7 Foot and Ankle

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The foot and ankle function together in an extremely complex network of structures, each of which can be affected by injury. Multiplanar movement is achieved by interactions between the ankle, hindfoot, midfoot, and forefoot. Stability is provided primarily by the medial (deltoid) and lateral ligaments. The mobility and repetitive stress on the foot and ankle make them susceptible to injury. The bones and their cartilaginous articulations are subject to degeneration, fracture, and inflammation. The muscles, tendons, and ligaments can suffer from acute or chronic tearing or overuse. Peripheral neuropathy and vascular disease can lead to injury and impair healing.

The clinical utility and superiority of ultrasound guidance for technical accuracy when performing injections in the foot and ankle has been well reported and will be cited throughout the chapter. Given the high density of structures in this region, accuracy is key in ensuring diagnostic and therapeutic efficacy. More importantly, the ability to visualize the neurovascular structures and bony landmarks allows for increased patient safety and comfort.

Tibiotalar ("Ankle") Joint

The tibiotalar joint is a diarthrodial joint comprised of the talus inferiorly, the distal tibia superiorly and medially, and the distal fibula laterally. The medial and lateral malleoli articulate with the chondral surface of the talus on their respective sides. A capsular joint ligament surrounds the ankle and is strengthened by the medial and lateral ligament complexes. Although sprains and other soft tissue injuries to the surrounding structures of the joint are common, arthritis is the primary source of intra-articular pain. An anterior approach with the ankle in plantar flexion is preferred due to optimal visualization of effusions and needle access for aspiration and injection [1–3]. Ultrasound can detect as little as 2 mL of fluid in the tibiotalar joint; up to 3 mL can be considered normal (Table 7.1) [6, 7].

Scanning Techniques and Anatomy to Identify

Scan the anterior aspect of the joint in the sagittal plane to visualize the anterior recess. Identify the distal tibia, the talar head, and the talar dome in between them with its thin anechoic cartilage. The joint capsule extends as a hyperechoic line between the distal tibia and the talar head. Immediately deep to the capsule is the intra-articular fat pad, which is triangular shaped, like a wide arrowhead pointing posteroinferiorly into the joint space. Sweep medially and laterally to visualize the surface of the talar dome, exploring for effusion or osteochondral defects. Rotate the transducer 90° to the axial plane. Position it slightly inferior to the distal tibia, and identify the tendons of the tibialis anterior, extensor hallucis longus, and extensor digitorum longus muscles. Identify and avoid the anterior tibial artery and deep fibular nerve (Fig. 7.1).

Table 7.1 Accuracy of tibiotalar joint injections

Study – tibiotalar joint injection	Author	Accuracy (%)
Palpation	Wisniewski et al. [4]	88
Ultrasound guided	Kirk et al. [5]	100

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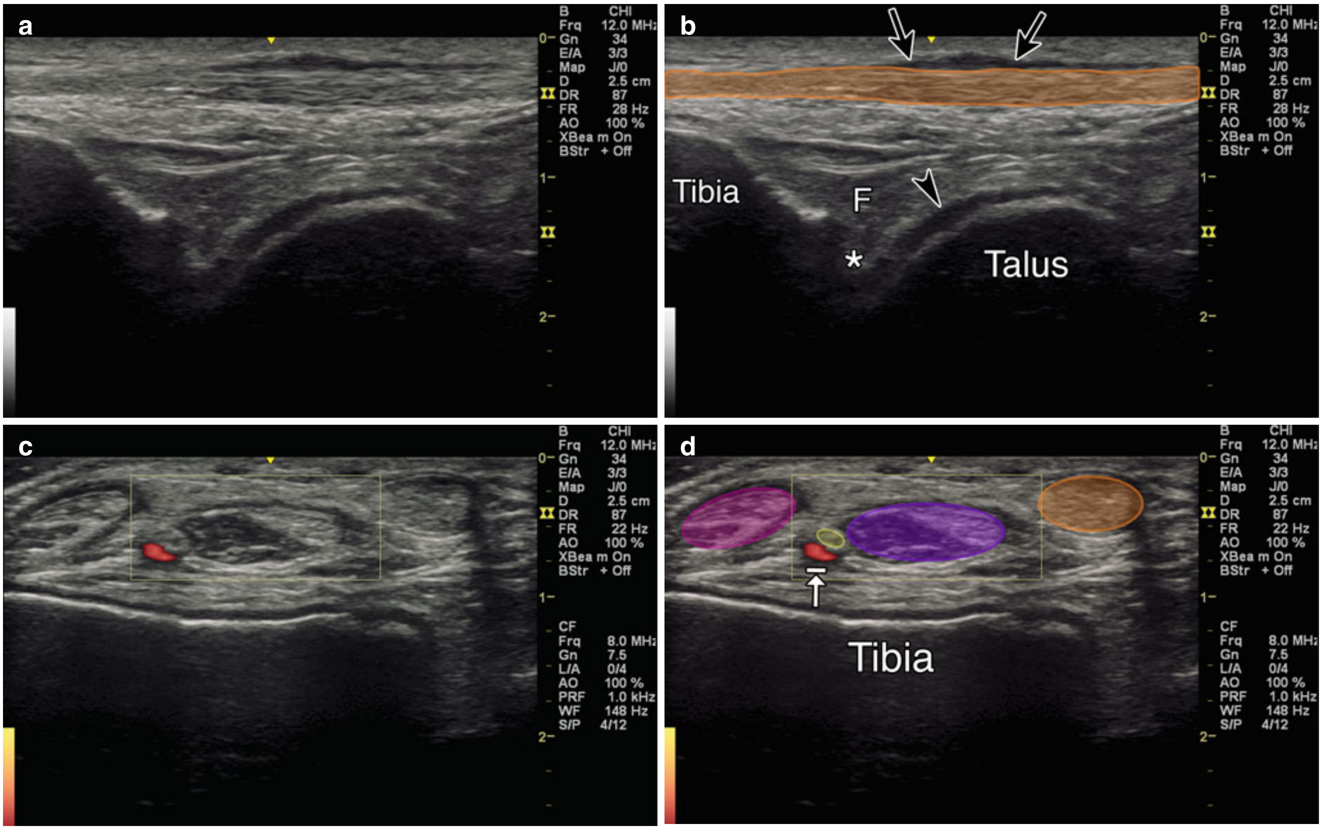

Fig. 7.1 (**a**) Sagittal view of tibiotalar joint. (**b**) *Orange* indicates tibialis anterior tendon. *Arrowhead* indicates hyaline cartilage. Arrows indicate fluid within tibialis anterior tendon sheath. *Asterisk* indicates joint space. *F* fat pad. Tibia and talus labeled. (**c**) Axial view of tibiotalar joint. (**d**) *Orange* indicates tibialis anterior muscle. *Purple* indicates extensor hallucis longus muscle. *Yellow* indicates deep peroneal nerve. *Arrow with stop* indicates the anterior tibial artery. *Magenta* indicates extensor digitorum longus muscle

Injection Technique: In-Plane Sagittal Anterior Approach [2, 8]

Patient positioning: Lay the patient supine, knee flexed with foot flat. Alternatively, the ankle can rest off the end of the table with the foot passively plantar flexed.

