Ultrasound is an excellent tool for evaluating common ankle problems. It is more economical than MRI and its real-time nature helps in correlating the study with the symptomatic area. US can be used in ankle to evaluate tendons (including tears, tendinitis and tenosynovitis), joints, plantar fascia, ligaments, soft tissue masses, ganglion cysts, Morton’s neuroma, and to look for foreign bodies. Power Doppler can be used to evaluate blood flow in acute inflammatory process and in reflex sympathetic dystrophy.

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MUSCULOSKELETAL ULTRASOUND (US) has opened up new opportunities in the field of diagnostic ultrasound. US is easily available, economical, and portable. Its ability to be performed in real time helps in clinical correlation of the site of pain and comparison with the contralateral side. Movement of the tendons and joints can be directly visualized with dynamic US scanning. Structures such as tendons are better visualized with US than with MRI. Tendons appear as signal void on MRI but show a characteristic internal architecture on US.

This article reviews techniques and application of US imaging of the ankle and foot.

TECHNICAL ASPECTS

Among the different body areas that can be scanned by musculoskeletal US, we feel ankle US imaging is among the easiest. The tendons run parallel at the most commonly scanned areas and are readily accessible. However, having said this, it should be noted that it will take some practice becoming familiar with the normal appearance of tendons and other structures for one to eventually be able to diagnose pathologic conditions.

As is true in any ultrasound examination, high-resolution equipment is essential. This is especially true in musculoskeletal US, in which pathologies can sometimes be subtle. A high-frequency linear transducer should be used. The frequencies available range from 7 to 13 MHz. Though a 7-MHz frequency linear transducer will usually suffice, a 10- to 13-MHz frequency broadband linear transducer is desirable and will make a significant difference in diagnostic confidence. The transducer should be placed directly on the skin with an acoustic coupling gel; no stand-off pad is necessary.

The ultrasound equipment presets that are suitable for musculoskeletal imaging should be created. Though new machines or updated software versions on the older machines might have the preconfigured musculoskeletal presets, it might become essential for one to tune the parameters (such as gray-scale maps, persistence, line density, and so on) for optimal tendon visualization.

NORMAL ANKLE TENDONS

Routine examination of the ankle tendons is begun with the patient in the prone position and the foot hanging off the examination table. We find this approach gives easier access to the posterior, medial, and lateral aspects of the ankle where most of the commonly imaged tendons of the ankle reside.

On US, a normal tendon appears as fine parallel echogenic lines alternating with thinner hypoechoic lines caused by the longitudinally oriented collagen fibrils. (Fig 1A) Though image optimization should be performed as in any other US study, one pitfall common in musculoskeletal (MS) US should be kept in mind: While scanning, it is important to make sure that the US beam is perpendicular to the tendon structure. This will ensure that normal fibers appear echogenic. If the US beam that hits the tendon fibers is not perpendicular, the tendon might appear hypoechoic. This is called anisotropy (Fig 1B). This artifact might lead to the erroneous diagnosis of abnormal tendon. Anisotropy can be corrected with heel-toeing the transducer to align the tendon fibers perpendicular to the beam.

For simplicity, the commonly imaged tendons around the ankle can be divided into groups based on anatomic site:

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Achilles tendon. The Achilles tendon is the largest tendon in the body and its function is to plantar flex the ankle. The US study is begun with the patient in the prone position. The tendon is first imaged in the longitudinal plane from its origin at the gastrocnemius and soleus muscle to its insertion on the calcaneus (Fig 2A,B). In this view, the Achilles is surrounded by 2 hyperechoic lines. This is the paratenon.\(^1\) The Achilles tendon has no sheath. Dorsiflexion of the ankle helps to stretch the Achilles tendon and keep it straight during scanning. The retrocalcaneal bursa is visualized at the insertion of the Achilles tendon on the calcaneus (Fig 2B); normally it measures less than 2.5 mm.\(^2\) The Achilles is then examined in the transverse plane, in which it is seen as elliptical in shape (Fig 2C). The size of the normal Achilles tendon depends on the gender and habitus of the patient and is approximately 5 to 6 mm in the anteroposterior diameter.\(^3\) Other structures seen from this posterior approach include the pre-Achilles (Kager’s) fat pad, the flexor hallucis longus muscle and posterior ankle joint recess.

**Medial Tendons**

Posterior tibial (PTT), flexor digitorum longus (FDL) and flexor hallucis longus (FHL). The PTT, FDL, and FHL are the primary adductors and inverters of the foot. With the patient still in the prone position, the transducer is placed directly behind the medial malleolus (Fig 3A). The transverse plane is imaged first because it helps get one oriented to the relative size and positions of the PTT and the FDL, which lie side by side (Fig 3B). The posterior tibial tendon measures about 4 to 6 cm in diameter.\(^1\) The FDL tendon is about two thirds the size of PTT and, though not commonly injur, serves as a good size comparison for the PTT. The PTT is the most anterior, followed by the FDL tendon, the neurovascular bundle, and the FHL. The FHL is not part of the routine US study because it is rarely injured, but can be imaged if there is a strong clinical suspicion.

