Ultrasound of Ankle and Foot: Overuse and Sports Injuries

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ABSTRACT

Sports and overuse injuries of the ankle and foot are commonly encountered in clinical practice. Ultrasound (US) has been established as an excellent diagnostic modality for foot and ankle injuries, providing a rapid noninvasive, economical, and readily available tool that is well tolerated by the patient with acute or chronic pain. The opportunity for dynamic examination is another advantage of US in evaluating ankle and foot pathology, where maneuvers such as muscle contraction and stressing of the joint may be particularly helpful. In many cases, US can be used as a first-line and only imaging modality for diagnosis. This article focuses on ankle disorders related to sports or overuse that affect tendons, including tendinosis, tenosynovitis, paratendinitis, rupture, dislocation, and ligaments that are commonly torn. The sonographic features of certain common foot disorders related to physical activity and overuse are also discussed, including plantar fasciitis, Morton's neuroma, stress fractures, and plantar plate injury.

KEYWORDS: Ultrasound, ankle tendons, ankle ligaments, musculoskeletal sports injuries

Ultrasonography (US) has been widely accepted as an effective method for assessing musculoskeletal disorders.[1] Technological refinements with higher resolution transducers have made possible the evaluation of small superficial structures of the ankle and foot with higher spatial resolution than magnetic resonance imaging (MRI), making US a competitive modality for the evaluation of tendons and ligaments. Moreover, a US examination can be performed at 19% the overall professional and technical cost of a MRI study of the same anatomical region.[2]

US can evaluate ankle ligament and tendon pathology with accuracy,[2,3] as well as a wide variety of foot disorders related to physical activity and overuse. Application of various dynamic maneuvers may be of great value in the diagnosis of ankle and foot lesions. Moving or applying a stress on the ankle joint stretches specific structures and can depict a morphological abnormality that is not visible in the static position.[4] It may also depict an intermittent process such as a tendon dislocation or an impingement phenomenon.[5] The use of color and power Doppler may aid diagnosis by revealing neovascularization due to inflammatory or fibrovascular reparative processes. Because US anatomy and technique of examination have already been recently covered in a dedicated article,[2] we focus on the US features of ankle and foot pathology related to sports and overuse injuries, highlighting the use of dynamic examination.

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TENDONS OF THE ANKLE

The prevalence of tendon injuries has increased substantially in recent years.[6,7] In the setting of acute trauma, tendon injuries can be challenging to diagnose on physical examination due to swelling and pain. US is well tolerated by the acutely injured patient and provides an accurate mean for evaluating ankle tendons.[3,8–10] Indeed, US can detect more subtle injuries to ankle tendons than MRI[11] because of its superior spatial resolution.[12] Moreover, evaluation of the tendons can be done sequentially along their entire course rather than being restricted to the three orthogonal planes of a routine MRI examination. This is an important advantage given the abrupt change in direction of tendons at the level of the ankle, which may make their evaluation with MRI more difficult because of the magic angle effect. Scanning from the myotendinous junction to the insertion of the tendon, in both transverse and longitudinal planes, is essential for a proper assessment and can be done routinely with US. In the transverse plane, normal tendons are round or ovoid and have a speckled hyperechoic echotexture. In the longitudinal plane, the US probe must be properly positioned parallel to the tendons to obtain the typical fibrillary pattern of hyperechoic lines.[13] Any obliquity of the transducer surface relative to the tendon can render the internal structure hypoechoic because of anisotropy and mimic pathology.[14] This anisotropy may be evident as the tendons curve around the ankle, where the sonographer has to adjust the transducer position carefully to accommodate progressively to the tendons' change in orientation. The proper perpendicular plane can be found by rocking the transducer or, alternatively, by keeping the transducer fixed while moving the joint or actively contracting the muscle of the studied tendon.

Overuse and traumatic lesions of the ankle tendons include tendinosis, tenosynovitis, stenosing tenosynovitis, rupture, and dislocation, and they have the same sonographic features as elsewhere in the body. Signs of tendinosis include thickening of the tendon, focal or diffuse areas of hypoechogenicity, and loss of the fibrillar appearance in the longitudinal plane.[1,13] It may occasionally be difficult to differentiate an area of tendinosis from a small partial-thickness tear on US. Tenosynovitis is accompanied by fluid in the tendon sheath circumferentially and/or hypervascularized synovitis, appearing as a "target sign" in the axial plane and a "railtrack" appearance in the longitudinal one.[15,16] Nazarian et al have reported that thin amounts of fluid, sometimes > 1 mm, can be found in the posterior tibial or peroneal tendon sheaths in an asymptomatic population. Moreover, this pattern was unilateral in 25 to 30% of cases, thus making comparison with the contralateral side less reliable.[16]

Partial-thickness tears appear as linear or globular hypoechoic areas within the substance of the tendon, with lack of tendon retraction.[10] At the ankle, they are frequently longitudinally oriented and are best depicted in the transverse plane.[17,18] Complete tears appear as disruption of fibers in the longitudinal plane, with retraction of the proximal end and filling of the gap by hematoma, granulation tissue, or fibrotic scar, depending on the chronicity of the lesion.[19,20]

Peroneal Tendons

Lesions of the peroneal tendons may be due to acute trauma or overuse, resulting in tenosynovitis, tendinosis, rupture, or dislocation. US is highly effective in the diagnosis of peroneal tendon injury, with 100% sensitivity, 85% specificity, and 90% accuracy, and it could be used as a first-line imaging test for peroneal tendon evaluation.[21] Predisposing factors to peroneal tendon pathology include anatomical variants such as hypertrophy of the peroneal tubercle or retrotrochlear eminence,[22,23] peroneus quartus muscle, low-lying peroneus muscle belly, flat or convex fibular groove, os peroneum, lax superior peroneal retinaculum, as well as acquired conditions, such as altered foot mechanics (e.g., due to tarsal coalition[24]), orthopaedic hardware complications, and post-traumatic distal fibular or calcaneal osseous abnormalities.[25]

The most common peroneal tendon abnormalities are tenosynovitis and tendinosis. Tenosynovitis is common in the athletic population,[24,26] being notably associated with acute inversion injuries and overuse with chronic lateral ankle instability.[27,28] As mentioned earlier, a thin layer of effusion within the tendon sheath can be normal,[29] whereas circumferential involvement with hypoechoic fluid or hypoechoic synovial tissue is more typical of tenosynovitis (Fig. 1). Fluid in the tendon sheath of the peroneal tendons may also be an indirect sign of calcaneofibular ligament disruption rather than tenosynovitis. Peroneal tendinosis may also be acute or chronic and signifies a more advanced injury than tenosynovitis.[24]