Probe positioning: Position the transducer so that the center of the screen is in between the extensor hallucis longus and tibialis anterior, and then rotate back to the sagittal plane for the injection (Fig. 7.2a).

Markings: Identify the dorsalis pedis artery, deep fibular nerve, tibialis anterior tendon, and extensor hallucis longus tendon.

Needle position: Enter in-plane and maintain a relatively steep angle to avoid scraping the talar dome, which can sometimes appear contiguous with an overlying effusion.

Safety considerations: Avoid the dorsalis pedis artery, deep fibular nerve, tibialis anterior tendon, and extensor hallucis longus tendon.

Pearls:

- There should be minimal resistance during injection.
- Superior migration of the overlying fat pad further confirms intra-articular spread of injectate.
- If visualization is poor, gel standoff can be used.

Equipment needed:

- Medium-frequency linear array transducer (8–12 MHz)
- 22–25G 1.5″ needle
- 0.5–1.0 mL of steroid preparation
- 1–3 mL local anesthetic

Subtalar Joint (Talocalcaneal Articulation)

The subtalar joint is comprised of three articulations between the talus and the calcaneus. The anterior facet is located above the anteromedial corner of the calcaneus, the middle facet is located medially, and the posterior facet is located posteriorly. The anterior and middle facets are contiguous and together comprise the anterior subtalar articulation [9, 10]. The current literature only focuses on the posterior articulation, perhaps because it is the largest of the three and presumably bears the majority of the weight across the joint. In one study blind injection using an anterolateral approach resulted in a 27 % rate of extravasation into the surrounding structures in an unpredictable distribution [9]. The posterolateral approach was found to be superior (91.2 % vs. 67.6 %) [10]. A study comparing ultrasound-guided anterolateral, posterolateral, and posteromedial approaches resulted in 100 % accuracy for all three methods, with rates of extravasation 25, 25, and 8.3 %, respectively [11]. Furthermore, using dynamic ultrasound may allow a smoother needle trajectory, minimizing contact with surrounding structures [12].

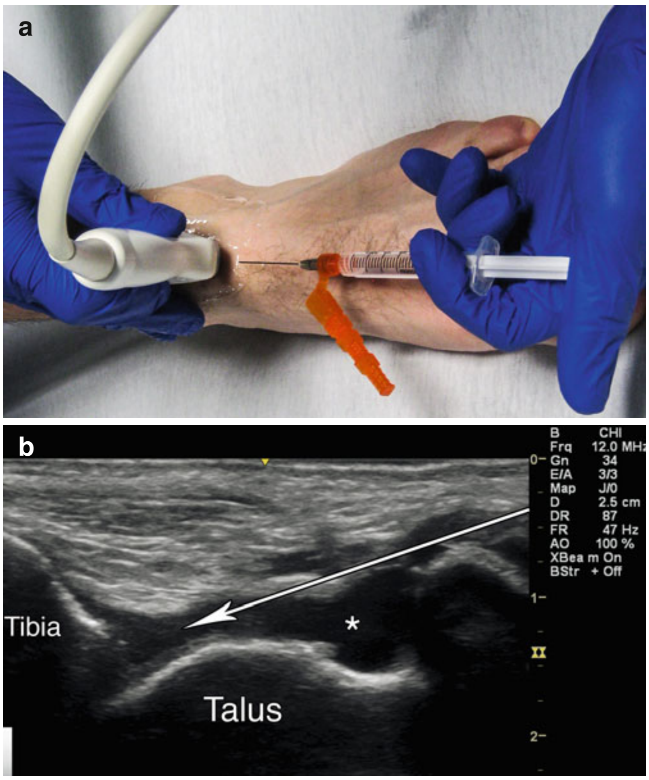

Fig. 7.2 (**a**) Example of sagittal probe position over anterior tibiotalar joint with in-plane needle position. (**b**) Sagittal view tibiotalar joint. *Arrow* indicates needle trajectory. *Asterisk* indicates effusion. Tibia and talus labeled

Scanning Techniques and Anatomy to Identify

The posteromedial approach has been shown to have the best accuracy (reference above). Position the patient side lying with the medial aspect of the affected joint upwards and a rolled towel beneath the lateral malleolus to place the ankle in subtalar eversion. Place the transducer in the coronal plane with the proximal end on the medial malleolus and the distal end over the sustentaculum tali of the calcaneus. Identify the middle subtalar facet, which appears as an anechoic space between the sustentaculum tali and the talus. Sweep the transducer posteriorly to locate the anechoic medial aspect of the posterior subtalar joint line (Fig. 7.3).

Injection Technique: Out-of-Plane Coronal Posteromedial Approach

Patient positioning: Lay the patient on their side with the medial aspect of the affected ankle facing upwards. A rolled-up towel can be placed below the lateral malleolus to promote subtalar eversion.

Probe positioning: Place the probe in the coronal plane just posterior to the sustentaculum tali and medial malleolus (Fig. 7.4a).

Markings: Identify and avoid the tarsal tunnel.

Needle position: Insert the needle out-of-plane, anterior to the transducer, and angle it posteriorly and laterally.

Safety considerations: Avoid the tibialis posterior, flexor digitorum, and flexor hallucis longus tendons and the plantar nerves and arteries.

Pearls:

- Subtalar alignment can vary based on the type of pathology
- Gel standoff can be used to optimize trajectory

Equipment needed:

