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Title Page

Title: Normal and injured ankle ligaments on ultrasonography with magnetic resonance imaging correlation

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Summary

Ultrasound (US) has been increasingly used in the evaluation of the ankle ligamentous injuries given its advantages as a dynamic, efficient, non-invasive, and cost-effective imaging method. Understanding the anatomy of the ankle ligaments is critical for correct diagnosis and treatment. This pictorial essay describes and illustrates US scanning technique and potential pitfalls in evaluating the ankle ligaments, and also provides an overview of the US appearance of normal and injured ankle ligaments with magnetic resonance imaging (MRI) correlation. Highlighted structures include the lateral complex, medial/deltoid complex, spring (calcaneonavicular) ligament complex, and syndesmosis.

Key Words: Ultrasound; Ankle; Ligaments; MRI

Introduction

The ankle is the most commonly injured major joint in the body, with ankle ligamentous sprains being an extremely common sports injury.[1] Imaging plays an important role as an adjunct to the physical exam in the evaluation of ligamentous injury of the ankle. While MRI is superior in evaluation of bone marrow and articular cartilage abnormalities, ultrasound (US) has been found to be an effective method to evaluate the integrity of the ankle ligaments in particular.[1-8] Ultrasound provides the advantages of dynamic imaging, noninvasiveness, lower cost, and quicker scan times. Ultrasound is also helpful in patients with contraindications to MRI or local metallic implants, which could create significant artifacts. The main limitation of US in the evaluation of the ankle ligaments is operator-dependence, which can be overcome by a thorough understanding of scanning technique and potential pitfalls, allowing the recognition of normal and injured sonographic appearance of the ankle ligaments. The purpose of this pictorial essay is two-fold: 1) To review US examination technique and scanning pitfalls in the evaluation of the ankle ligaments and 2) To illustrate the US appearance of normal and injured ankle ligaments with MRI correlation.

US Technique and General Principles

US of the ankle is typically completed with the patient supine and the foot and ankle on the examination table, and a high-frequency transducer of at least 10 MHz should be used, preferably 15 – 18 MHz.[9] A small footprint, or “hockey stick,” transducer can be used as needed depending on ligament size and patient anatomy. The ankle ligaments are best evaluated in long axis, with short axis imaging for problem solving. Similar to other ligaments, the ankle ligaments should appear as echogenic with a more compact fibrillar structure than tendons, most commonly connecting two osseous structures. A general consideration regarding patient positioning is that the ligament should be slightly taut during evaluation to eliminate redundancy. The transducer should be angled so that the ligament fibers are perpendicular to the sound beam, to eliminate anisotropy. Normal thickness of the ankle ligaments ranges from 2-5 mm.[8]

Some general principles apply when it comes to the US appearance of ligament injury. Acute partial-thickness ligament tears typically appear as hypoechoic thickening with preservation of some continuous fibers.[2] Acute full-thickness ligament tears typically present as discontinuity, non-visualization of the ligament, and/or visualization of hypoechoic or heterogeneous material representing torn ligament and hemorrhage.[2] Dynamic US may show lack of normal tendon tightening during stress maneuvers in complete tears.[10] Chronic injury may appear as ligamentous thickening, attenuation, or non-visualization. Avulsion injuries may demonstrate tiny echogenic shadowing fragments of bone.

Lateral Collateral Ligament (LCL) Complex

The LCL complex of the ankle consists of the anterior talofibular ligament (ATFL), the posterior talofibular ligament (PTFL), and the calcaneofibular ligament (CFL) (Fig 1). For evaluation of the lateral ligaments, the patient is asked to internally rotate the hip or turn up slightly onto the contralateral side to expose the lateral ankle.