Peroneal tendon tears are more commonly longitudinal partial-thickness tears than full-thickness tears,[21] and they more commonly involve peroneus brevis than longus.[26] The peroneus brevis split may be secondary to acute trauma in young individuals, or may be chronic, especially in the older population, where these splits may be asymptomatic.[30] Peroneus brevis splits usually arise in the retromalleolar groove and may extend proximally or distally. They may be seen without[31] or with[32–34] peroneal retinaculum disruption. On US, longitudinal splits of peroneus brevis appear as intrasubstance linear hypoechoic foci in both axial and longitudinal planes.[17,18] The peroneus longus tendon usually insinuates within the tear, preventing healing. Tears are more conspicuous on US when there is fluid in the tendon sheath. Peroneus quartus, a common accessory muscle, can be confused

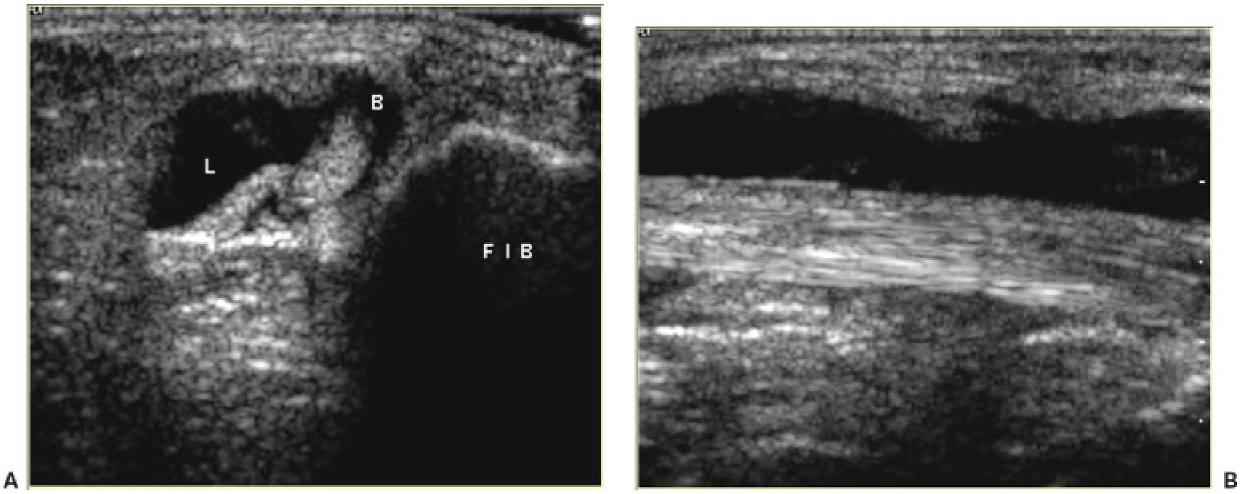

Figure 1 Peroneal tenosynovitis. (A) Transverse and (B) longitudinal scans show a large amount of fluid distending the peroneal tendon sheath, with areas of mixed echogenicity in keeping with synovitis. Tendons are normal. B, peroneus brevis tendon; L, peroneus longus tendon; FIB, distal fibula.

with a peroneus brevis split; this possible pitfall can usually be avoided by exploring the tendon along its entire trajectory.[22,29,35]

Peroneus longus tears are more common in middle-age athletes.[26] They may be either associated with peroneus brevis tears within the retromalleolar groove[17,18,36] or be isolated at the level of the midfoot.[22] A fractured or posteriorly dislocated os peroneum may be associated with peroneus longus tears and can also be diagnosed by US.[19,37] Complete discontinuity and retraction of the proximal segment can be demonstrated by US indicating complete peroneal longus tendon rupture.[19]

Peroneal tendon dislocation is usually post-traumatic in origin and may be acute or chronic recurrent. The mechanism of injury is a sudden dorsiflexion and eversion of the ankle with injury to the superior peroneal retinaculum or its insertion.[38] It is an intermittent phenomenon in most cases[17] and thus may be diagnosed by MRI only through indirect signs.[39,40] With its dynamic capabilities, US plays a significant role in the depiction of peroneal tendon dislocation, and a standardized method has been reported.[3,17] The patient lies in the lateral decubitus position to expose the lateral aspect of the examined ankle. With the probe focused on the retromalleolar groove in the transverse plane, the foot is actively or passively dorsiflexed and everted while the sonographer applies an opposing force on the lateral aspect of the hindfoot.[5,18,33] Peroneus brevis, peroneus longus, both, or only one bundle of a longitudinally split tendon may dislocate anteriorly.[5,17] Peroneus brevis remains the most vulnerable to dislocation due to its anterior position within the fibular groove. The tendons may also remain in the fibular groove but reverse position on each other, a condition termed "retromalleolar intrasheath subluxation" that is essentially only diagnosable by dynamic US[17,41] (Fig. 2).

The Anterior Tendons

Pathology of the anterior tendons is uncommon, likely due to their straighter course that subjects them to less

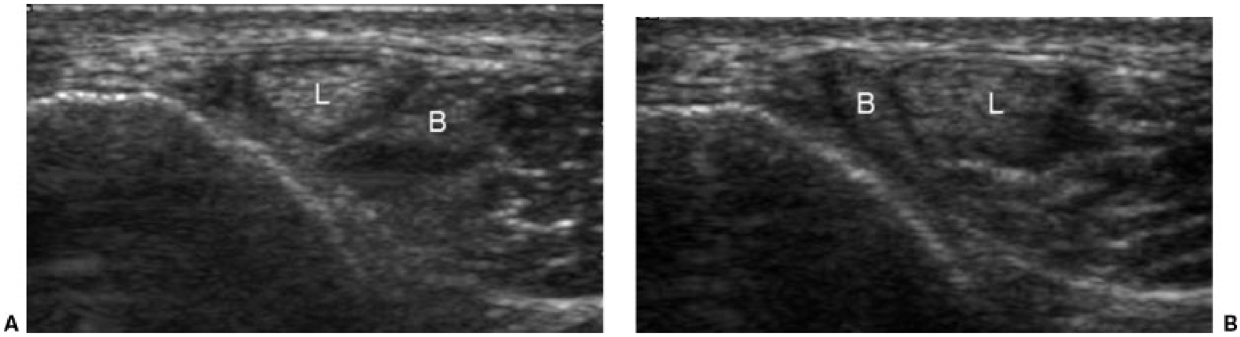

Figure 2 Peroneal intrasheath subluxation. Transverse scans during ankle dorsiflexion and eversion (A) and at rest (B) showing the peroneal tendons reversing position on each other while remaining in the fibular groove. B, peroneus brevis tendon; L, peroneus longus tendon. The distal fibula is on the left of the images.