- High-frequency linear array transducer

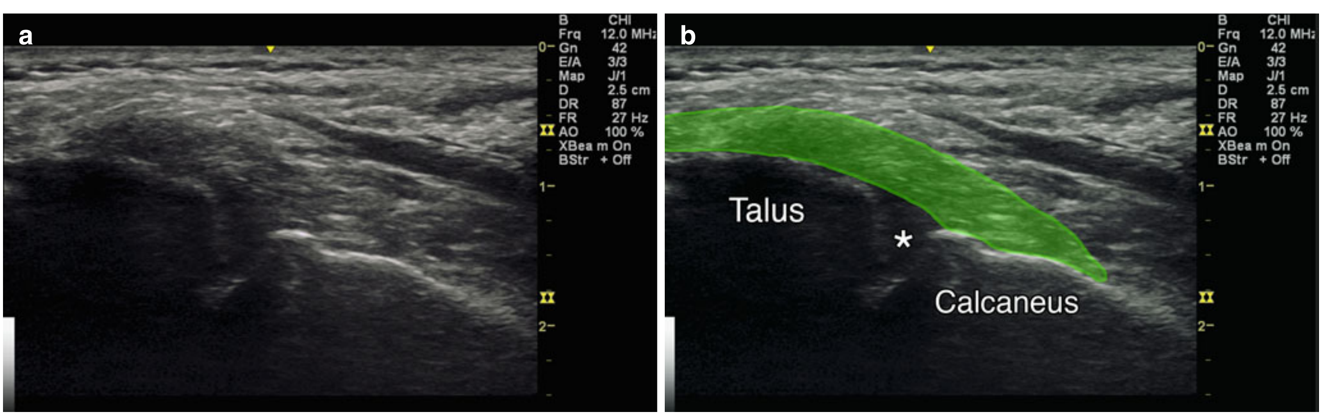

Fig. 7.3 (**a**) Coronal view of posterior subtalar joint. (**b**) *Green* deltoid ligament. *Asterisk* indicates subtalar joint. Talus and calcaneus labeled

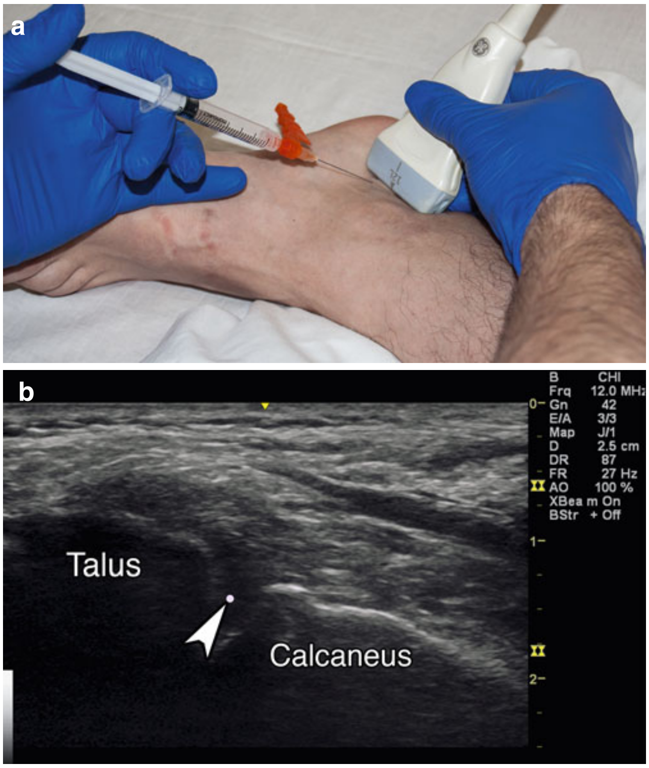

Fig. 7.4 (**a**) Example of coronal probe position over posteromedial subtalar joint with out-of-plane needle position. (**b**) Coronal view over subtalar joint. *Arrowhead* indicates needle tip. Talus and calcaneus labeled

- 22–25G 1.5″ needle
- 0.5 mL of steroid preparation
- 1–3 mL local anesthetic

Medial (Deltoid) Ligament

Ankle sprains have been found to account for 15–40 % of all athletic injuries [13–15]. The medial ligament is composed of the posterior tibiotalar, tibiocalcaneal, tibionavicular, and anterior talotibial ligaments. The complex is stronger, more stable, and less commonly injured than the lateral ligaments. It is a major contributor to ankle stability during weight bearing and is the primary limiter of lateral talar shift and talar external rotation. External rotation fractures at the lateral malleolus are associated with medial ligament injuries. Local swelling, tenderness, and ecchymosis have been shown to be unreliable in establishing a diagnosis. MRI is useful for visualization of ligament irregularity but is unable to demonstrate instability. A 2004 study found the most commonly used radiographic finding for deltoid ligament rupture and medial ankle instability (the medial clear space) to be unreliable [16]. In a prospective study of 12 patients with supination external rotation injuries, ultrasound accurately diagnosed acute deltoid ligament rupture with a sensitivity and specificity of 100 % [8]. No current evidence supports the use of local injections for medial ligament injuries. However, emerging studies seem promising for the eventual development of an appropriate injectate.

Scanning Techniques and Anatomy to Identify

Position the patient in side-lying position with the medial aspect of the affected joint facing upwards. Use a rolled-up towel below the lateral malleolus to place the ankle in subtalar eversion. Maintain the proximal end of the transducer over the medial malleolus and rotate the distal end to the neck of the talus for the anterior tibiotalar ligament, the navicular bone for the tibionavicular ligament, the sustentaculum tali for the tibiocalcaneal ligament, and the posterior process of the talus for the posterior tibiotalar ligament, which sits deep to the tibialis posterior tendon (Fig. 7.5).

Injection Technique: In-Plane Coronal Approach

Patient positioning: Lay the patient on their side with the medial aspect of the affected ankle facing upwards. A rolled-up towel can be placed below the lateral malleolus to promote subtalar eversion.

Probe positioning: Maintain the proximal end of the probe over the medial malleolus while rotating the distal end to the talar neck for the anterior tibiotalar ligament, the navicular bone for the tibionavicular ligament, the sustentaculum tali for the tibiocalcaneal ligament, and the posterior process of the talus for the posterior tibiotalar ligament, which sits deep to the tibialis posterior tendon (Fig. 7.6a).

Markings: Identify the tarsal tunnel and avoid inadvertent puncture.

Needle position: Enter with a superficial trajectory, in-plane with the probe.

Safety considerations: Avoid the posterior tibialis, flexor digitorum, and flexor hallucis longus tendons, and the plantar nerves and arteries.

Pearls:

- Manipulate the ankle to provide slack vs. tension to the structures of interest while scanning.
- Placing tension on the ligament may help the “feel” of the needle tip piercing its surface.
- Placing slack on the ligament may cause it to appear thicker, resulting in better visualization.