The ATFL extends from the anterolateral border of the lateral malleolus to the lateral surface of the talar neck and restrains anterior talar motion.[8] To visualize the ATFL, the ankle is slightly inverted and the transducer is placed parallel to the sole of the foot between the distal tip of the lateral malleolus and the talus. The ligament will often appear hypoechoic initially due to anisotropy, so the transducer must then be angled perpendicular to the ligament fibers (Fig 2).[9] In addition, the ATFL most commonly consists of two bands or fascicles, which should not be interpreted as a ligament tear.[11] The ATFL may also be imaged with US dynamically, analogous to the anterior drawer sign, to visualize discontinuity of the ATFL ligament fibers.[12]

The PTFL extends horizontally from the lateral tubercle of the posterior process of the talus to the posterior aspect of the lateral malleolus (the fibular malleolar fossa, Fig 3).[8] The PTFL is the strongest and deepest ligament of the LCL complex and is rarely torn in ankle sprains. Given that it is uncommonly injured, its deep location, and poor acoustic window, the PTFL is uncommonly assessed by US though it can be seen.[9]

The CFL extends from the tip of the lateral malleolus to the trochlear eminence on the lateral surface of the calcaneus.[8] Its role is to stabilize the subtalar joint. Laying the ankle on its medial aspect with dorsiflexed foot (which tightens the CFL), the transducer is placed in an oblique plane between the fibular tip and the posterior aspect of the heel. Here the CFL can be identified deep to the peroneal tendons (Fig 4). Lack of elevation of the peroneal tendons with dorsiflexion is an indirect indicator of CFL tear.[13] The normal CFL may appear hypoechoic due to anisotropy when the foot is in a neutral position, which is a potential pitfall.

The ATFL is the most commonly injured ligament in the body, (Figs 5 and 6), isolated or in combination with CFL tear in up to 70% of cases (Figs 7 and 8).[2] The CFL is usually sequentially torn after the ATFL is torn during inversion injuries, so an isolated tear of the CFL is unlikely when a normal ATFL is identified. Complete CFL tears may be accompanied by fluid in the overlying peroneal tendon sheath.[1] Ultrasound accuracy in the diagnosis of ATFL and CFL tears has been reported to range from 87-100%.[8] Ultrasound was shown to have an accuracy of 91% in the diagnosis of ATFL injury vs 97% for MRI.[14] Ultrasound was also shown to be highly sensitive and specific for chronic lateral ankle ligament injury.[15]

Medial Collateral Ligament (MCL, Deltoid) Complex

The MCL or deltoid complex is the primary medial stabilizer of the ankle and consists of two distinct layers (Fig 9). The deep layer has talar attachments extending from the medial malleolus and consists of the anterior and posterior tibiotalar ligaments.[8,16] The superficial layer has variable attachments, extending from the medial malleolus to the navicular bone (tibionavicular ligament), the superomedial spring ligament (tibiospring ligament), and the calcaneus (tibiocalcaneal ligament).[8] The posterior tibiotalar ligament has also been described has having both superficial and deep components.[17] For evaluation of the medial ligaments, the patient is asked to externally rotate the hip or turn up onto the ipsilateral side to expose the medial ankle. The transducer is initially placed in the coronal plane at the level of the medial malleolus and inferior aspect rotated slightly posterior. The tibiocalcaneal component of the deltoid ligament can be identified extending from the tibia to the calcaneus (Fig 10). To visualize the posterior tibiotalar component, the foot is dorsiflexed and the distal aspect of the transducer is rotated posteriorly while the proximal aspect is fixed to the medial malleolus (Fig 10). Of note, the tibiotalar ligament complex may appear hypoechoic due to its angulation and interspersed fat; this appearance should not be mistaken for a tear.[8] Within the MCL complex, the posterior tibiotalar ligament is considered the strongest component.[16,18] Next, the proximal aspect of the transducer is fixed to the medial malleolus and the distal aspect is rotated into the coronal plane to identify the more superficial tibiospring, and then rotated more anteriorly to identify the tibionavicular, and deeper anterior tibiotalar components (Fig 11).