mechanical stress.[42] Anterior tibial pathology is usually located within 3 cm from the distal insertion of the anterior tibial tendon, where the tendon passes beneath the inferior extensor retinaculum.[43,44] The presence of a hypovascular zone in this area as an explanation is controversial.[44,45] Mechanical irritation has been proposed as a cause[44] because lesions are associated with impingement of the tendon against tarsal bony abnormalities (such as navicular spur, a ridge shape of the medial aspect of the medial cuneiform bone, or an osteophyte at the medial aspect of first tarsometatarsal joint)[44] or under the oblique superomedial limb of the inferior extensor retinaculum.[46] Tenosynovitis and tendinosis of the anterior tibial tendon are more prevalent than tendon tears, and they are an underestimated cause of dorsomedial chronic pain of the foot in older individuals.[47] Tendon tears may have a history of a minor trauma with forceful plantar flexion.[47,48] Closed acute tears of anterior tibial tendon during sport activity is very rare, with only isolated cases reported.[48,49] Acute ruptures may also be secondary to laceration and fractures.[50,51] Lesions due to arthroscopy or impingement with orthopaedic hardware[52] or ankle prosthesis[25] have also been reported. Clinical diagnosis of anterior tibial tendon rupture is often delayed. A complete rupture may have the confusing clinical appearance of a firm lump at the anterior aspect of the ankle,[47] especially when ankle dorsiflexion and eversion are partially preserved because of the action of extensor hallucis longus and extensor digitorum longus.

With anterior tibial tendinosis, the tendon increases in size and becomes hypoechoic on US. Distally, the tendon looses its flattening along the dorsal aspect of the tarsal bones (Fig. 3). At this site, a 5-mm thickness has been proposed on MRI as the threshold value to make the diagnosis of tendinosis or partial tear.[44] A less well-known distal enthesopathy or tendinopathy of the anterior tibial tendon may be a cause of chronic medial midfoot pain and may well be demonstrated by US.[3,53] US can confirm the diagnosis of a complete anterior tibial tendon tear by showing a hypoechoic zone within the tendon with discontinuity of the fibers.[20,53] US is also well suited to demonstrate tendon impingement during tendon motion and any underlying osseous abnormality.[25] It should be noted that a longitudinal split within the distal part of the tendon has been described in asymptomatic volunteers using MRI and could, in some instances, represent a normal variant.[44]

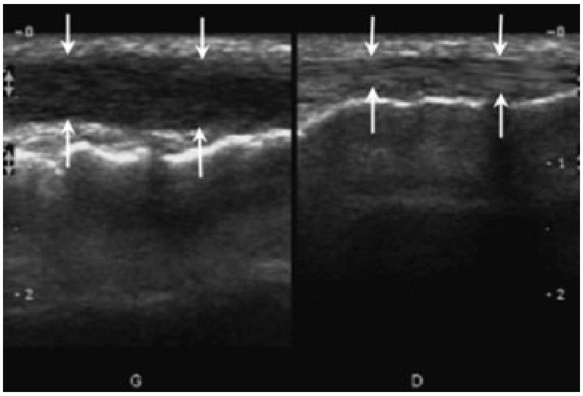

Figure 3 Anterior tibial tendinosis. Sagittal scans of the anterior tibial tendon (arrows) bilaterally. On the right is marked thickening and hypoechogenicity of the tendon, with effacement of its fibrillar pattern. On the left is the normal side for comparison.

Lesions of the extensor hallucis longus tendon and extensor digitorum longus tendon are infrequent because these tendons are also subject to low mechanical stress. Friction with shoes or impingement with underlying degenerative or post-traumatic osseous remodeling is reported to be a cause of tenosynovitis.[3] Dynamic sonography with plantar flexion may show an impingement between extensor digitorum longus tendon and a dorsal talar ridge.[25] Extensor retinaculum tears have only occasionally been reported and can lead to extensor tendon dislocation,[54,55] but to our knowledge no US description has yet been published.

Tendons of the Tarsal Tunnel

The posterior tibial tendon (PTT) is the most powerful foot inverter and a fundamental stabilizer of the medial longitudinal arch. Pathology of the PTT is most typically seen in obese middle-age patients (more commonly women) presenting with a progressive flatfoot deformity. Acute and chronic tenosynovitis initially occurs, followed by partial then complete rupture. Sports-related PTT injury most commonly presents as acute tenosynovitis related to overuse;[56] tendon rupture is uncommon.[57] An accessory navicular bone predisposes to PTT tears.[58]

PTT dysfunction is a common but often missed diagnosis that may lead to severe disability.[59,60] Imaging plays a useful role in the diagnosis and classification of PTT injury because early diagnosis is key to a successful outcome.[61] US is highly effective in the diagnosis of PTT lesions and has comparable or greater sensitivity and accuracy compared with MRI.[10,62,63] One study found US to be slightly less sensitive than MRI, but the discrepancies did not affect clinical management.[64]

PTT pathology shares similar features with peroneal tendon pathology[15,62] (Fig. 4), although longitudinal splits and dislocations[65] are less common. Chronic tears most commonly occur behind the medial malleolus, whereas tears in young athletes are usually at the navicular insertion.[56] US can identify cortical thickening and irregularity in the tendon groove that sometimes accompany chronic PTT tendinopathy. In the axial plane, the mean diameter of PTT is about twice that of its neighboring flexor digitorum longus

