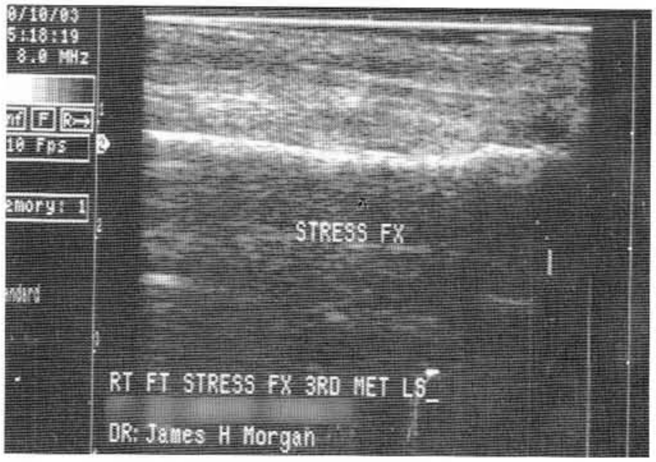

Figure 21. Longitudinal scan of the same patient. Note the easily detected cortical thickening and hypoechoic fracture line.

Figure 20. Lateral oblique radiograph of a patient with a 2 week history of pain, edema, and ecchymosis over the forefoot. Note the questionable cortical thickening of the third metatarsal shaft.

PLANTAR FASCIITIS

The numerous possible causes of plantar heel pain (plantar fasciitis, infracalcaneal bursitis, enthesiopathy, nerve entrapment, systemic arthritis, radiculopathy, or stress fracture) can make the diagnosis difficult. Ultrasound combined with radiographs can provide valuable information in atypical cases of heel pain.

The fascia appears as a hyperechoic linear structure that measures thicker than the contralateral, uninvolved side (Figures 18, 19). A thickness of greater than 4.5 millimeters overall or greater than 1 millimeter thicker than the contralateral side is widely accepted as a positive finding. A plantar calcaneal spur appears as a hyperechoic band at the insertion of the fascia on the calcaneus surrounded by a hypoechoic region and an acoustic shadow. An infracalcaneal bursitis will appear as a circumscribed mixed echogenicity or fluid filled mass with echogenic debris.

The major advantage of ultrasound compared to MRI for diagnosis of plantar fasciitis is the ability to directly assess symptomatic portions of the plantar fascia during the examination. The transverse scan can be used to directly visualize the placement of corticosteroid injections.

METATARSAL STRESS FRACTURES

Metatarsal stress fractures are initially a diagnosis based on clinical findings. Radiographic findings will often delay 2 weeks after onset of the fracture. Nuclear medicine studies have been used when radiographs are inconclusive. The author has found ultrasound to be useful in earlier detection of metatarsal stress fractures in the absence of radiographic findings in a limited set of patients. Ultrasonographic appearance of the fracture on the longitudinal scan is seen as an increased thickness of the hyperechoic cortex closest to the transducer with an overlying hypoechoic region representing the early external callus (Figures 20, 21). The point of maximum tenderness can be verbalized by the patient to the examiner insuring the accuracy of the exam.

ADVANTAGES AND DISADVANTAGES

Ultrasound can be used to determine the exact location and dimensions of foot and ankle pathology. There is no radiation exposure. The cost is much less than a computed tomography (CT) or a MRI scan. Ultrasound is the only modality where there is a direct contact between the examiner and the patient. The point of maximum tenderness may be related by the patient to the examiner insuring examination of the symptomatic pathology. The entire tendon can be visualized in multiple planes and at multiple angles so that artifact is minimized. MRI requires a still patient with no examiner interaction. If the foot is not in the correct position or the patient moves, an important portion of the structure may be poorly visualized. Ultrasound has no patient contraindications.

The quality of the ultrasound image is operator and machine-dependent. If the examiner is inexperienced or the transducer is low-resolution, false-negative results can occur. When using a high-resolution transducer, if the involved anatomic region is not scanned, then a false-negative result can occur because of the small focal area of this type of transducer. Ultrasound cannot image beyond the near cortex of bone due to acoustic shadow.

CONCLUSION

Diagnostic ultrasound is an underutilized imaging modality that is gaining popularity in the examination of soft tissue pathology in the foot and ankle. The ability to interact directly with the patient insures that the area of tenderness is appropriately examined. The exam can be performed in the office setting providing a less expensive and a more timely diagnosis compared to MRI. The exact location and dimensions of the pathologic tissue can also be determined during the exam. This information can decrease the overall operation and anesthesia time as well as reduce the amount surgical dissection. Diagnostic ultrasound should be considered as the next imaging modality following plain film radiographs for the examination of foot and ankle soft tissue pathology and metatarsal stress fractures.

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