The deltoid ligament complex is less frequently injured than the lateral complex, but may be injured during eversion stress. Ultrasound evaluation of deltoid ligament tears can be challenging given its complexity and variability.[19] Deltoid ligament injuries typically produce hypoechoic swelling that involves several components with or without frank disruption and avulsion fracture fragments (Fig 12). Stripping of the medial malleolus fascial sleeve, comprised of the tibial attachments of the superficial deltoid ligament and flexor retinaculum, and periosteum, has been described as an important sign that indicates superficial deltoid ligament tear.[20] Deep ligament tears are more common than superficial ligament tears, and partial tears are more common than complete tears (Figs 12 and 13).[18,21,22] When the deltoid ligament is acutely torn, the possibility of associated lateral malleolar fractures or distal tibiofibular ligament tears should be evaluated.[1,7] In the setting of Weber type B and C fractures, US was found to have 100% sensitivity for the detection of complete rupture of the deltoid ligament but only a sensitivity of 50% for partial ruptures, thus may be helpful but not entirely replace MRI for the assessment of medial instability in this clinical setting.[23] Another study demonstrated 100% sensitivity and specificity of ultrasound for medial deltoid rupture with 100% correlation between ultrasonography and arthroscopy in supination external rotation fractures of the ankle, thus possibly obviating the need for stress radiographs.[24]

Spring Ligament Complex (Calcaneonavicular Ligament)

The spring ligament complex is composed of the superomedial, medioplantar, and inferoplantar calcaneonavicular ligaments (Fig 14).[16,25] The spring ligament is one of the major stabilizers of the longitudinal arch and for supporting the head of the talus.[8,26]

With the foot rotated externally with dorsal extension, the transducer is initially placed in the transverse plane inferior to the medial malleolus and over the sustentaculum tali. The transducer is then moved anteriorly and angled superiorly toward the talar head, allowing the superomedial calcaneonavicular ligament to be identified in long axis (Fig 15).[27] The medioplantar and inferoplantar calcaneonavicular ligaments are not consistently visualized on US due to their deep and complex course.[8] The superomedial calcaneonavicular ligament thickness has been described as 1.9 – 4.7 mm in thickness.[25]

The superomedial calcaneonavicular ligament is the most likely to be injured (Fig 16). Disorders of the calcaneonavicular ligament are associated with tibialis posterior tendon tears, both of which contribute to flatfoot deformity.[28] Injury to the spring ligament appears as thickening, thinning, or frank discontinuity.[25,28] Sonography is an effective tool for assessing spring ligament abnormalities in patients with symptomatic PTT dysfunction.[28]

Ankle Syndesmosis

The ankle syndesmosis is stabilized by the anterior inferior tibiofibular ligament (AITFL), the posterior inferior tibiofibular ligament, the inferior transverse ligament, and the distal interosseous ligament (Fig 17).[16] The interosseous membrane is found more proximally between the tibial and fibular diaphysis, and the distal aspect of the interosseous membrane is continuous with the interosseous ligament.[29]

With the ankle slightly inverted, the transducer is placed with the posterior edge on the lateral malleolus and its anterior edge is rotated upwards along the distal tibia. Here the anterior inferior tibiofibular ligament may be identified, extending obliquely downward and laterally from the anterior tibial tubercle to the anterior border of the distal fibular shaft and lateral malleolus (Fig 18).[8] The normal thickness of the AITFL ranges from 2.6 to 4 mm. The AITFL consists of multiple fascicles that should not be confused with injury.[8,30,31] An accessory anterior inferior tibiofibular ligament (or Bassett's ligament) is visualized in up to 94% of subjects, and may be abnormally thickened when associated with anterolateral ankle impingement.[32] The distal interosseous membrane may be imaged by placing the transducer in an axial plane between the distal tibia and fibula above the joint from an anterior approach (Fig 19), with the interosseous ligament identified at its most inferior extent proximal to the tibial plafond. The posterior inferior tibiotalar ligament and the inferior transverse ligament are not routinely evaluated given their depth and poor acoustic windows.