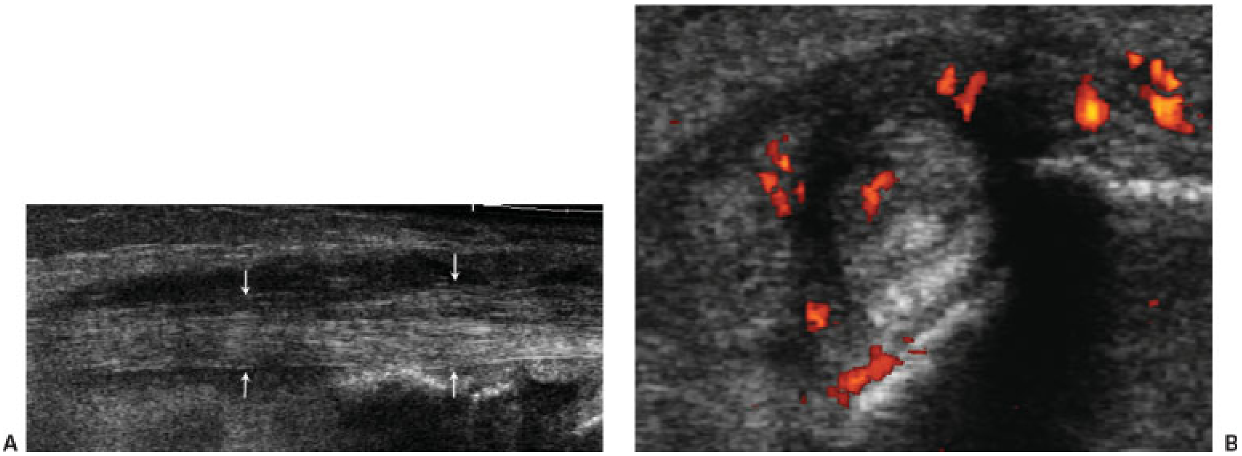

Figure 4 Posterior tibial tenosynovitis and tendinosis. (A) Panoramic longitudinal and (B) transverse scans of posterior tibial tendon show fluid distending the tendon sheath and associated tendinosis, with tendon thickening (arrows) and heterogeneous echotexture and probable intrasubstance longitudinal partial tears. Color Doppler in (B) shows increased blood flow to the region.

tendon (FDLT).[66] A PTT diameter that is great than twice that of FDLT indicates tendinosis, whereas a same or lesser diameter indicates stretching and elongation of PTT, a form of partial tear. In the presence of a complete retracted chronic PTT tear, a pitfall to avoid is the anterior displacement of the FDLT at the level of the malleolus, which can mimic normal tendon. At its navicular insertion, the fibrillary pattern of the tendon is normally lost because of anisotropy caused by the fanning fibers; the diagnosis of insertional tendinosis or partial tear can be raised, however, if there is tenderness or pain on scanning this region. The FDLT is not known classically to suffer from any sport-related or overuse condition.

The flexor hallucis longus tendon (FHLT) is vulnerable to injury because it passes through a fibro-osseous tunnel between the medial and lateral talar tubercles. Disease of the FHLT is most often found in athletes who perform sports that require extreme plantar flexion, notably ballet dancers and soccer and basketball players.[67,68] Repeated friction in the tarsal tunnel can lead to acute tenosynovitis, stenosing tenosynovitis, and tendinosis.[68] Predisposing factors for FHLT disease include the presence of an os trigonum or local post-traumatic osseous changes.[69] This tendon has been involved in the posterior impingement syndrome of the ankle, in association with tibiotalar and subtalar synovitis.[69] FHLT pathology may also be seen at the plantar aspect of the foot at the level of Henry's knot (the anatomical crossover between FHL and FDLT).[67] More rarely, the FHLT may be avulsed at its distal insertion on the hallux as a result of dorsiflexion injury. Despite its deep position, the FHLT can be followed in the longitudinal plane using sagittal scanning. Recognition of its fibers is made easier by scanning dynamically, that is, during active or passive flexion and extension of the hallux.

Achilles Tendon

The Achilles tendon (AT) is the longest and strongest tendon of the body. In contrast to the other ankle tendons, the AT lacks a synovial sheath but has a thin vascular membrane called the paratenon. Of all the overuse tendon lesions, AT injuries are most closely related to sports.[6,7] These injuries are most commonly seen in running, track and field, soccer, tennis, and badminton.[7,70,71] The mechanism of injury involves a sudden dorsiflexion of the plantar-flexed foot or, less commonly, a direct blow to the posterior ankle. The spectrum of lesions includes acute and chronic paratendinosis, tendinosis, and rupture, the latter usually occurring 2 to 6 cm above the calcaneal insertion. Achilles tendon lesions may also be insertional (i.e., found at the calcaneal insertion). There may be associated retrocalcaneal bursitis with or without Haglund's disease,[67] which may be related to ill-fitting shoes, overuse, and/or a prominent posterosuperior calcaneal tuberosity (the Haglund deformity).

The US evaluation of the AT has been extensively studied.[72–75] Peritendinosis can be present with or without tendinosis and manifests as poorly defined tendon margins, with thickening of the surrounding soft tissues, with or without semicircular fluid accumulation[75] (Fig. 5). Tendinosis appears as focal or diffuse thickening, usually with a fusiform appearance in the longitudinal plane[73,74,76] (Fig. 6A). In the transverse plane, the tendon shows a loss of its anterior concavity, with a mean thickness of 9 mm (normal tendon measures 5 to 7 mm).[74] With tendinosis, the tendon is usually diffusely hypoechoic but may contain nodular hyperechoic foci or calcifications[73] (Fig. 6B). Partial tears appear as a more well-defined area of hypoechogenicity within the substance of the tendon, with focal loss of its fibrillar appearance in the longitudinal plane.[73,77] Distinguishing tendinosis from partial-thickness tears on US (and on

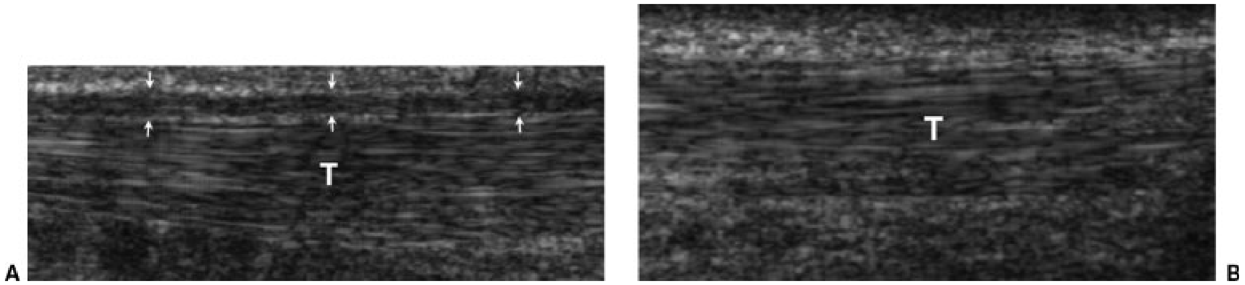

Figure 5 Achilles paratendinitis. Longitudinal scan shows (A) area of hypoechogenicity surrounding Achilles tendon, with (B) normal side for comparison. There is very mild tendinosis with slightly heterogeneous echotexture in (A). T, Achilles tendon.

