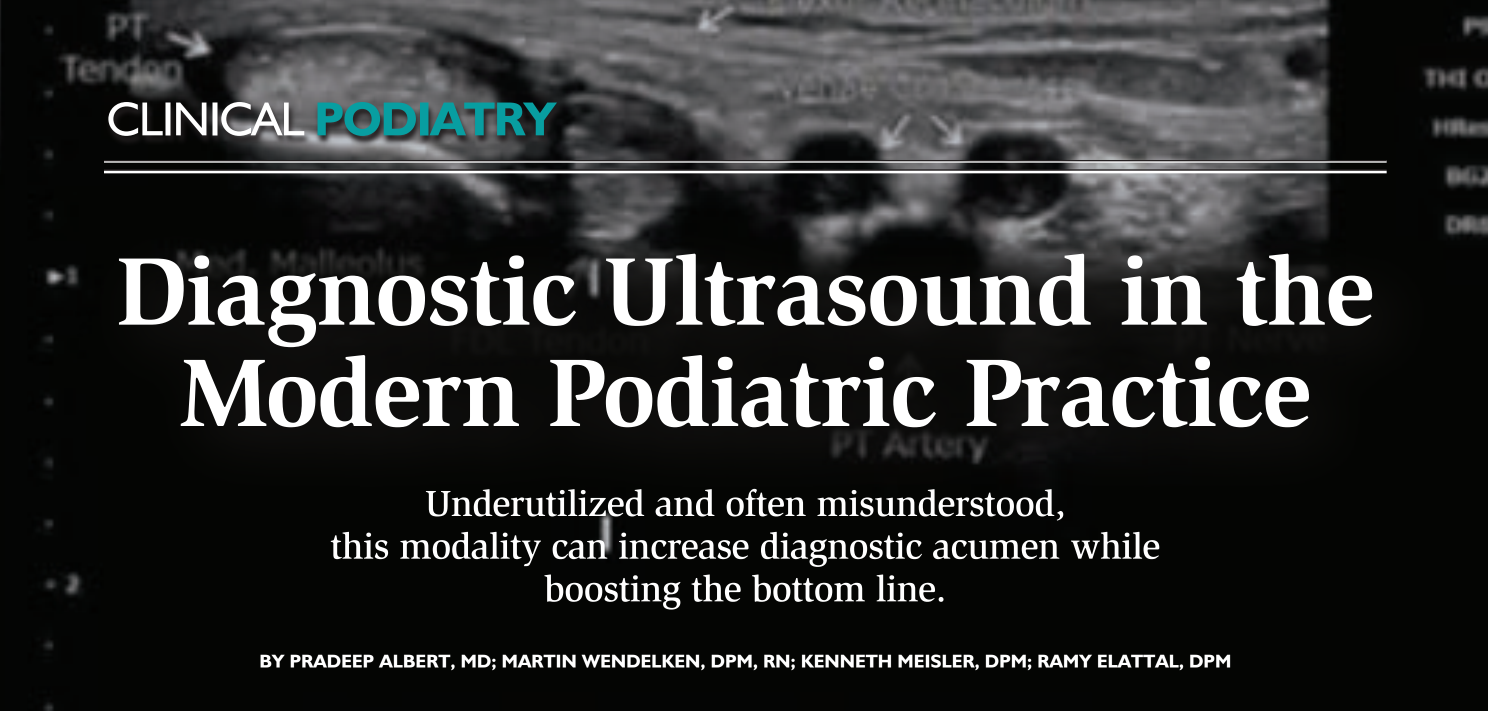

Diagnostic Ultrasound in the Modern Podiatric Practice

Underutilized and often misunderstood, this modality can increase diagnostic acumen while boosting the bottom line.

BY PRADEEP ALBERT, MD; MARTIN WENDELKEN, DPM, RN; KENNETH MEISLER, DPM; RAMY ELATTAL, DPM

Introduction

Diagnostic ultrasound can be a tremendous asset for all podiatry practices. It can help diagnose and treat patients more effectively. Diagnostic Ultrasound will save money for insurance companies by reducing MRI use and at the same time can increase revenue for the practice.

Very few podiatry practices have incorporated ultrasound into their practices to the degree they have other modalities and treatment options such as X-ray, surgery, wound care, biomechanics and orthotics. Podiatrists frequently tell us that they are either not utilizing ultrasound or utilizing only a small portion of its capabilities. Some doctors state that they have purchased an ultrasound machine but that it has ended up in the corner and is not being used. This is unfortunate but happens for a number of reasons, including lack of training, low end scanners that have poor image quality, and a lack of knowledge about how to incorporate the treatment into their practices. Residents also state that ultrasound is one of the few things about which they have very little experience after completing their residency program.