A syndesmotic ligament injury defines a high ankle sprain (Fig 20 and 21). It may be an isolated injury, occur in conjunction with other ligamentous injuries (typical LCL complex), or be associated with Weber B or C fractures of the distal fibula. Isolated injuries are rare but often undiagnosed.[10] The accuracy of US in the evaluation of anterior inferior tibiofibular ligament injuries is quoted at approximately 85%.[8,33] Dynamic evaluation of the AITFL using ultrasound with the ankle in eversion can show widening of the tibiofibular clear space and ligament fiber discontinuity.[34]

In the setting of an anterior inferior tibiofibular ligament tear, an associated tear of the distal interosseous ligament and membrane should be considered and evaluated (Fig 22). Tear of the interosseous membrane appears as abnormal hypoechogenicity and discontinuity.[29] This injury may also be associated with a proximal fibular fracture or Maisonneuve injury.[29]

Additionally, a joint effusion in the tibiofibular recess on MRI that extends greater than 12 mm proximal to the tibial plafond may suggest interosseous ligament injury.[16]

Conclusion

Ultrasound provides exquisite delineation of normal anatomy of the ankle ligaments, and can be used effectively to evaluate ligament integrity. Knowledge of the normal US anatomy, technique, and common pitfalls is important for the successful interpretation of ligamentous injury of the ankle.

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Medical Illustrator: Danielle Dobbs

Compliance with Ethical Standards

IRB: This study was approved by the institutional review board at our institution and performed in an HIPAA-compliant manner.

Conflict of Interest: The authors declare that they have no conflict of interest.

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Figure 1. Illustration of normal anatomy of the lateral complex. Anterior view (a), posterior view (b), and lateral view (c). Anterior talofibular ligament (ATFL), posterior talofibular ligament (PTFL), calcaneofibular ligament (CFL), interosseous membrane (star), anterior inferior tibiofibular ligament (white arrowhead), posterior inferior tibiofibular ligament (black arrowhead).

Figure 2. Ultrasound appearance of the anterior talofibular ligament (ATFL). With the ankle slightly inverted, the transducer is placed parallel to the sole of the foot between the distal tip of the lateral malleolus and talus (a). The ATFL can be seen as a hyperechoic fibrillar band (arrowheads in b). Angling the transducer can help to avoid an anisotropic appearance of the ligament (c). Corresponding T2 weighted MR images shows a normal ATFL (arrowhead in d). Lateral malleolus (LM). Anterior talofibular ligament (ATFL).

Figure 3. Ultrasound appearance of the normal posterior talofibular ligament (PTFL; a). Axial T2-weighted (b) and T1-weighted (c) MR images show normal marked signal heterogeneity and thickening (arrowheads) caused by the presence of fat striations, which should not be misinterpreted as a tear. Peroneal tendons (star in a). Lateral malleolus (LM).

Figure 4. US appearance of the calcaneofibular ligament (CFL). With the ankle on its medial aspect with the foot dorsiflexed, place the transducer in an oblique plane between the fibular tip and the posterior aspect of the heel (a). The CFL (arrowheads in b) can be identified deep to the peroneal tendons (*). The normal CFL may appear hypoechoic (arrowheads) due to anisotropy when the foot is in neutral position (c). Axial T2-weighted MR image demonstrates a normal CFL (arrow). Calcaneus (CAL).

Figure 5. 29-year-old male with remote partial anterior talofibular ligament (ATFL) injury. US image longitudinal to the ATFL (a) shows hypoechoic thickening without discontinuity (arrowheads). Axial T2-weighted (b) and T1 weighted (c) MR images from the same patient demonstrate similar findings (arrowhead) with increased internal signal and adjacent edema. Lateral malleolus (LM).