The above tendons are then imaged in the longitudinal plane. The PTT is imaged first. The scan is started at the proximal portion of the PTT above the medial malleolus (Fig 3C), the transducer is then slid distally to follow the PTT around the medial malleolus, up to the insertion at the navicular bone. (the navicular physically can be felt

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**Fig 1.** Normal tendon appearance. (A) Normal anterior tibial tendon shows fine parallel echogenic lines alternating with hypoechoic lines. (B) When the US beam hitting the tendon is not perpendicular the tendon appears hypoechoic (arrowheads). This is called anisotropy.

**Fig 2.** Achilles tendon. (A) Scanning technique for the Achilles tendon. (B) Normal appearance of the Achilles tendon in longitudinal and (C) transverse axis. (c, cortical echo of the calcaneus).
Fig 3. Medial ankle tendons. Posterior tibial tendon and flexor digitorum longus: (A) scanning technique. (B) Normal appearance of PTT 'p' and FDL 'f' in transverse at the level of the medial malleolus 'M'. (C) Longitudinal scan of PTT at medial malleolus.

as a prominent bony protrusion distal to the medial malleolus). It should be noted that the PTT fans out at this insertion site; hence it might appear hypoechoic. This anisotropy should not be confused with an abnormality. Then this distal part of the PTT also can be imaged in the transverse plane. Up to 4 mm of fluid has been reported around the distal PTT in normal volunteers. 2

The FDL and the FHL are not commonly abnormal but can be examined scanning posterior to the PTT. The FHL can be followed as it courses under the sustentaculum tali, and all the tendons can usually be followed to their respective insertion sites in the foot.

Lateral Tendons

Peroneus longus (PL) and peroneus brevis (PB). The PL and PB are routinely examined. The primary function of the PL and PB is abduction (eversion) of the foot. The tendons are examined in a manner similar to that of the medial tendons. First, a transverse scan is performed to visualize the tendons; they lie just posterior to the lateral malleolus. Both the tendons are stacked one above the other like pancakes (Fig 4A,B). Transverse and longitudinal scans of the supramalleolar and inframalleolar portions of the tendons are performed. Normally, some fluid might be seen (up to 3 mm) within the common peroneal sheath. 3

Anterior Tendons

The anterior tibial tendon (ATT), the extensor hallucis longus (EHL) and the extensor digitorum longus (EDL). These tendons can be evaluated. The primary function of these anterior tendons is

Fig 4. Lateral ankle tendons. Peroneal tendons. (A) Transverse US of Peroneus longus 'l' and brevis tendon 'b' at the level of lateral malleolus 'LM'. (B) Longitudinal US of the peroneal tendons. Note the tendons are stacked one on top of another.
extension or dorsiflexion of the ankle. The ATT, which can be felt as a prominent tendon, is scanned in longitudinal (Fig 1) and transverse view. One may scan other tendons if a strong clinical suspicion exists.

ANKLE TENDON PATHOLOGIES

Achilles Tendon

The Achilles is the most commonly injured ankle tendon. US is useful in the diagnosis of tendinitis and complete and partial tears of the Achilles tendon. The most frequent site of rupture is the zone of relative avascularity located 2 to 6 cm proximal to the calcaneal insertion. Complete tear of the Achilles appears as a focal, complete discontinuity in the normal fibrillar pattern of the tendon. With acute tears, the torn area is often filled with hematoma and appears heterogeneous (Fig 5A,B). Herniation of the Kager's fat into the defect can sometimes be seen with complete rupture (Fig 5A). With complete tendon tear, the extent of the gap should be measured with foot in dorsi and plantar flexion. Diastasis of the tendon stumps in plantar flexion is used as an indication for surgical repair, whereas complete approximation in plantar flexion is treated conservatively. In chronic rupture, the tendon discontinuity is filled by echogenic granulation tissue. A partial Achilles tear might be intrasubstance and appear as hypoechoic foci within the tendon (Fig 6). These tears might extend to the tendon surface and be accompanied by paratenonitis, that is fluid and inflammation in the paratenon surrounding the tendon.