Equipment needed:

- High-frequency linear array transducer
- 25G 1.5″ needle
- 0.5 mL of injectate
- 1–3 mL local anesthetic

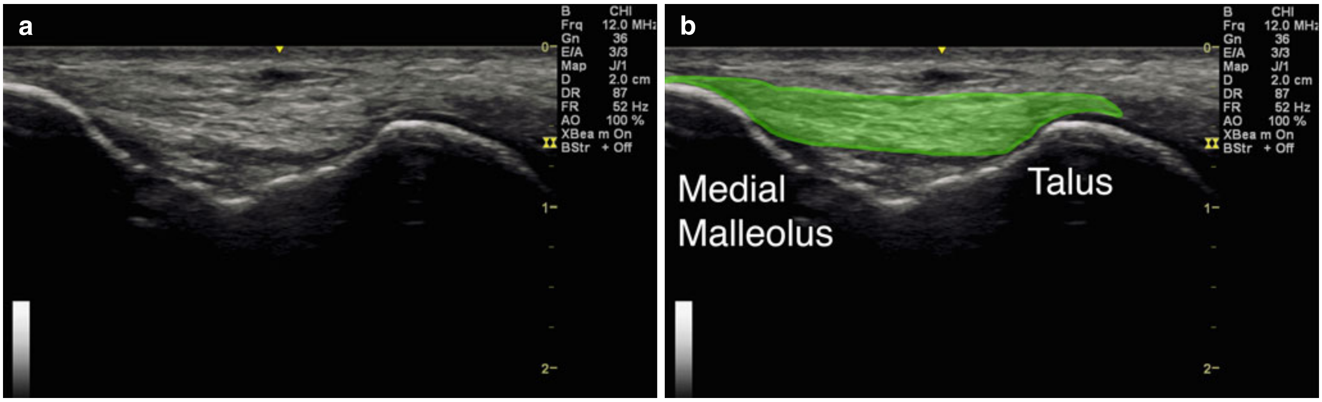

Fig. 7.5 (**a**) Coronal view of anterior tibiotalar ligament. (**b**) *Green* indicates tibiotalar component of deltoid ligament. Medial malleolus and talus labeled

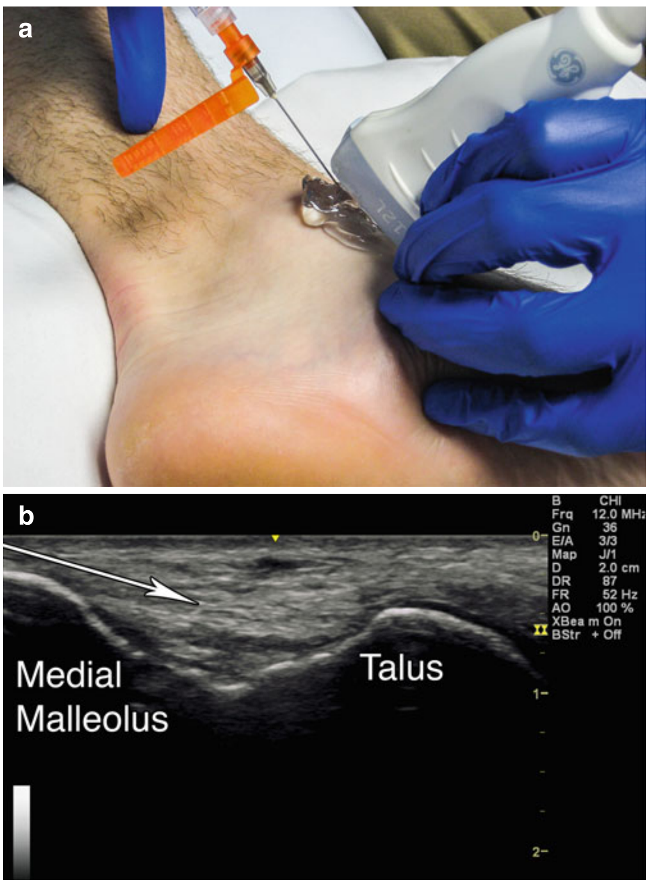

Fig. 7.6 (**a**) Example of coronal probe position with gel standoff over anterior tibiotalar ligament with in-plane needle position. (**b**) Coronal view of anterior tibiotalar ligament. *Arrow* indicates needle trajectory. Medial malleolus and talus labeled

Lateral Ligament Complex

The lateral ligament complex consists of the anterior talofibular ligament (ATFL), the calcaneofibular ligament (CFL), and the posterior talofibular ligament (PTFL) [17, 18]. In one study, point tenderness over the ATFL and CFL correlated with ligament rupture 52 and 72 % of the time, respectively. 71 % of patients with a positive anterior drawer sign, 68 % of patients with a positive talar tilt, 70 % of patients with ≥4 cm of swelling under the lateral malleolus, and 91 % of patients with such swelling in combination with point tenderness were shown to have lateral ligamentous injury [19]. Ultrasound has been shown to have the diagnostic accuracy of 95 % for ATFL tears and 90 % for CFL tears (Table 7.2) [17, 18].

Scanning Techniques and Anatomy to Identify

Position the patient on their side with the lateral aspect of the affected ankle facing upwards. Use a rolled-up towel under the medial malleolus to place the ankle in subtalar inversion. For the ATFL, passively plantar flex the ankle and place the proximal edge of the transducer over the anterior aspect of the lateral malleolus, with the distal edge over the talus, reaching horizontally towards the midfoot. Visualize the lateral malleolus, the talus, and the ligament between them. For the CFL place the ankle in neutral and position the proximal edge of the transducer over the lateral malleolus. Aim the distal edge inferiorly and slightly posteriorly. Dorsiflexing the ankle may help visualize the ligament by placing it in tension. Immediately superficial to the CFL at the level of the superior edge of the calcaneus, the fibular tendons appear in cross section. The sural nerve runs inferior to these tendons, at a similar depth (Fig. 7.7) [21].

Injection Techniques: In-Plane Axial Approach

Patient positioning: Lay the patient on their side with the lateral aspect of the affected ankle facing upwards. A rolled-up towel can be placed under the medial malleolus to promote subtalar inversion. Place the ankle in plantar flexion for ATFL and dorsiflexion for CFL.

Table 7.2 Anatomy of lateral ligament complex

Ligament [12, 20]	ATFL	CFL	PTFL
Origin	1 cm proximal to the distal tip of the fibula	Distal tip of the fibula	10 mm proximal to the distal tip of the fibula
Insertion	lateral talar neck	Calcaneus	Posterior talus
Size	6–10 mm wide × 10 mm long × 2 mm thick	Cylindrical in shape, 20–25 mm length × 6–8 mm diameter	
Notes	Weakest, most commonly injured	Attachment point of the peroneal tendon sheath	Strongest, least commonly injured