Figure 6. 38-year-old male with complete anterior talofibular ligament (ATFL) tear. US image (a) longitudinal to the ATFL shows absence of the ATFL with a fluid filled gap (arrowhead). Axial T2-weight MR image in a different patient, a 21-year-old female, (b) shows similar findings of complete ATFL tear. Lateral malleolus (LM).

Figure 7. 28-year-old male with partial calcaneofibular ligament (CFL) tear. US image (a) shows hypoechoic thickening of the CFL (arrowheads) deep to the peroneal tendons (*). Corresponding axial T2-weighted MR image (b) demonstrates similar findings with surrounding edema in a different patient. Calcaneus (CAL).

Figure 8. Complete calcaneofibular ligament (CFL) tear. US image (a) shows hypoechoic thickening of the CFL (arrows) with a defect of the distal CFL (arrowheads). Corresponding axial T2-weighted MR image from a 22-year-old female (b) reveals a similar finding with additional tear of the peroneus brevis (arrow). Peroneal longus (*), Calcaneus (CAL).

Figure 9. Illustrations of the normal anatomy of the medial (deltoid) ligament complex. Medial view (a). Tibionavicular ligament (light blue), tibiospring ligament (yellow), tibiocalcaneal

ligament (green), anterior tibiotalar ligament (orange), posterior tibiotalar ligament (purple), superomedial calcaneonavicular ligament (blue with star). Coronal view (b) shows the superficial (arrow) and deep (arrowhead) layers of the medial complex. Navicular (N), Calcaneus (CAL).

Figure 10. US anatomy of the medial (deltoid) complex. Placing the superior edge of the transducer over the medial malleolus and rotating the distal aspect of the transducer posterior or parallel (a), different components of the medial (deltoid) complex can be identified: posterior tibiotalar ligament (arrowheads in b), tibiocalcaneal ligament (arrowheads in c). Coronal T2-weight MR image (d) shows intact posterior tibiotalar ligament (arrowheads), with large arrow pointing to the PTT. Medial malleolus (MM), Calcaneus (CAL), Posterior tibialis tendon (PTT).

Figure 11. Normal US and MRI appearance of the medial (deltoid) complex continued. The transducer is rotated into the coronal plane, demonstrating the tibiospring ligament (arrowheads in a), and then rotated anteriorly to demonstrate the anterior tibionavicular ligament (arrowheads in b), and anterior tibiotalar ligament (arrows in b). Coronal T2-weighted fat saturated MR image (c) shows the normal tibiospring ligament (arrow) and partial visualization of the anterior tibiotalar ligament (white arrowhead). Axial T2-weighted fat saturated MR image (d) shows the normal superficial (arrowhead) and deep (arrow) fibers of the medial (deltoid) complex. Spring ligament in a and c (*). Posterior tibialis tendon (PTT, black arrowhead in c). Medial malleolus (MM). Navicular (N).

Figure 12. Medial (deltoid) complex injury. US image (a) in a patient after acute injury shows heterogeneous hypoechoic discontinuity of the deltoid ligament with adjacent fracture fragment (black arrow), involving both the superficial (arrowhead) and deep (white arrow) components. Axial T2-weighted MR images (b and c) from a different patient, a 21-year-old male, show a tear involving both superficial (arrowhead) and deep (white arrows) components, with fracture fragment (small white arrow in c) and intact posterior tibiotalar ligament (* in b and c).

Figure 13. Medial (deltoid) complex injury continued. US image (a) after acute injury shows heterogeneous hypoechoic discontinuity of the deltoid ligament (white arrow) with adjacent fracture fragment (black arrow), involving the deep component, predominantly the anterior tibiotalar ligament. The superficial complex (white arrowhead) remains intact. Coronal (b) and axial (c) T2-weighted MR images from a different patient, a 36-year-old male, show a tear involving the deep component (white arrow), predominantly the posterior tibiotalar ligament with adjacent fracture fragment (black arrow).