In acute tendinitis, the Achilles tendon appears swollen and hypoechoic, either focally or diffusely (Fig 7). There might be associated paratenonitis, presenting as a hypoechoic ring around the tendon. Chronic Achilles tendinitis usually occurs secondary to repetitive trauma and the tendon appears...
thickened and heterogeneous. Nodular hypoechoic areas or calcifications also can be seen (Fig 8). US can be valuable in detecting Achilles tendon xanthomas in patients with heterozygous familial hypercholesterolemia. US appearance ranges from a single hypoechoic nodule to diffusely enlarged, heterogeneously hypoechoic tendon. US can show the presence of hypoechoic xanthomas before they become clinically apparent. Abnormality of the retrocalcaneal bursa usually can be seen as distention (> 3 mm) and is frequently caused by inflammation or hemorrhagic bursitis. (Fig 9).

**Posterior Tibial Tendon (PTT)**

Of the 3 medial tendons, PTT is most commonly affected by pathologic processes. Tendinitis/tendinosis and tenosynovitis are the most frequent abnormalities. Clinically, PTT dysfunction is the most common cause of asymmetric flatfoot deformity. Other presentations include medial ankle pain, hindfoot valgus, and forefoot abduction. US has been shown to have sensitivity of 100%, specificity of 88%, and accuracy of 93% in detecting of ankle tendon pathologies, mainly that of the PTT. PTT tears most commonly occur just distal to the medial malleolus, followed by the insertion on the navicular. Chronic tear from repetitive injury is more common than acute tear.

On US, complete tear is seen as disruption of the tendon fibers, with the gap filled by hematoma. Partial tears of the PTT can be either perpendicular or parallel to the long axis of the tendon (Fig 10). Partial PTT tear appears as a linear hypoechoic area within the substance of the tendon, often correlating with the focal tenderness. Accompanying fluid in the tendon sheath might be seen and, if markedly asymmetric, should be considered abnormal. If PTT tendinitis is accompanied by abnormal fluid in the tendon sheath, the process is properly termed as tenosynovitis, indicating inflammation of the tendon and its surrounding sheath (Fig 11). Tenosy-
Fig 11. Posterior tibial tendon tenosynovitis. Transverse scan of the PTT shows fluid distending the tendon sheath. The tendon itself is slightly heterogeneous but otherwise normal. (T, tibia)

Tenosynovitis might result from systemic inflammatory conditions (arthritis, inflammation, gout, and so on) or mechanical factors such as overuse. In tenosynovitis, despite the surrounding fluid, the tendon itself can appear sonographically normal. Thickening of the PTT tendon can be seen, which might be focal or might extend throughout the length of the tendon. PTT thinning has been seen in rheumatoid arthritis, though there is considerable overlap with control subjects.

Peroneal Tendons (Longus and Brevis)

The common problem seen with the peroneal tendons is subluxation. Subluxation or dislocation of the peroneal tendons is caused by injury to the superior peroneal retinaculum, which is often secondary to a calcaneal fracture or avulsion fracture of the lateral malleolus. A congenital flat or convex fibular groove also can cause dislocation. Inflammation of the peroneal tendon sheath can sometimes be seen (Fig 12).

US provides the advantage of dynamic scanning. US is performed while simultaneously dorsiflexing and evertmg the ankle. Subluxation is diagnosed if one or both the peroneal tendons are seen lateral and/or anterior to the lateral malleolus.

Peroneal tendon tears are relatively rare. A longitudinal partial tear (called a split) is usually seen and is more common in the peroneus brevis, because of increased stress on this tendon as it is trapped between the PL and the fibula.

Anterior tibial tendon pathology is rare, likely because of the absence of a bony fulcrum and a strong vascular supply to the ATT. A closed spontaneous rupture might occur. Sometimes a tear or inflammation can be caused by trauma. The tendon then appears hypoechoic and is thickened (Fig 13A,B).

OTHER ASPECTS OF ANKLE ULTRASOUND

Plantar Fasciitis

Sometimes a patient presents with the ankle pain, but when asked specifically about the site of pain will point to the plantar aspect of the foot. Plantar fasciitis is reported to be the most frequent cause of inferior heel pain. US is performed with the patient in prone position and the fascia is scanned in the longitudinal axis. The normal fascia has a fibrillar echotexture and measures about 3 to 4 mm in thickness (Fig 14A). In plantar fasciitis, a mean thickness of 5.2 mm has been shown (Fig 14B).

Ankle Joint

The anterior joint can be examined with ultrasound in the longitudinal plane. The normal joint capsule is hyperechoic and adjacent to the anterior tibial margin and hypoechoic cartilage of the talar
Fig 13. Anterior tibial tendon rupture. (A) Longitudinal scan shows the tendon (arrows) is thickened and heterogeneous with loss of normal tendon architecture indicating full-thickness tear. (B) Transverse scan shows the thickened tendon (ATT). Note the size relative to the adjacent normal tendons. EHL, extensor hallucis longus; EDL, extensor digitorum longus.

dome (Fig 15A). A small amount of fluid (up to 3 mm) normally can be seen in the anterior recess.