The goal of this article is to educate you on how diagnostic ultrasound can be used in your practice. For those podiatric physicians who are not using ultrasound, we invite them to consider the modality. At the same time, for those doctors who are already utilizing ultrasound, it is hoped that this article will aid them in increasing the scope of its use in order to provide better outcomes for their patients.

Podiatrist—as compared to other clinicians—have fewer options when it comes to diagnostic tools (EKG, spirometry, stress tests, pulse oximetry, ophthalmoscope, oto-acoustic testing, vision testing etc.) Basic imaging modalities comprise general X-ray, mammographic X-ray and ultrasound. These modalities comprise 51% of medical imaging.[1] Diagnostic ultrasound is a "point of care" modality that provides non-invasive imaging of soft tissue and the cortical surface of bone. Having both X-ray and ultrasound will enable you to use both imaging modalities in-office.

> **Having both X-ray and ultrasound will provide the capability of having both modalities of imaging in the office setting.**

Background

Before going into diagnostic specifics, a very simplified background of ultrasound physics and how the sonographic images are created will be discussed.

The ultrasound scanner is basically a sophisticated computer with a transducer or probe. Pulsed ultrasound waves are created by piezoelectric crystals within the probe. The transducer is a device which emits ultrasound waves at a frequency from 5-18 Megahertz (Hertz = cycles per second) into the body. The transducer also is a receiver that listens for echoes created by the different tissues based on the acoustic impedance (resistance) of the tissue (bone vs. muscle vs. tendon, etc.). The computer converts and compiles the captured echoes through an analog to digital converter into an image displayed on the ultrasound scanner monitor.

The frequency plays a large role in image quality. In general, the higher the frequency the higher the resolution. There is a tradeoff, however: as the frequency increases there is less penetration. Penetration of tissue (depth) is generally not an issue in podiatric medicine as most of the structures in the foot and ankle are considered to be superficial. It should be noted that the frequency is not the only thing that dictates image quality. There are proprietary algorithms that greatly influence image quality. Two scanners imaging at the same frequency most likely will not have

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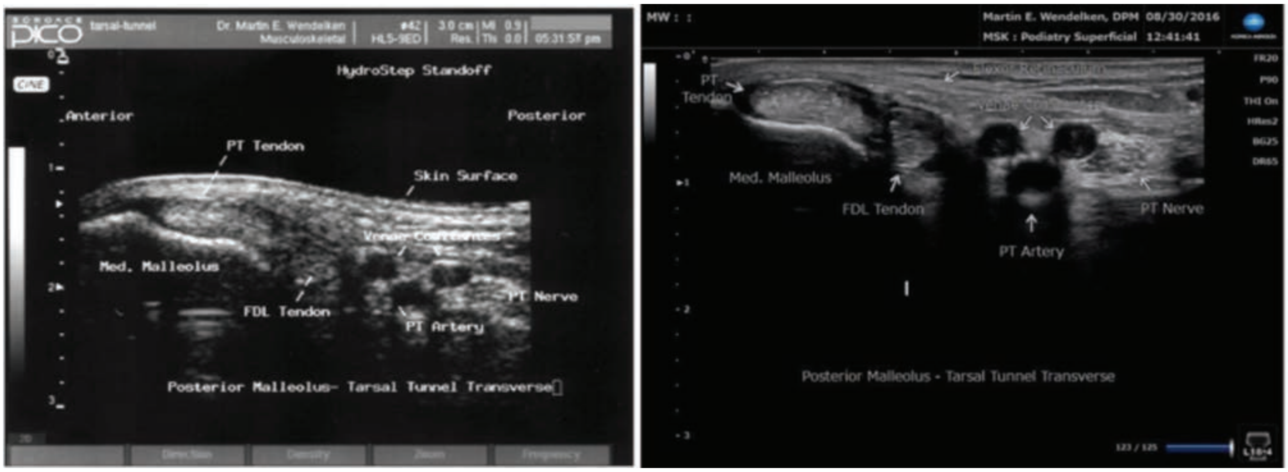

Figure 1: Above left—Ultrasound scan of a transverse section of the tarsal tunnel at 8 MHz while the same scan of the same tarsal tunnel (above right) on today's high resolution ultrasound at 18 MHz . Note the clarity of the structures including the PT and FDL tendons, PT artery with vena comitantes, PT nerve and even the flexor retinaculum.

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the same image quality. Today's higher end ultrasound scanners have image quality that makes it easier to learn and diagnose pathology. When one compares today's ultrasound scanners to those from 7-10 years ago there is significant improvement (Figure 1).