Figure 14. Illustration of the normal anatomy of the spring ligament complex (calcaneonavicular ligament). Superomedial calcaneonavicular ligament (* in a). Medioplantar oblique calcaneonavicular ligament (arrow in a and b). Inferoplantar longitudinal calcaneonavicular ligament (arrowhead in a and b).

Figure 15. Normal US appearance of the spring ligament. Rotating the foot externally with dorsal extension, the superomedial calcaneonavicular ligament is imaged by placing the transducer parallel to the plantar surface inferior to the medial malleolus over the sustentaculum tali, with the other end of the transducer slightly tilted superiorly over the talar head towards the medial aspect of the navicular bone (a). US image showing identification of the ligament as a hyperechoic fibrillar structure (arrowheads in b) deep to the posterior tibialis tendon (* in b and c). Navicular (N). Corresponding axial T2-weighted MR image (c) shows a normal superomedial calcaneonavicular ligament (black arrowheads).

Figure 16. 29-year-old male with superomedial calcaneonavicular ligament injury. US image (a) longitudinal to the superomedial calcaneonavicular ligament in a patient with acute injury shows abnormal hypoechoic thickening in the distal superomedial calcaneonavicular ligament (arrowheads). Navicular (N). Corresponding axial T2-weighted MR image (b) in the same patient demonstrates similar findings with abnormal signal (arrowhead). Posterior tibialis tendon (*).

Figure 17. Illustration of the normal ankle syndesmosis. Anterior inferior tibiofibular ligament (arrows). Posterior inferior tibiofibular ligament (arrowhead). Distal interosseous membrane and ligament (*).

Figure 18. US and MR appearance of the normal anterior inferior tibiofibular ligament. With the ankle slightly inverted, the transducer is placed with the posterior edge on the lateral malleolus and its anterior edge is rotated upwards (a). The anterior inferior tibiofibular ligament can be seen as a hyperechoic fibrillar band (arrowheads in b). Lateral malleolus (LM). Corresponding axial T2-weighted MR image shows normal anterior inferior (arrowhead in c) and posterior tibiofibular ligaments (arrow in c). Peroneus longus and brevis (*).

Figure 19. Normal US appearance of the distal interosseous membrane. To image the intraosseous membrane, the transducer is placed in an axial plane between the distal tibia and fibular above the joint from an anterior approach (a). The intraosseous membrane will appear hyperechoic, thin, and taut (arrowheads in b). Fibula (F).

Figure 20. 26-year-old male with partial anterior inferior tibiofibular ligament tear. US image (a) longitudinal to the anterior inferior tibiofibular ligament in a patient after injury shows abnormal hypoechoic thickening (arrowheads). Lateral malleolus (LM). Corresponding axial T2-weighted MR image (b) from a different patient, a 22-year-old male, demonstrates similar findings with abnormal signal (arrowhead). Medial malleolus (MM). Lateral malleolus (LM).

Figure 21. 39-year-old female with complete anterior inferior tibiofibular ligament tear. US image (a) longitudinal to the anterior inferior tibiofibular ligament after injury shows anechoic discontinuity (arrow) of the anterior inferior tibiofibular ligament (arrowheads). Corresponding axial T2-weighted MR image (b) in the same patient demonstrates similar findings with abnormal signal (arrowhead). Note the posterior inferior tibiofibular ligament is also torn (black arrow). Lateral malleolus (LM).

Figure 22. 68-year-old male with interosseous membrane injury. Transverse US image (a) of the anterolateral lower leg above the ankle joint shows nonvisualization of the interosseous membrane (arrow). The contralateral leg imaged at the same location demonstrates an intact interosseous membrane (arrowheads). Fibula (F). Coronal T1-weighted fat saturated image from MR arthrography (b) from a different patient, a 19-year-old male, with ankle pain demonstrates intra-articular contrast extending >12 mm into the tibiofibular recess (arrow), suggestive of interosseous ligament and membrane tear.