On US, a simple joint effusion can be shown as anechoic fluid (Fig 15B), whereas a complex effusion appears as heterogeneous fluid collection. A complex fluid collection can be caused by infection, inflammatory, or metabolic conditions. Other causes include intra-articular hemorrhage, pigmented villonodular synovitis, or synovial osteochondromatosis. US is also useful in showing intra-articular loose bodies. The loose bodies appear as echogenic foci that move within the joint capsule in real time.

Ligaments

The anterior talo-fibular ligament is the most commonly injured ankle ligament. Injury can be caused by external rotation force on the tibio-talar syndesmosis. Though diagnosis is usually made clinically or by radiograph showing an avulsion bony fragment, US can be helpful to confirm the diagnosis. Normal ankle ligaments appears echogenic (Fig 16A), but appear thickened and hypoechoic when injured (Fig 16B). A complete tear appears as a hypoechoic gap through the ligament.

Soft Tissue Masses

US is useful in evaluating different soft tissue masses in the ankle. US can differentiate a solid from a cystic mass and help determine its size, shape, and, occasionally, its origin from a specific joint or tendon sheath. On US, a cyst will be anechoic, have a smooth posterior wall, and show increased through transmission. Commonly seen cystic lesions are synovial or ganglion cysts. Other masses that can be seen by US are lipomas, abscesses, vascular masses (like hemangiomas, arteriovenous malformation [AVM]), and so on.

Ganglion Cysts

Ganglion cysts are very common in the ankle and dorsum of the foot, second only to the hand and wrist in frequency. Ganglia might present as asymptomatic masses and might be painful. They
Fig 15. Anterior ankle joint. (A) Normal tibiotalar joint is hyperechoic with hypoechoic cartilage (arrowheads) of the talar dome. Cursors show anterior tibial tendon. (B) Small effusion (arrow) is seen.

Fig 16. Anterior talo-fibular ligament. (A) Normal ligament (cursors). (B) Thickened and hypoechoic ligament (cursors) is seen at the site of the pain on the contralateral side.

Fig 17. Ganglion cyst. Palpable and tender lesion on the medial aspect of the ankle shows presence of a cyst with internal echoes (arrowhead) consistent with ganglion.

Fig 18. Morton's neuroma. Transverse scan of the foot shows an hypoechoic lesions (arrowheads) in the third web space. 3, third metatarsal; 4, fourth metatarsal.

Ganglion cysts are fluid-filled nontumorous structures with a synovium-like lining and a fibrous capsule. On US they appear anechoic (Fig 17), but might contain internal echoes when they are inflamed or have undergone hemorrhage. When ganglia are large and have been present for a long time, they might cause scalloping of the underlying bone.

Morton's Neuroma

Morton's neuroma is a benign mass of perineural fibrosis affecting the plantar digital nerve. The most common cause involves repetitive trauma or mechanical compression (eg, use of high-heeled shoes). Morton's neuroma is most commonly seen in middle-aged patients; more than 80% are women. Patients usually present with pain and paresthesias with walking. The most common location is the third web space, followed by the second web space, with fewer than 10% seen in the first
Foreign Bodies

Foreign bodies from penetrating injuries are common in the foot. Foreign bodies include glass, wood, and metal. US is an excellent method for detecting radiolucent foreign bodies. Foreign bodies can be detected by the echoes they produce. Sometimes a distal acoustic shadowing is seen and, in case of metal objects, a comet-tail reverberation artifact can be seen. A hypoechoic halo sometimes can be seen around the foreign body and can aid in localizing the foreign body (Fig 19). US has been shown to have an accuracy of 92%, sensitivity 90%, and specificity 97%. Foreign bodies as small as 1 mm × 0.5 mm have been localized with US.\(^\text{34}\)

Applications of Power Doppler (PD) US:

PD can be an additional tool in diagnosing musculoskeletal abnormalities. Increased power Doppler flow can be seen in acute inflammatory process (Fig 20 A,B).\(^\text{35}\) Increased power Doppler flow has been shown in soft tissues of patients with reflex sympathetic dystrophy.\(^\text{36}\)

CONCLUSION

US is emerging as a new modality for musculoskeletal imaging. US can be performed faster and at lower expense than MRI, and its excellent showing of the tendon structure should make US the first-line modality for evaluating ankle tendons. A focal dynamic examination of the symptomatic area with clinical correlation helps pinpoint the diagnosis. Though US is highly user-dependent, its applications in musculoskeletal US will definitely increase as more experience is gained. We have found that getting the referring physicians involved in the US study has helped increase the awareness of the availability of this new diagnostic modality.

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