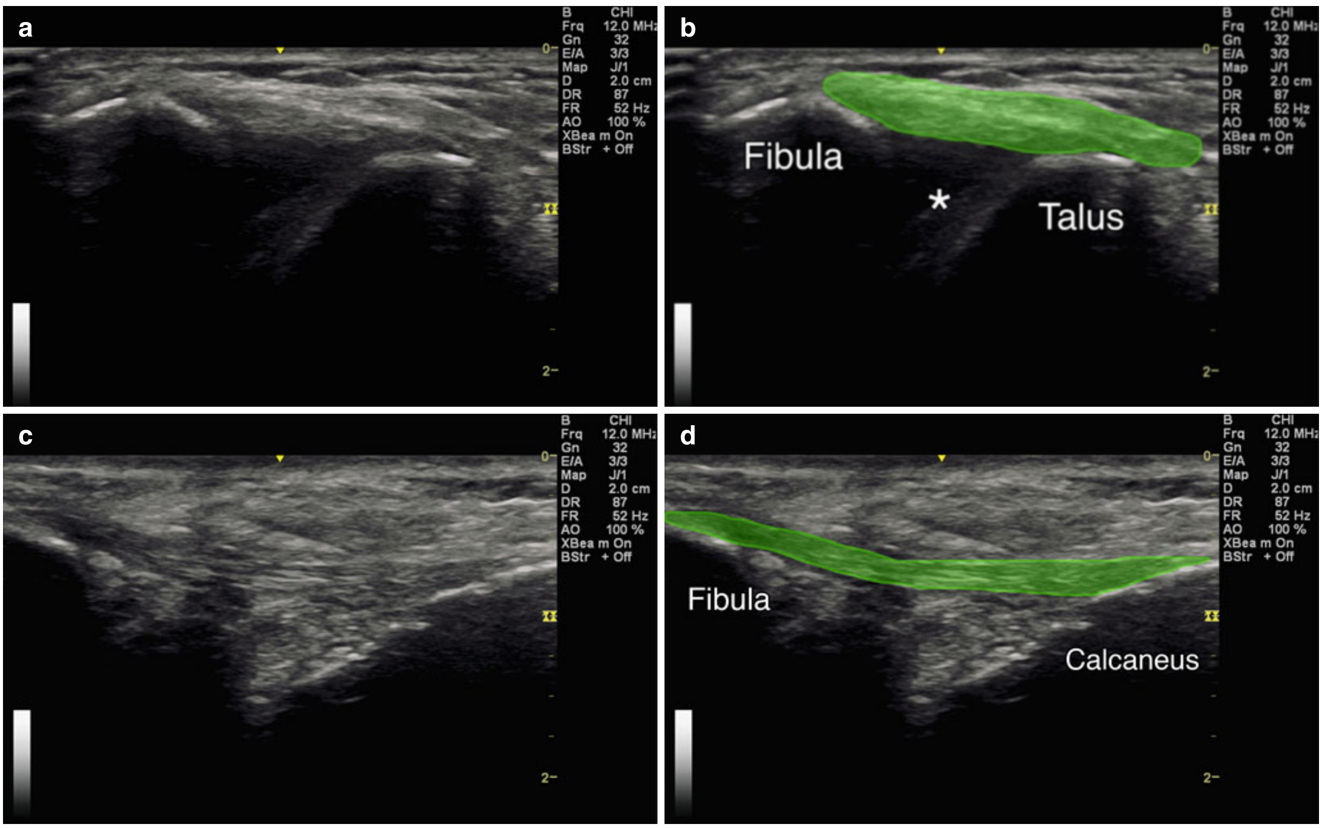

Fig. 7.7 (**a**) Axial view of the ATFL. (**b**) *Green* indicates the ATFL. *Asterisk* indicates joint space. Fibula and talus labeled. (**c**) Coronal oblique view of the CFL. (**d**) *Green* indicates the calcaneofibular ligament. Fibula and calcaneus labeled

Probe positioning: Maintain the proximal edge over lateral malleolus. Place the distal edge over the talus in the axial plane for the ATFL (Fig. 7.8a). Place the distal edge over the calcaneus in the coronal plane for the CFL.

Markings: Identify and avoid the sural nerve.

Needle position: Enter the skin with a superficial trajectory, in-plane with the probe.

Safety considerations: Avoid the sural nerve, peroneal tendons, and lesser saphenous vein.

Pearls:

- Manipulate the ankle to provide slack vs. tension to the structures of interest while scanning.
- Placing tension on the ligament may help the "feel" of the needle tip piercing its surface.
- Placing slack on the ligament may cause it to appear thicker, resulting in better visualization.
- The ATFL is contiguous with the ankle joint capsule and can appear as a discrete capsular thickening.
- The CFL is the only extra-articular ligament within the lateral complex.

Equipment needed:

- High-frequency linear array transducer
- 25G 1.5″ needle
- 0.5 mL of steroid preparation
- 1–3 mL local anesthetic

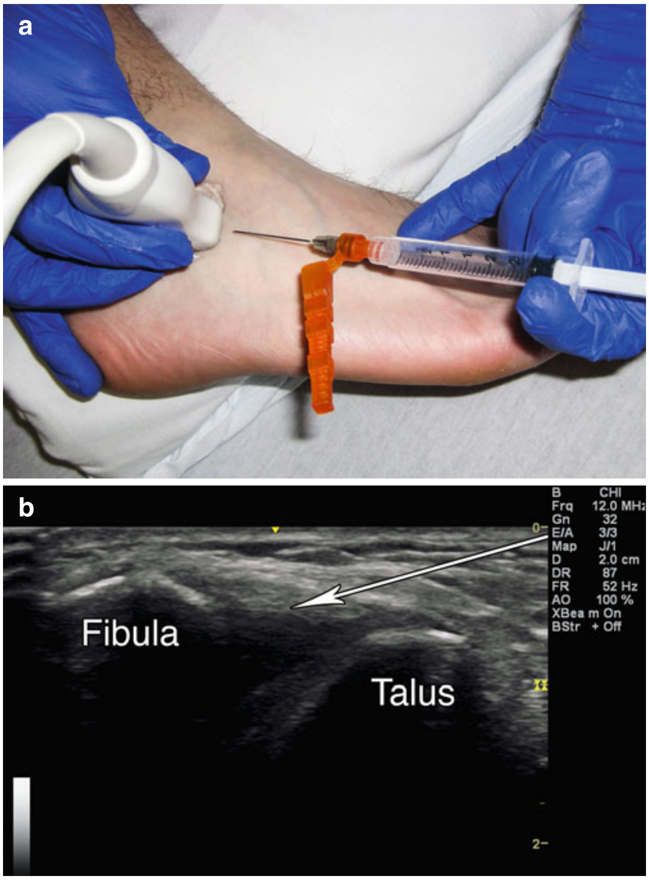

Fig. 7.8 (**a**) Example of axial probe position over ATFL with in-plane needle approach. (**b**) Axial view of ATFL with *arrow* indicating needle trajectory. Fibula and talus labeled

Retrocalcaneal Bursa

The retrocalcaneal bursa is located immediately superior and deep to the distal insertion of the Achilles tendon on the posterior calcaneus. Ultrasound has been shown to accurately visualize the bursa and guide targeted intervention [20]. One study suggests that merely visualizing the bursa on ultrasound suggests pathology [22]. An anterior to posterior diameter greater than 2.5 mm is generally considered abnormal [15]. The Achilles (retro-Achilles/subcutaneous calcaneal) bursa is larger and located superficial to the Achilles tendon at the same level. Any evidence of fluid here on ultrasound is pathologic.