MRI) is challenging,[72,78] but this limitation may not be of clinical relevance because both conditions are managed nonoperatively.[74] Neovascularization on power Doppler correlates with pain severity rather than with clinical outcome.[76]

Acute rupture of AT is often obvious clinically. Nevertheless, initial diagnosis is missed in $>20\%$ of cases.[42,79] On US, the AT must be scanned from its calcaneal insertion to its myotendinous junction. Complete tears appear as disruption of the fibrillar structure of the tendon, with separation of the two fragments[73,77] (Fig. 7A). The gap is filled with a hematoma that tends to develop into granulation tissue and fibrous scar in chronic stages.[73] Hartgerink et al[74] found that pre-Achilles (Kager) fat herniation into the area of tendon abnormality, posterior acoustic shadowing at the torn tendon ends (Fig. 7B), and easy visualization of the plantaris tendon are features that help in identifying complete tears.[74] An intact plantaris tendon may move posteriorly into the region of the AT tear and lead to a false diagnosis of a partial tear.[29,74] Dynamic examination can also aid diagnosis: With ankle flexion and extension, the tendon gap will narrow and widen in cases of complete tears. In addition, the radiologist may perform the Thompson test by squeezing gently the calf muscles as the AT is being scanned. In cases of complete tear, asynchronous motion of tendon edges is seen because only the proximal part will be retracting proximally. If the US diagnosis is equivocal for a complete tear, use of MRI may be required; usually only complete ruptures require surgery.[80]

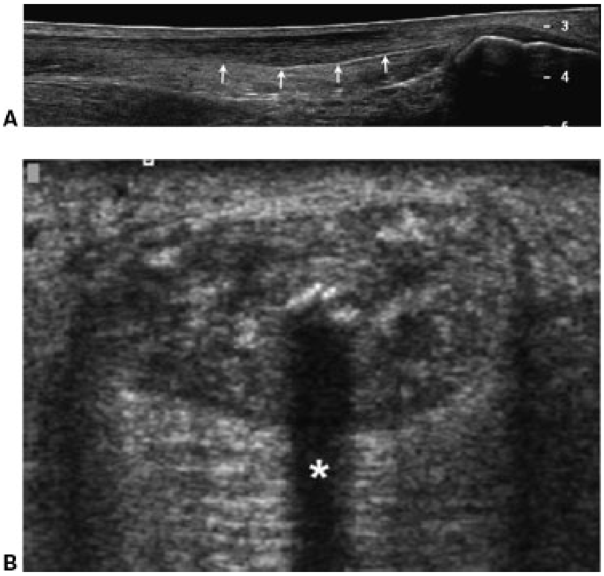

Figure 6 Chronic Achilles tendon lesions. (A) Panoramic longitudinal scan shows fusiform thickening of tendon (arrows) in keeping with tendinosis. (B) Transverse scan in another patient showing multiple intrasubstance shadowing (asterisk) echogenic foci in keeping with calcifications; note thickening of the tendon with loss of its anterior concavity consistent with tendinosis.

On US, the retrocalcaneal bursa appears as a small anechoic triangular image between the upper posterior edge of the calcaneus and distal tendon. It was visible among 50% of Nazarian et al's study of healthy volunteers, having a mean dimension of 1.5 mm. It is interesting to note that it was unilateral in 37% of cases, cautioning against comparison with the contralateral side.[16] Diagnosis of retrocalcaneal bursitis should be considered when a round or ovoid accumulation of fluid is depicted. Less common is retroachillean or infracalcaneal bursitis, appearing as small fluid-filled anechoic effusion in the soft tissues behind the distal tendon or under the posterior aspect of the calcaneus, respectively.

LIGAMENTS OF THE ANKLE

Ankle sprains are by far the most common type of ankle injury.[81] Lateral ankle ligament tears secondary to inversion injury account for the vast majority of all ankle sprains.[82,83] Van Dijk et al[84] found that for the diagnosis of ankle ligament ruptures, physical examination alone, 5 days after the injury (when swelling and pain diminish), has a sensitivity of 96% and a specificity of 84%. Although additional tests, including US, were found not to be cost effective in this study, US can play a role in aiding diagnosis in selected equivocal acute cases and in chronic cases with persistent pain. Accurate diagnosis is important because ankle sprains are often undertreated and can result in chronic pain, muscular weakness, instability, and/or impingement syndromes, sometimes requiring surgical ligament reconstruction.[83] US is an

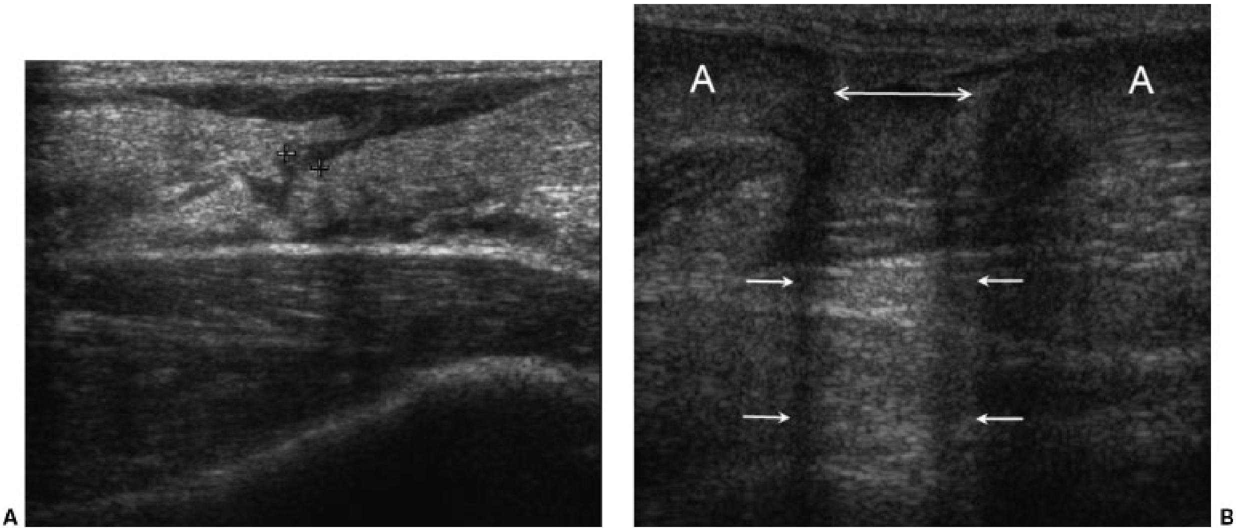

Figure 7 Complete Achilles tendon ruptures. (A) Longitudinal scan shows clear depiction of irregular tendon ends at gap (cursors), with intervening and surrounding hypoechoic fluid in this acute complete tear. (B) Longitudinal scan shows a complete subacute/chronic tear with echogenic material in the tendon gap, likely representing granulation tissue. The artifact of rarefaction (arrows) at the tendon ends is a helpful sign in confirming a complete tendon tear. A, Achilles tendon ends.

effective method to evaluate the integrity of the ankle ligaments.[4,85] The accuracy of US in the diagnosis of anterior talofibular tears is 90 to 100%; of calcaneofibular tears, 87 to 92%; and of anterior tibiofibular tears, 85%.[86]

On longitudinal scans, ligaments are well-defined linear structures having a fibrillar appearance. Normal ankle ligaments should not exceed 2 mm in thickness.[4] Like tendons, ligaments have anisotropic properties, so they must be examined with the US probe perpendicular to the plane of the ligament. Knowledge of simple dynamic maneuvers to stress each ligament is useful for the US diagnosis and classification of sprains; only small movements are required, which is an advantage in painful acute sprains.