In terms of image quality, there are multiple studies that have shown a properly trained diagnostic sonographer can obtain better images in terms of signal to noise than a 3 Tesla MRI machine.[2] In the world of podiatry, there are not many affordable imaging tools. Currently,

In-office ultrasound provides immediate non-invasive imaging and the ability to visualize and pick up occult pathology during a typical office encounter.

most podiatrists usually perform radiographs and then jump to MRIs. Having a high frequency ultrasound scanner in a properly-trained podiatry practice will benefit the clinician and patient because of the significant amount of information gained using the modality. In-office ultrasound provides immediate non-invasive imaging and the ability to visualize and pick up occult pathology during a typical office encounter.

Basic Principles of Musculoskeletal Imaging

Ultrasound provides high-resolution imaging of the structures in the foot and ankle. This involves all structures including muscles, tendons, ligaments and bones. The images are described by evaluating the soft tissue in terms of shades of grey. *Isoechoic* refers to images that

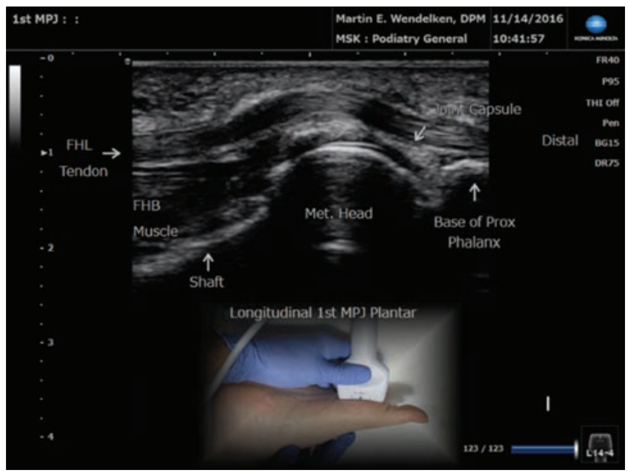

Figure 2: Above scan reveals a view of the plantar 1st MPJ in the long axis. The picture in picture reveals the probe position on foot. Note in this ultrasound scan the contour of the cortical surface of the 1st metatarsal, FHB muscle (left). FHL tendon coursing left to right, the joint capsule/plantar plate attachment to the base of the proximal phalanx, and finally the skin and subcutaneous tissue of the plantar 1st MPJ (top of image).

display regions that are similar in tissue brightness and appear homogenous in content. *Hypoechoic* areas are tissues that are darker as compared to surrounding tissue (e.g., fluid within tissue). *Hyperechoic* refer to bright white areas within the image indicating increased signal (e.g., foreign bodies, bone). *Anechoic* structures are those that generate no echoes and appear black within the ultrasound scan (e.g., cysts, blood, edema). Lastly, the images or structures within the image can be described as having homogeneous or heterogeneous patterns.

Ultrasound imaging of bone provides a view of the outer contour of bone. One can clearly evaluate the cortical surface. Since ultrasound cannot penetrate bone, it casts what is called an acoustic shadow. Since the soundwaves are blocked, the image will appear black below the cortical surface. Ultrasound is excellent for imaging mus-

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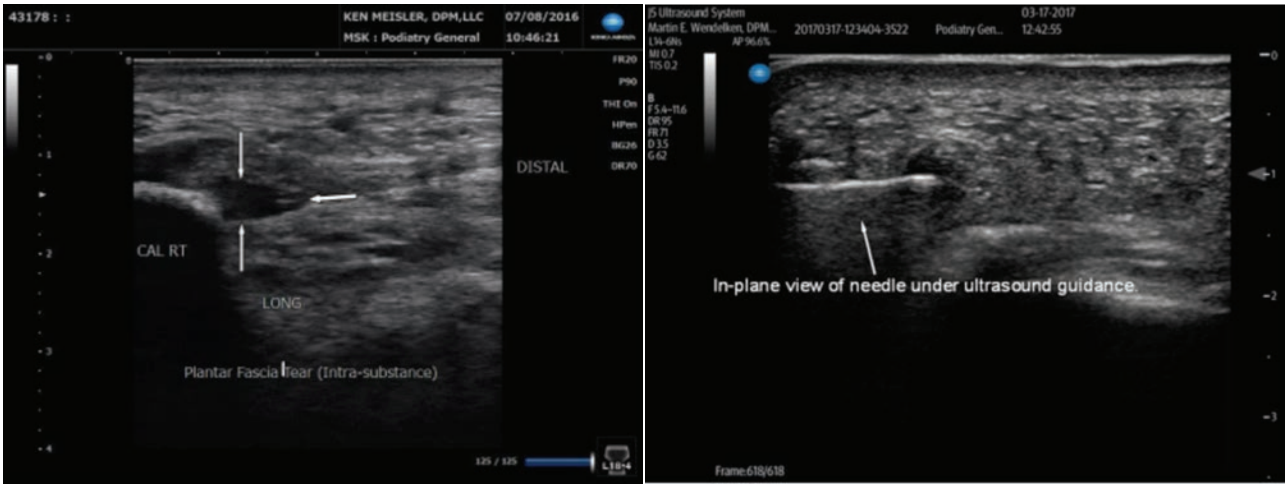

Figure 3: Upper Left: Image of the plantar fascia longitudinal axis reveals anechoic area representing an intra-substance tear at the attachment of the fascia on calcaneus. Upper Right: A transverse image of an ultrasound guided injection of the plantar fascia. This is an in-plane view of the needle that is noted in the mid-field of the scan. Note the anechoic area at the needle tip showing denoting the fluid exiting the distal tip of the needle.