Scanning Techniques and Anatomy to Identify

Position the patient prone with the ankle and foot hanging off the table edge. Place the transducer in the longitudinal plane directly over the Achilles tendon. Visualize the Achilles tendon, its calcaneal insertion, and Kager's fat pad,

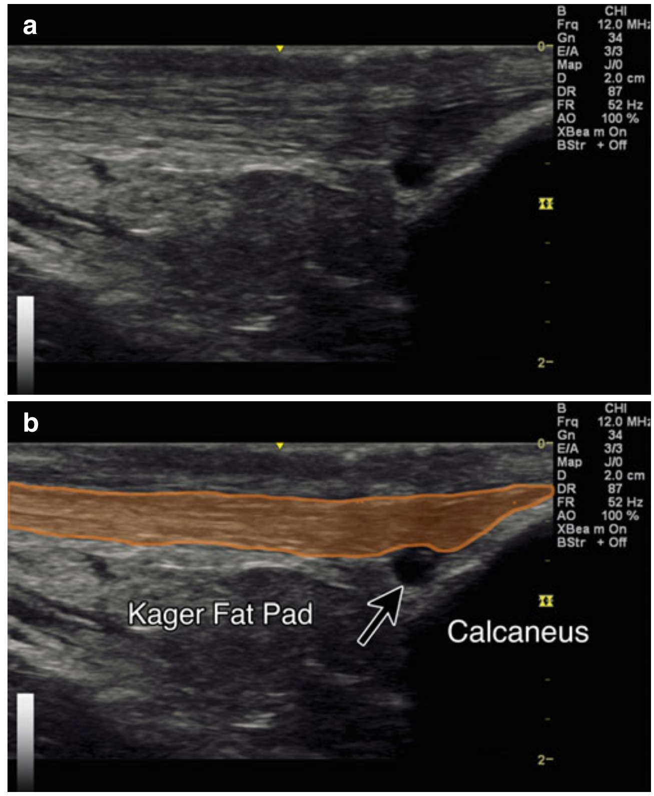

Fig. 7.9 (**a**) Sagittal view of Achilles tendon and retrocalcaneal bursa. (**b**) *Orange* indicates Achilles tendon. *Arrow* indicates retrocalcaneal bursitis. Kager's fat pad and calcaneus labeled

which is deep to the tendon immediately proximal to its insertion. The retrocalcaneal bursa sits in between these three structures and is not always visible. Rotate the transducer 90° into the axial plane and identify the aforementioned structures [23]. The fat pad should not be visible since it is directly superior to this viewing level, above the bursa. Moving the transducer superiorly and inferiorly will bring the fat pad and calcaneus into view, respectively (Fig. 7.9).

Injection Technique: In-Plane Axial Approach

Patient positioning: Lay the patient prone with the foot hanging off the table edge.

Probe positioning: Place the probe in the sagittal plane directly midline over the Achilles tendon at its calcaneal attachment. Center the bursa on the screen in the sagittal plane, then rotate into the axial plane. Use Doppler to identify any surrounding blood vessels and use a medial or lateral approach accordingly (Fig. 7.10a).

Markings:

Needle position: Enter the skin in-plane with the transducer from the medial or lateral side.

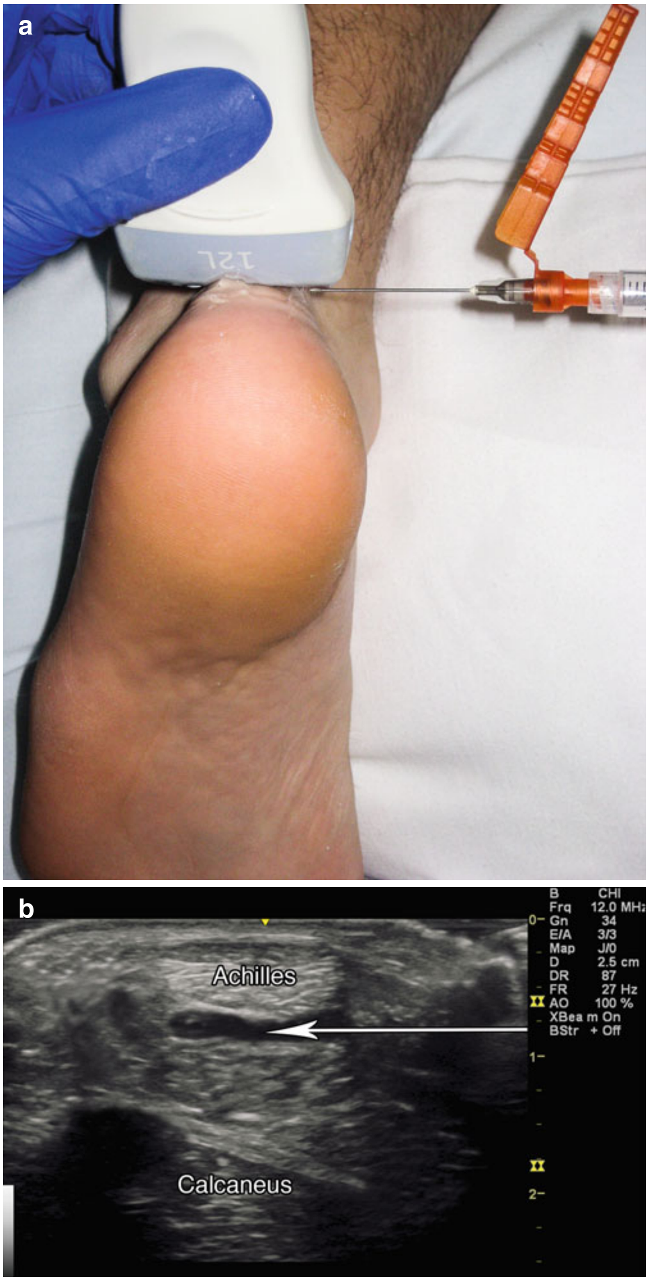

Fig. 7.10 (**a**) Example of axial probe position over retrocalcaneal bursa with in-plane needle position. (**b**) *Arrow* indicates needle trajectory into retrocalcaneal bursitis. Cross section of Achilles labeled. Calcaneus labeled

Safety considerations: Avoid the sural nerve and any obvious vessels with the lateral approach.

Pearls:

- Doppler can also be used to confirm hyperemia within the bursa.