Morvan et al[87] have proposed an US classification in three categories. In mild acute sprains, the ligament may be normal or slightly thickened, and its hyperechoic fibrillar structure may be slightly altered. In a moderate to severe (partial) tear, there is partial interruption in the midsubstance or insertion of the ligament manifested by an anechoic area, but the ligament remains taut during dynamic examination. In the more severe (complete) ligamentous tear, there is complete interruption or avulsion of fibers manifested by a hypoechoic gap; the ligament may be wavy and does not tauten with dynamic stress (Fig. 8). The gap allows a hemorrhagic effusion to extrude outside the joint, into the subcutaneous soft tissues or within a neighboring tendinous sheath. Bony avulsion at a ligamentous insertion is another manifestation of a severe sprain and can be demonstrated with US.[3,88] With chronic tears, US shows thickening of the ligament, and ossifications can be found within its substance.[4] The anterior tibiofibular ligament plays an important role in distal tibiofibular stability. Tears of this ligament are often underestimated.[43] The ligament can be examined dynamically in dorsiflexion and varus position of the ankle, which puts tension on the ligament.

The anterior talofibular ligament (ATFL) is the most frequently torn during inversion strains of the ankle.[89] It is the most frequently injured of the three lateral collateral ligaments, in isolation or in association with the calcaneofibular ligament (CFL). This ligament represents the superficial margin of a triangular hypoechoic anterolateral pouch described as the "delta sign."[90] To examine this ligament dynamically, plantar flexion, inversion stress, or an anterior drawer test may be employed to put tension on the ligament.[88] When scanning this region, a perpendicular tilt of the probe allows inspection of the lateral aspect of the talus in search for a talar lateral process fracture.[91]

The CFL is usually sequentially torn after the ATFL during inversion sprains; an isolated sprain is very unusual but can occur. Ankle dorsiflexion with inversion of the hindfoot is required to stretch the ligament and avoid anisotropy. When the ligament is continuous, this dynamic maneuver displaces the peroneal tendons superficially. Lack of this displacement with a persistent deep position of the peroneal tendons against the calcaneus during this test have been described as indirect signs of a complete CFL tear.[4] As previously mentioned, complete CFL tears are often accompanied by fluid in the peroneal tendon sheath.

The posterior tibiofibular ligament is not easily accessible to US and not routinely explored.[92] All authors agree on the extreme rarity of its involvement in ankle sprains.[86–93] The strong deltoid ligament make eversion sprains less common than inversion sprains. This ligament is best evaluated by applying gentle

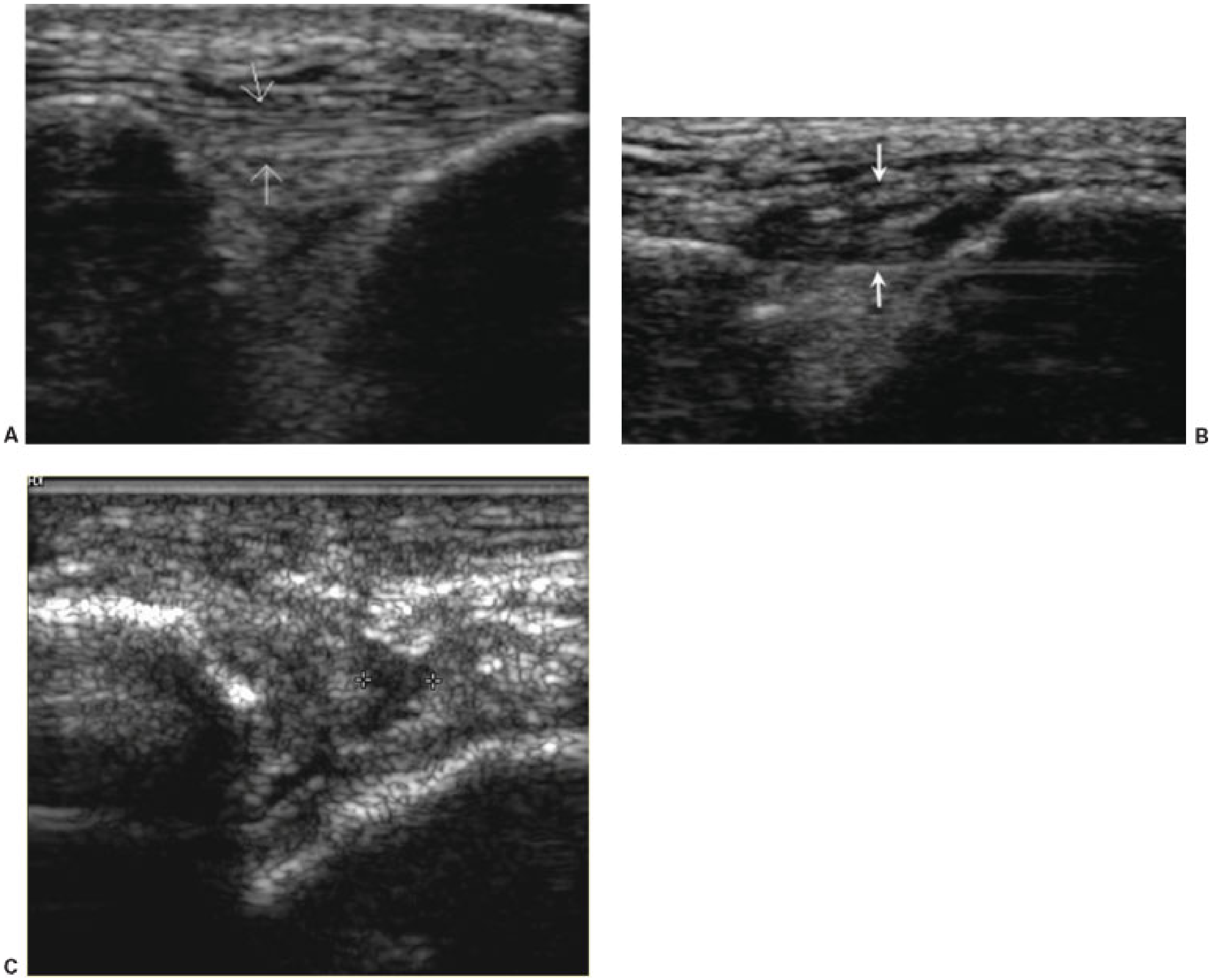

Figure 8 Anterior talofibular ligament tears. (A) Normal ligament (arrows) with thin fibrillar appearance. (B) Partial tear of ligament (arrows), with thickening, hypoechogenicity, and focal intrasubstance gaps. (C) Severe tear with interruption of ligament in its midsubstance (callipers) and hypoechoic, wavy ligament segments.