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cle. Its ability to evaluate tendons is far superior to MRI when performed by an experienced practitioner. The ability to follow the course of the tendon is not limited to simple slices—it provides continuous evaluation of the structures in real time (Figure 2).

When evaluating for ligament injuries, high-resolution ultrasound provides better images than almost any other imaging modality. Also consider that ultrasound is dynamic and allows the evaluation of structure under stress, either actively by the patient or passively by the clinician. This modality can and should be performed on tendons, muscles, ligaments, and joints.[3]

Since moving objects and structures can be evaluated, ultrasound scanners are also used to image blood vessels. If the scanner has duplex color Doppler, it can evaluate blood flow within the vessels or lack thereof. Power Doppler allows for viewing areas of hyperemia and injury. Soft tissue masses may be evaluated as to whether they are solid or cystic. A mass can be diagnosed as highly suspicious for a malignancy if duplex imaging reveals blood flow within the mass.

TABLE 1:

Partial List of Podiatric Indications for Diagnostic Ultrasound

Plantar Fasciitis, Tear, Rupture	**Neuromas**—all interspaces
Tendonitis, Tear, Rupture	**Soft Tissue Masses:**
Achilles Tendon	Plantar Fibromas
Post. Tribal Tendon	Cysts, Ganglions
Ant. Tibial Tendon	Lipomas
Peroneal Longus; Brevis	Bursal Sacs
FHL Tendon, EHL Tendon	Art. Ven. Malformation
EDL Tendon, FDL Tendon	Tumors
Foreign Bodies	Hematomas, Abscesses
Muscle Tears, Contusions	**MPJ Issues:** Capsulitis, Plantar Plate
Ligament Sprains, Tears	**Stress Fracture, Avulsion Fracture**
Deltoid, ATFL, CFL, PTFL	**Arthritis/Joint Effusions**

Indications for Diagnostic Ultrasound

It is well known that heel pain is one of the most common presenting symptoms for treatment in the podiatric practice. Although just about all practitioners obtain X-rays to assist in the evaluation of heel pain, it is far more common to find that the pain is being caused by a soft tissue ailment rather than an osseous issue. Yes, it is very important to know that there is no fracture or bone tumor of the calcaneus. Diagnostic ultrasound can help the clinician differentiate between plantar fasciitis, plantar fascia tear, inferior calcaneal bursitis or other soft tissue issues. Table 1 provides a partial list of some of the pathology that can be evaluated using diagnostic ultrasound.

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Images of Common Foot and Ankle Pathology

Imaging the Plantar Fascia

How is ultrasound used in the diagnosis and treatment of plantar fasciitis? First, image and evaluate the thickness of the plantar fascia. Normal plantar fascia measures 2.5 to 3.5 mm. If it's thickened more than 4 mm, it is considered plantar fasciitis. Next, evaluate and see if there is a partial tear or if the plantar fascia is ruptured. Experienced podiatrists are surprised to find how many cases of plantar fasciitis are in fact partial tears. One may also evaluate if there are enthesophytes or spurs there, sometimes not seen on X-rays. The plantar fascia should be evaluated along its entire length in both the longitudinal and transverse planes. In Figure 3 there are two images, the first an intra-substance tear of the plantar fascia and the second an ultrasound-guided injection of the plantar fascia.

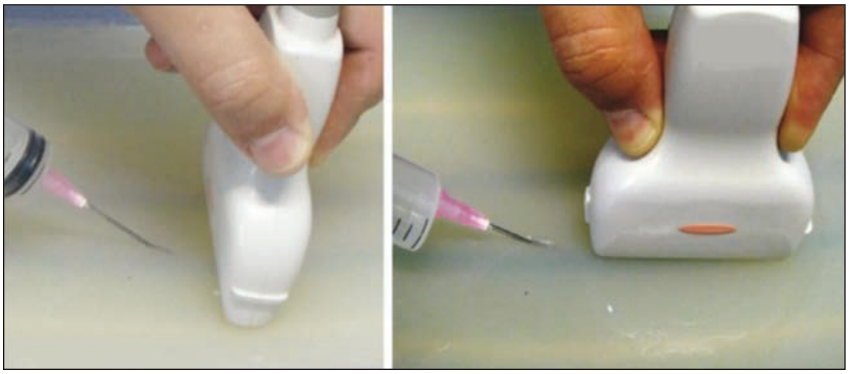

Figure 4: Ultrasound Guided Injections—Top Left: Indirect or out of plane approach. Reveals a small transverse hyperechoic image of the needle. Top Right: Direct or in plane approach provides a longitudinal hypoechoic view of the needle in the ultrasound field.