Equipment needed:

- High-frequency linear array transducer
- 25G 1.5″ needle
- 0.5 mL of steroid preparation
- 1–3 mL local anesthetic

Table 7.3 Accuracy of achilles tendon injections

Study – Achilles tendon injection	Author	Accuracy (%)
Ultrasound guided (unblinded)	Reach et al. [2]	100

Achilles Tendon/Paratenon

Ultrasound is useful in identifying small tears, partial ruptures, retrocalcaneal bursitis, and chronic tendinosis [24–26]. Corticosteroid injection is generally not recommended due to the risk of rupture; however, in the setting of acute and/or chronic inflammation, corticosteroid injection to the surrounding paratenon sheath can alleviate symptoms. If symptoms become chronic, dry needling and injection of reparative substances are potential interventions (Table 7.3) [27].

Scanning Techniques and Anatomy to Identify

Position the patient prone with the foot hanging off the end of the examination table. A pillow under the distal tibia can be used for comfort. Scan both views of the tendon from the myotendinous junction to the calcaneus. In the transverse plane, scan on both sides of the tendon to visualize the paratenon envelope or peritendinous sheath [1, 8]. Passive plantar/dorsiflexion may improve visualization of the tendon [28]. Look for the retro-Achilles and retrocalcaneal bursae. Power Doppler settings may be utilized to visualize neovascularization and inflammation [1]. Tendinosis appears as areas of hypoechogenicity with intact fibrillar structure. Thickening of the tendon or a relatively diffuse convex shape at the attachment of the tendon is abnormal [29, 30]. Generally, the injection approach is medial to avoid injuring the sural nerve [31–33]. Alternatively, inject the paratenon at the midportion level (2–6 cm proximal to the Achilles tendon insertion into the calcaneus) (Fig. 7.11) [34].

Injection Technique: In-Plane Sagittal Approach

Patient positioning: Lay the patient prone with foot resting off the end of the table.

Probe positioning: Place the probe in the sagittal plane for initial visualization and scan proximally and distally, looking for focal thickening and/or fluid (Fig. 7.12a). The probe can also be rotated 90° to the axial plane for an in-plane axial approach.

Markings:

Needle position: Enter in-plane, from proximal to distal or distal to proximal, and maintain a shallow trajectory.

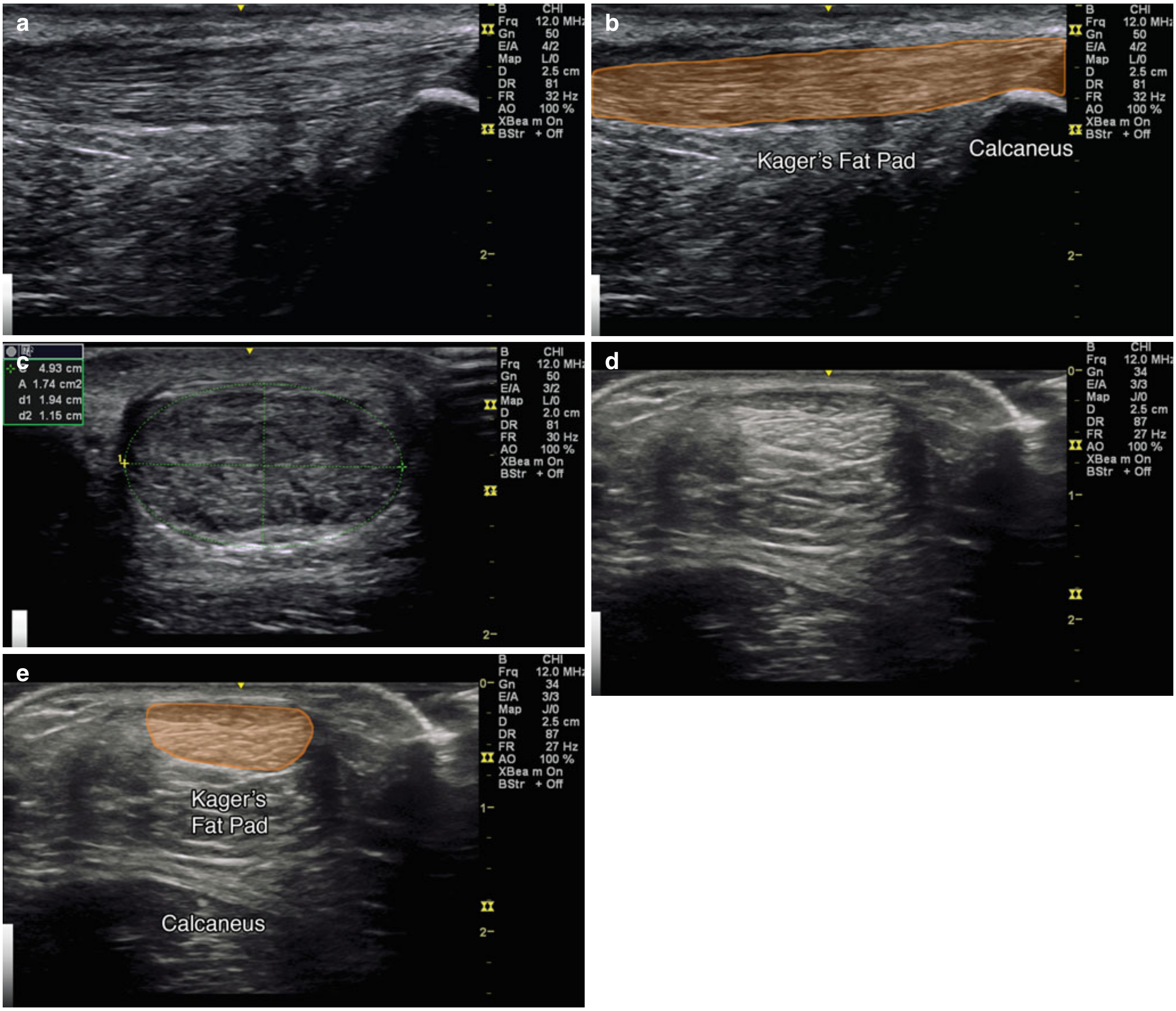

Fig. 7.11 (**a**) Sagittal view of Achilles tendon. (**b**) *Orange* indicates Achilles tendon, Kager's fat pad and calcaneus labeled. (**c**) Axial view of Achilles tendinosis. (**d**) Axial view of Achilles tendon (**e**) *Orange* indicates Achilles tendon. Kager's fat pad and calcaneus labeled

Safety considerations: Approach from medial to lateral to avoid damage to the sural nerve.

Pearls:

- Accurately measuring the depth of the target on the screen is important to maintain the trajectory parallel to the transducer.
- Ankle dorsiflexion stretches the Achilles tendon and may reduce anisotropy [30].
- Power Doppler may also be used to see areas of increased vascularity, representing inflammation [2, 35].