dorsiflexion and eversion stress on the hindfoot, thus avoiding anisotropy.[4] This same dynamic maneuver displaces the overlying posterior tibial tendon superficially from the medial aspect of the talus. Loss of this displacement should raise the suspicion of a complete deltoid ligament tear.[4] US is limited in the visualization of the proximal aspect of the CFL due to the overlying lateral malleolus. In acute tears of the deltoid ligament, there should be a systematic search for associated lateral malleolar fractures or distal tibiofibular tears.[87]

FOOT

The plantar aponeurosis (or fascia) is one of the main supporting structures of the medial arch of the foot.[94–] *Plantar fasciitis* is the most common cause of heel pain.[95] It is typically an affliction of the older population related to sports or excessive walking or standing, and it is also associated with obesity.[96] It is also found in the young athletes who perform sports involving running or jumping.[95,96] The more uncommon spontaneous rupture of the plantar fascia is also found in this population; an association with corticosteroid injection has been emphasized.[97] There is a higher incidence of plantar fasciitis in patients with Achilles tendon disease.[98]

Imaging of plantar fasciitis is valuable because its clinical diagnosis may be difficult owing to the broad differential diagnosis of heel pain. US diagnoses plantar fasciitis effectively,[98–102] with a reported sensitivity of 80% and a specificity of 88.5% when compared with MRI.[100] The plantar fascia is readily visualized with US on longitudinal scanning as a fibrillar echoic band measuring 3 to 4 mm in thickness[101,102] (Fig. 9A). In fasciitis, there is fusiform thickening at its calcaneal insertion (mean of 5.2 mm) and diffuse hypoechogenicity[98,99,102] (Fig. 9B). Color Doppler showed hyperemia of the fascia and its surrounding tissues in 40% of patients in a study by Walther et al.[103] Whereas plantar fasciitis involves the fascia near its calcaneal insertion, ruptures may occur in the proximal or middle portion. Acute tears appear as a

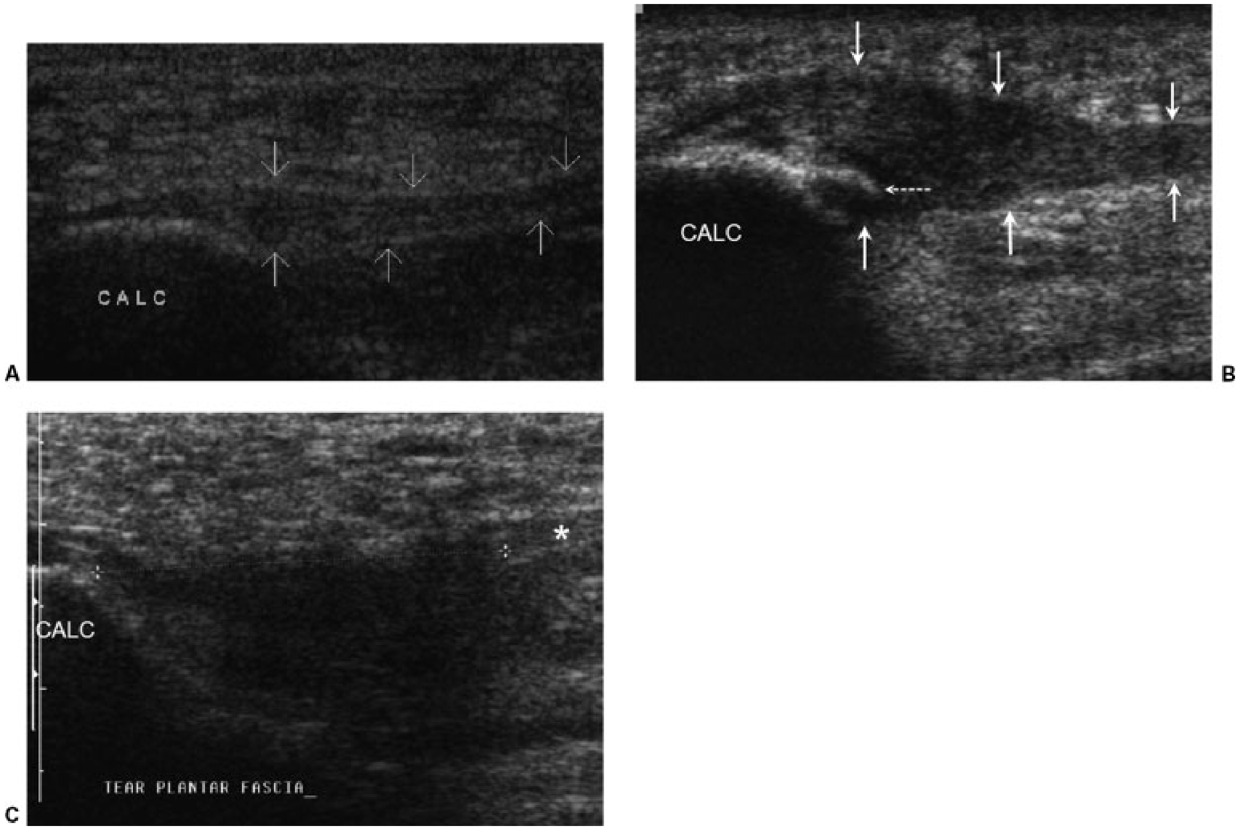

Figure 9 Plantar fasciitis. Sagittal scan of the inferior region of the calcaneus showing (A) normal plantar aponeurosis (arrows) that is thin, with an internal fibrillar echotexture; (B) plantar fasciitis, with prominent thickening of the aponeurosis at its calcaneal insertion (arrows), where there is an enthesophyte (dashed arrow); and (C) rupture of the plantar fascia near its insertion, with a wide area of interruption (cursors) of the aponeurosis (asterisk). CALC, calcaneus.

focal anechoic interruption of fibers, surrounded by fluid (Fig. 9C). Conspicuity of the fascia and associated pathology may be enhanced dynamically by extending the toes dorsally to stretch the fascia.