In terms of interventions, ultrasound is an incredible tool to enable a clinician to insure exact needle placement. Experienced podiatrists find that the area of maximum inflammation noted on ultrasound is frequently more proximal than the usual injection site for heel pain. More exact placement of the injection leads to better results.[4,5] The position of the needle in regard to the transducer is either a direct (in plane) or indirect (out of plane) approach (Figure 4).[6]

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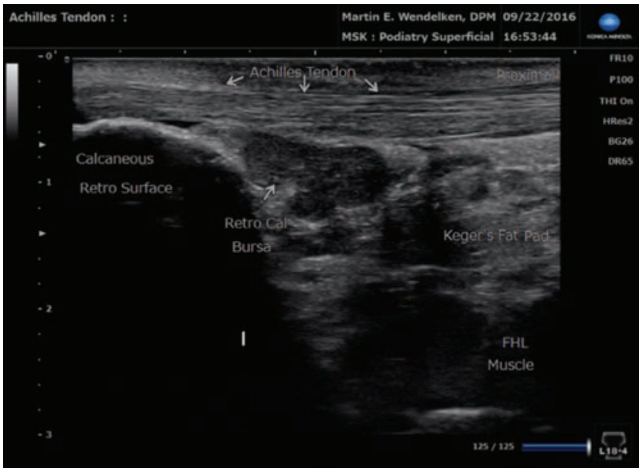

Figure 5: Above—A longitudinal scan of the Achilles tendon. The tendon runs in the long axis and is seen at the beginning of the inserting on the retro-calcaneal surface (left) running 4 cm proximal (right). Note the bursa that is clearly seen and can be viewed actively sliding between the tendon and the retro-calcaneal surface during the evaluation.

Figure 6a: A longitudinal scan of an Achilles tendon illustrating tendinosis. Note the fusiform shape of the tendon in the area of pathology.

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Achilles Tendon

Another common entity that is imaged using ultrasound is Achilles tendon. Here you can evaluate the retro-Achilles bursa, Achilles tendon, and calcifications/enthesophytes, muscle injuries in the area the Achilles tendon. Evaluating the Achilles tendon using ultrasound is one of the easiest parts of the body to image. Place the transducer directly on the posterior surface and visualize the Achilles tendon below (Figure 5).

An abnormal Achilles tendon can be viewed in Figure 6-a. Here it is seen as thickened, fusiform in shape, irregular, and edematous. One may also use a split screen mode to compare the contralateral limb, making it easy for the patient to see a difference in each tendon (Figure 6-b).

It can help differentiate between tendonitis, tendinosis, retrocalcaneal bursitis, interstitial tears and complete tears.

Ultrasound can significantly help in diagnosing the etiology of Achilles tendon pain.[7] It can help differentiate between tendonitis, tendinosis, retrocalcaneal bursitis, interstitial tears and complete tears. The differential can be made in real time. Sonography can also evaluate if there are enthesophytes in the Achilles tendon at the insertion or calcifications in the tendon. Is this patient a bone former, does this patient have psoriatic arthritis or some other systemic arthritis? (Figure 7) You can inject the Achilles tendon using some of the new biologicals. Since it does not have a tendon sheath, you can use nee-

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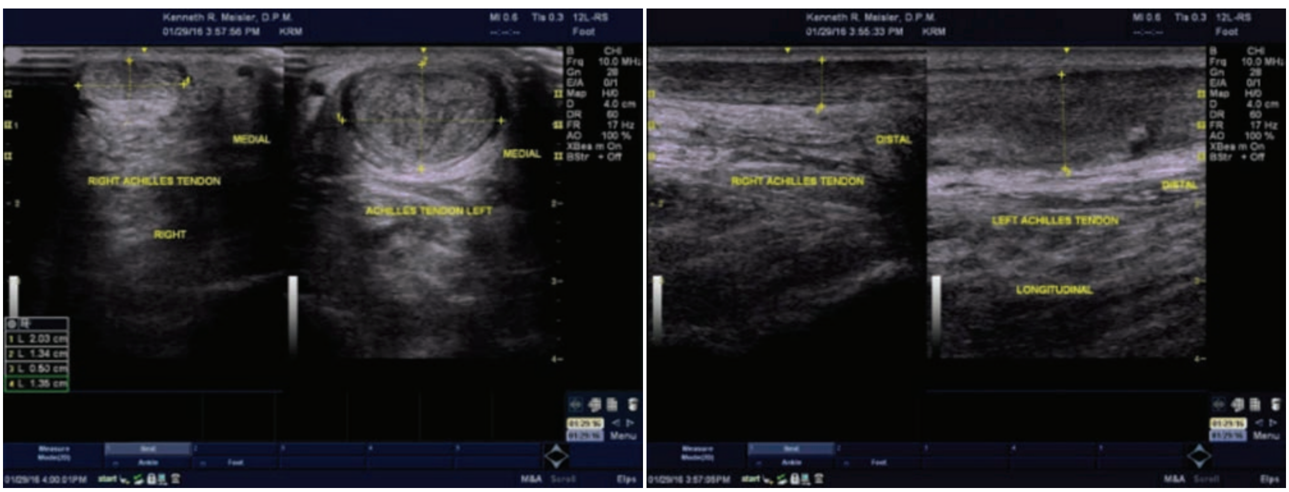

Figure 6b: Top Left—B-B Mode of a transverse scan showing the right and left Achilles tendon for comparison. Top Right—B-B Mode of the same tendon in the longitudinal axis. Both views show a large difference in the size of the tendon in both planes.

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dle guidance to go around the Achilles tendon and apply some steroid, platelet-rich plasma or growth factors derived from newer composite amniotic tissue membrane. In examining the ankle joint as well as the other tendons that course the ankle, one may also use ultrasound to look for muscle tears as the transducer is moved up to the gastrocnemius/soleus muscles.

Tendons are evaluated in both the longitudinal and transverse planes. Tendon tears are easily seen in real time (live) and should be evaluated dynamically. In Figure 8 the anterior tibial tendon is depicted with a partial tear viewed in both planes.

Plantar Tear

Plantar plate tears and ruptures are very easy to diagnose on sonography. Some musculoskeletal-trained radiologists prefer ultrasound to MRI for evaluating plantar plate tears or ultrasounds. Using ultrasound one can evaluate the metatarsal head and the local structures. During this evaluation the plantar plate is noted as it travels distal and attaches to the base of the proximal phalanx. Both types of plantar plate pathology are evaluated dynamically where the clinician will dorsiflex the toe, causing the tear to widen. This type of evaluation cannot be performed under CT, MRI or radiographs. Avulsion fractures of the base of the proximal phalanx related to plantar plate injuries are easily seen under ultrasound while not seen on X-ray. Sonography can help differentiate pain due to a metatarsal bursitis, capsulitis, neuroma, medial and lateral collateral ligament injury and injury to the plantar plate. The modality provides a path for the proper diagnosis and treatment plan.

Dynamic maneuvers that allow for the diagnosis of tendon subluxations can only be validated and best observed using ultrasound.[8]

Musculoskeletal ultrasound can be extremely helpful in the evaluation of rheumatologic disorders.

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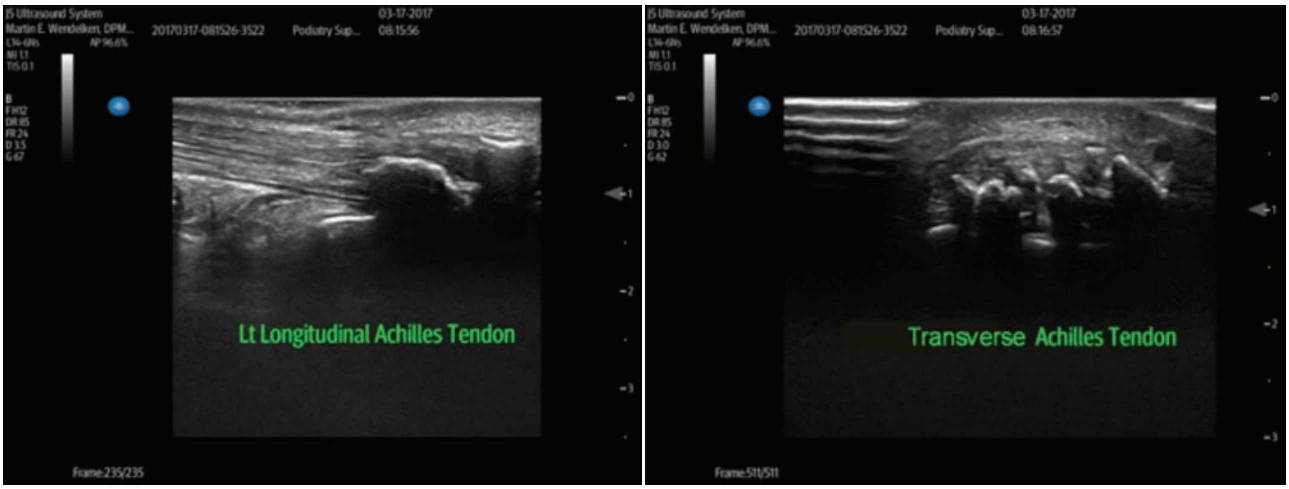

Figure 7: Above left—Longitudinal of the insertion of the Achilles tendon on retro-calcaneal surface reveals enthesophytes. Above left—The same tendon was imaged transversely and shows the number of enthesophytes on the calcaneus. Ultrasound provides better imaging of this pathology then radiographs.