Morton's neuromas are thought to be related to repetitive trauma or compression of the interdigital nerve and most commonly seen in middle-age women.[104] Predominantly occurring in the second and third interdigital spaces, they are non-neoplastic lesions of the digital nerves, which are located on the plantar side of the transverse intermetatarsal ligament. The use of imaging in the diagnosis of Morton's neuroma has been questioned.[105] However, imaging can greatly aid in the evaluation and affect management by confirming diagnosis and ruling out other causes of metatarsalgias when clinical presentation is atypical, as well as in the detection of multiple Morton's neuromas. US has a high detection rate for Morton's neuroma[106,107] that is comparable to MRI.[107] US scanning is usually done from the plantar aspect of the foot but may be done from its dorsal aspect. This lesion appears as a well-defined hypoechoic or anechoic mass that is round or ovoid in the transverse plane and fusiform in the longitudinal plane with length being greater than width.[106] It classically occurs at the plantar aspect of the intermetatarsal ligament (and metatarsal heads) but may also be seen between metatarsal heads, dorsal to their plantar aspect, or extending superficially to form a bilobed configuration.[106] It is probably not practical to use the 5-mm diameter that has been said to be the threshold for symptomatic Morton's neuromas[104,108] because it has been found that smaller lesions can be symptomatic.[106,109] Continuity with the plantar interdigital nerve may sometimes be depicted in the sagittal plane.[106] US allows use of the Mulder's maneuver, consisting of pressing both sides of the forefoot of a patient who is lying prone, protruding the tumor in the plantar direction and possibly increasing its conspicuousness.[110,111]

Inflammation of the adjacent intermetatarsal bursae (located on the dorsal aspect of the intermetatarsal transverse ligament) has been associated with Morton's neuroma[104,108] but can occur in isolation and explain many clinically occult metatarsalgias.[112] The size of a Morton's neuroma may be overestimated on US when there is adjacent intermetatarsal fluid.[106] US has shown a great accuracy in the depiction of intermetatarsal bursitis,[113] which appears as a large anechoic area separating the two metatarsal heads and bulging at least 1 mm under their level.[114] Compression using the transducer can aid in differentiating intermetatarsal fluid

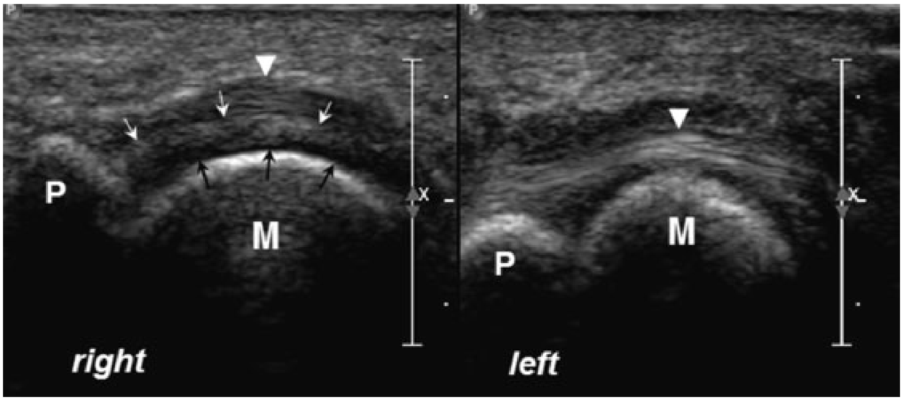

Figure 10 Plantar plate rupture. Longitudinal scans at the plantar aspect of the second metatarsophalangeal joint. On the right is a normal plantar plate, seen as homogeneous and mildly echoic (white arrows), lying deep to flexor tendon (arrowhead) and inserting into base of proximal phalanx; note hypoechoic line of hyaline cartilage (black arrows). On the left, there is complete rupture of the plantar plate, with flexor tendon (arrowhead) seen more closely apposed to metatarsal head. M, metatarsal head; P, proximal phalanx.

from the solid Morton's neuroma. In a study using MRI, Zanetti et al stated that physiological bursae are often visible in the first, second, and third intermetatarsal spaces, with a diameter not > 3 mm.[104]

Metatarsal stress fractures are common causes of metatarsalgias and often radiographically occult in the acute stage. US may be used for diagnosis at a lower cost and with easier access than a scintigraphic exploration. The sonographic features of stress fractures are a cortical break with periosteal elevation, adjacent small fluid collection, and surrounding hypervascularization on color Doppler.[115,116]

Plantar plates are fibrocartilaginous structures located on the plantar aspect of the metatarsophalangeal joints and serve as a central stabilizing structure of the joint. In many instances, overuse of the foot can lead to its insufficiency and subsequent instability.[117] Plantar plates are best visualized in the sagittal plane,[118] sandwiched between flexor tendon and hyaline cartilage of the metatarsal head. They are homogeneous, slightly echogenic structures extending from the diaphysis of the metatarsal neck to the base of the first phalanx. Tears may be partial or complete and mainly occur on the second but also third and fourth toe. They appear as a hypoechoic or heterogeneous focus within the fibers that may be enlarged by a dynamic dorsiflexion of the toe (Fig. 10). Tears are usually located distally and centrally but may extend laterally or medially.[118,119] In a study by Quinn in 2000, tears were nevertheless found in a large number of asymptomatic patients, suggesting that interpretation of lesions on imaging should be done with clinical correlation.[106]

CONCLUSION

US is a valuable, readily available, and economical imaging tool in the evaluation of the highly prevalent sports injuries and overuse lesions of the ankle and foot. It is essential to have a high level of technical skill and to use high-resolution equipment. US capacity for multiplanar imaging and its detailed depiction of small structures are especially advantageous in evaluating the ankle and foot. In the appropriate clinical setting, US can be used as a targeted examination to address a specific clinical query or symptomatic area of concern, rather than a diffuse or complex condition. US is effective in evaluating ankle tendons and can be used as a first-line modality in evaluating tendinosis, tenosynovitis, paratendinosis, dislocation, and rupture. In the evaluation of ankle ligaments, US plays a role in equivocal acute cases of ankle sprains and when symptoms persist following prior ankle injury. Real-time imaging provides the opportunity for direct correlation with the anatomical structure or area of concern, as well as for dynamic evaluation, which increases the diagnostic accuracy and sensitivity of US for many foot and ankle lesions.

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