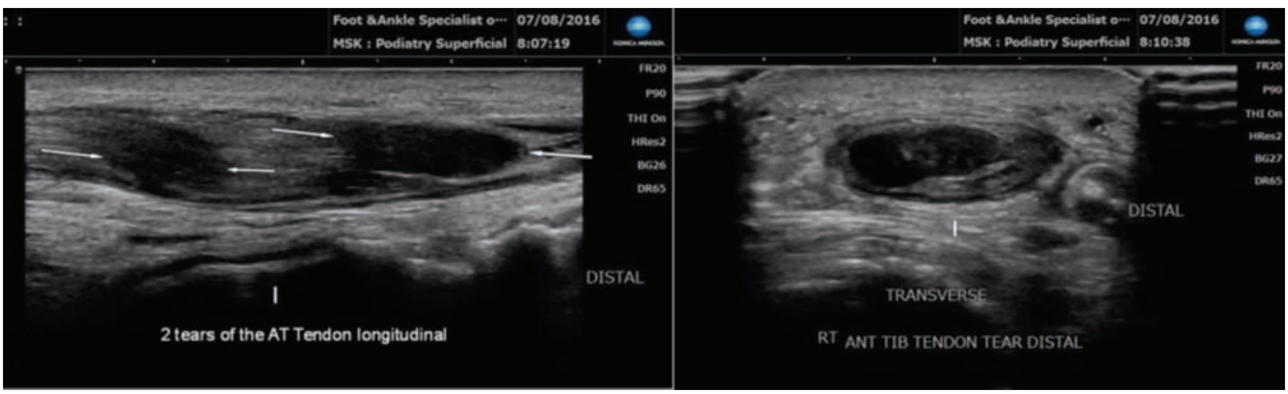

Figure 8: Above left—Longitudinal scan of the anterior tibial tendon reveals two partial tears noting the anechoic area within the tendon. Above right is a transverse scan of the anterior tibial tendon note the anechoic area easily visualized on the left side of the tendon.

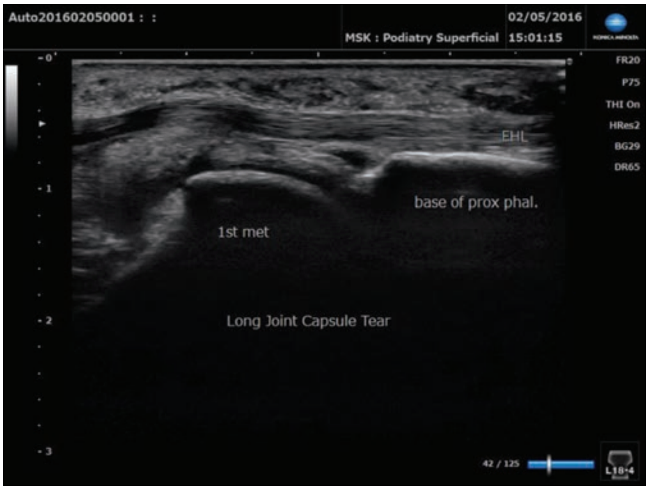

Figure 9: Longitudinal scan of the 1st MPJ with a plantar plate tear. The tear is located between the FHL tendon and the proximal end of the base proximal phalanx.

Figure 10: Patient presented with history of being treated for a ganglion cyst by a podiatrist who injected steroid into the lesion. After evaluation via ultrasound, it was noted that there was what appeared to be a heterogeneous mass with an arterial branch emanating from dorsalis pedis. Within minutes it was clear that this was not a cyst. Diagnosis—Synovial Sarcoma.

Figure 11: Transverse scan of Morton's Neuroma. Note the non-compressible hypoechoic are between the 3rd and 4th metatarsal. Clinical signs and symptoms along with diagnostic imaging confirm existence of a web space neuroma.

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Rheumatologic Disorders

Musculoskeletal ultrasound can be extremely helpful in the evaluation of rheumatologic disorders. Ultrasound reveals a double contour sign that is pathognomonic of gout. Erosions of rheumatoid arthritis can be seen very easily. If the patient has CPPD crystal deposition (Calcium Pyrophosphate Dihydrate) or chondrocalcinosis, clinicians can discover this using ultrasound. Other occult joint pathology such as synovitis, inflammation, abscess and infection will also be revealed.

Soft Tissue Masses

Sonography provides a simple method to differentiate masses from cysts. Cysts are anechoic soft tissue collections that are found in various locations on the foot and ankle. Physicians can quickly differentiate cysts from lipomas or fat. With ultrasound there will be no guessing regarding what you are dealing with; no blind aspiration of unknown masses need be performed. Ultrasound provides the answer live in real time.

Sonography provides a simple method to differentiate masses from cysts.

Ganglion cysts can be evaluated as to their etiology. Is the cyst emanating from a tendon or does it run deep to a joint? Clinicians, after the evaluation, can take a small needle under ultrasound guidance to insure that the cyst can be fully drained even if it is multilocular. Most importantly, diagnostic ultrasound with duplex imaging provides the ability to see if a mass has a vascular component leading to a diagnosis of a malignant tumor (Figure 10).[9] In this case imaging before aspiration will avoid accidently needling a sarcoma and potentially spreading the tumor.

Morton's Neuroma

Diagnostic Ultrasound is one of the best methods to confirm the existence of web space neuromas. MRI is not as accurate in the imaging of neuromas as an experienced clinician using sonography. At the same time, one should evaluate the structures adjacent to the interspace, including the MPJ's, for capsulitis, joint effusions, plantar bursitis and plantar plate issues. Neuromas appear as a hypo to almost anechoic mass that is non-compressible and shifts plantarly with lateral and medial compression (squeezing) of the forefoot (Mulder's sign).[10] Injection (longitudinally directly into the nerve via the distal web space) under ultrasound guidance is the best way to treat this mass. Serial

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sclerosing injections with dehydrated alcohol under ultrasound guidance is the most effective and safest way to insure the medication is delivered directly into the nerve (Figure 11). The authors of this article all concur with the literature indicating better results using ultrasound-guided injections vs injections without ultrasound guidance.

Conclusion

High-resolution diagnostic ultrasound can play an important role in the diagnosis of musculoskeletal pathology. Today ultrasound scanners have much higher resolution and image quality making it easier to learn and diagnose soft tissue pathology. In the hands of the podiatric physician, occult pathology is easily discovered during a typical office exam. The modality increases the diagnostic acumen while reducing costs when compared to other imaging methods. Ultrasound is painless and is considered a non-invasive imaging method. It is very safe and has no contraindications. It provides for static and dynamic evaluation of structures in addition to guidance for precision injections and foreign body removal. Like X-rays, diagnostic ultrasound is reimbursable. Patients greatly appreciate seeing live images on the screen during the diagnostic or treatment process. They also enjoy seeing confirmation of their presenting problem evaluated using ultrasound. **PM**

Today ultrasound scanners have much higher resolution and image quality making it easier to learn and diagnose soft tissue pathology.

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Dr. Pradeep Albert is a board-certified musculoskeletal-trained interventional radiologist who performs many diagnostic ultrasounds. He incorporates the modality when performing ultrasound-guided injections on all areas of the body. Dr. Albert completed his internship in internal medicine at Baylor College of Medicine in Houston, TX and his residency in radiology at St. Vincent's Hospital, New York, NY. He completed a fellowship in musculoskeletal radiology at the University of California at San Diego in 2003. In 2002, Dr. Albert was the recipient of the RSNA National Research Award. He is on staff and a board member at NY College of Podiatric Medicine.

Dr. Martin Wendelken was one of the first podiatrists to become significantly involved in the use of musculoskeletal ultrasound in podiatry. He has and continues to consult with a number of ultrasound companies, educates podiatrists in the field of sonography, and taught medical students (previous adjunct professor at TUSPM) diagnostic ultrasound. He has written numerous articles and performed numerous lectures in the field. Dr. Wendelken has also been awarded patents in the field of diagnostic ultrasound. Currently, he is working for 2020 Imaging as their ultrasound product specialist and their educational arm to podiatrists.

Dr. Kenneth Meisler is the owner of one of the largest podiatry practices in New York City. Dr. Meisler has held numerous positions including Co-chief, division of podiatry at New York Downtown Hospital and Director of Podiatric Medical Education and Director of Podiatric Residency Program at Beth Israel Medical Center. He is also on staff at New York Presbyterian-Weill Cornell Medical Center, Mount Sinai Medical Center and New York Downtown Hospital. He has been teaching residents for more than 35 years. He has gone from not using ultrasound for the first 25 years of his practice to making it an integral part of his practice for the last 15 years. Today, podiatrists frequently visit his office to see how ultrasound is utilized and to incorporate the modality in the office setting.

Dr.Ramy Elattal is an upcoming PGY1 resident at New York Presbyterian Brooklyn Methodist Hospital. He completed his Podiatric Medical training at Temple University School of Podiatric Medicine (Class 2016).