Equipment needed:

- High-frequency linear array transducer
- 25G 1.5″ needle
- 0.5 mL of steroid preparation
- 1–3 mL local anesthetic

Midtarsal Joint (Transverse Tarsal Joint)

The midtarsal or transverse tarsal joint, also known as the Chopart joint, is comprised of articulations between the talonavicular and calcaneocuboid joints. Ligaments that help to stabilize this joint are the dorsal talonavicular, dorsal and plantar calcaneocuboids, spring, and bifurcate ligaments. The spring ligament attaches from the sustentaculum tali of the calcaneus and attaches to the medial and plantar border of the navicular bone, providing strong plantar support for the talar head along with the short and long plantar ligaments (plantar calcaneocuboids and calcaneocuboid metatarsal ligaments, respectively), as well as maintaining the longitudinal arch of the foot [5].

Although injuries to the midtarsal joints are rare with the incidence estimated to be at 3.6 per 1,000,000 year, up to

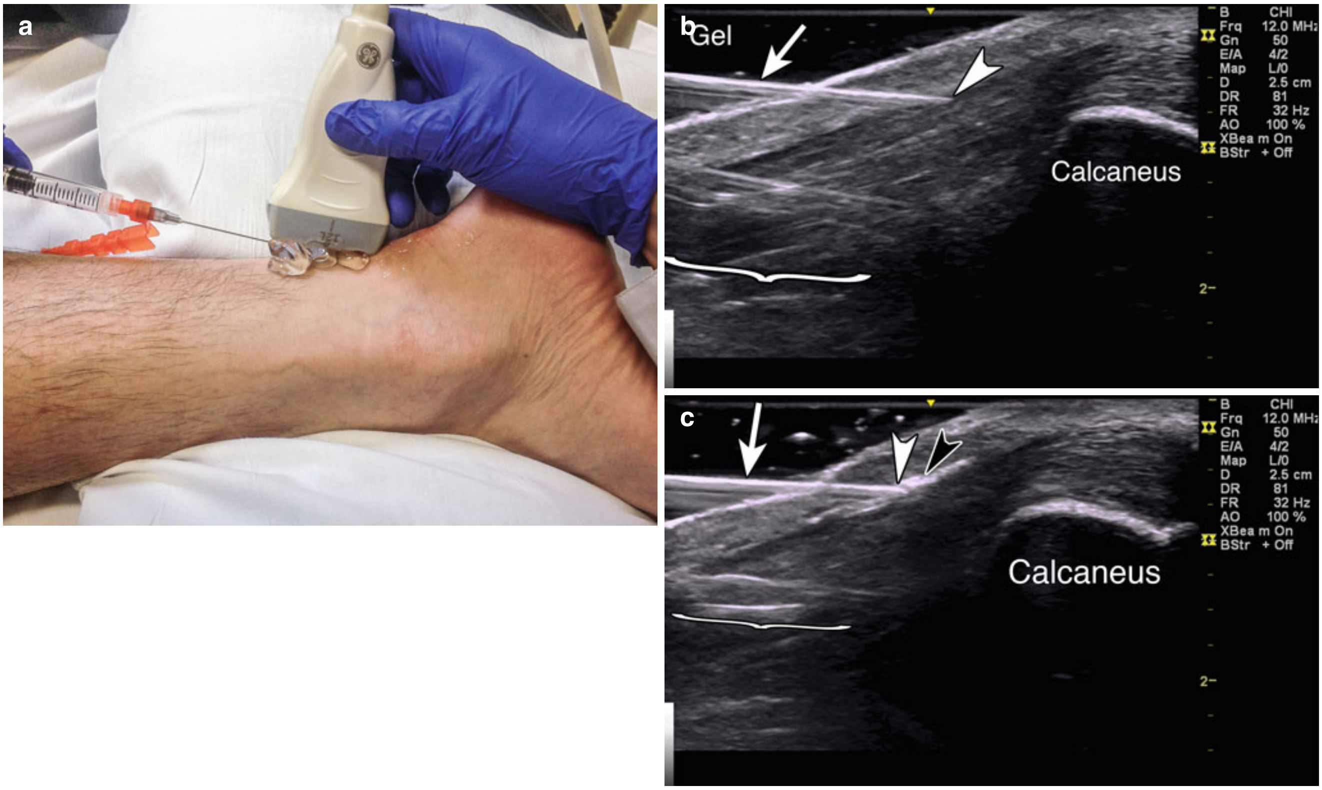

Fig. 7.12 (**a**) Example of sagittal probe position with gel standoff over Achilles tendon with in-plane needle position. (**b**) Example of in-plane injection with *arrowhead* in tendon sheath. *Arrow* indicates needle. Gel shows standoff positioning. *Bracket* indicates needle reverberation. Calcaneus labeled. (**c**) *Black arrowhead* indicates steroid flash within in sheath superficial to the Achilles tendon. *White arrowhead* indicates needle tip. *Arrow* indicates needle. *Bracket* indicates needle reverberation. Calcaneus labeled

41 % of these cases are misdiagnosed, possibly secondary to poor imaging choices [36]. In the detection of midfoot fractures, standard dorsoplantar and oblique radiographic views are reported to have low sensitivities ranging anywhere from 25 to 33 % [37]. In regard to tendinous injuries, insufficiency of the spring ligament is associated with increased risk for development of pes planus and dysfunction of the posterior tibial tendon [38]. Osteoarthritis of the midfoot may occur as a result of aging, trauma, and/or misalignment.

Scanning Techniques and Anatomy to Identify

Place the patient supine with the ipsilateral knee bent so that the foot is resting comfortably on the table. Use the medial and lateral malleoli as starting points for the proximal end of the transducer, and place the distal end sagittal, towards the midfoot. For the talonavicular joint, start at the medial malleolus and slide the transducer anteriorly while identifying the talus, then the navicular bone. For the calcaneocuboid joint, start at the lateral malleolus and slide the transducer anteriorly while identifying the talus, then calcaneus, then cuboid bone (Fig. 7.13).

Injection Technique: In-Plane Axial Approach

Patient positioning: Lay the patient supine with the knee bent and the foot resting comfortably on the table.

Probe positioning: For the talonavicular joint, start with proximal tip over the medial malleolus and the distal tip extending towards the midfoot. Slide distally while identifying the talus, and then the navicular bone. For the calcaneocuboid joint, start with proximal tip over the lateral malleolus and the distal tip extending towards the midfoot. Slide distally while identifying the talus, then calcaneus, then cuboid bone (Fig. 7.14a). Center the joints on the screen and build up adequate gel standoff.

Markings: None.

Needle position: Enter the skin in-plane with the probe, using gel standoff to optimize the trajectory (proximal to distal for the talonavicular joint and distal to proximal for the calcaneocuboid joint).

Safety considerations: Avoid the dorsalis pedis artery by using power Doppler to plan the needle entry point.

Pearls:

- The angle of needle entry must be fairly steep to steer clear of the medial and lateral malleoli. Improve the angle by performing the injection distal to proximal.

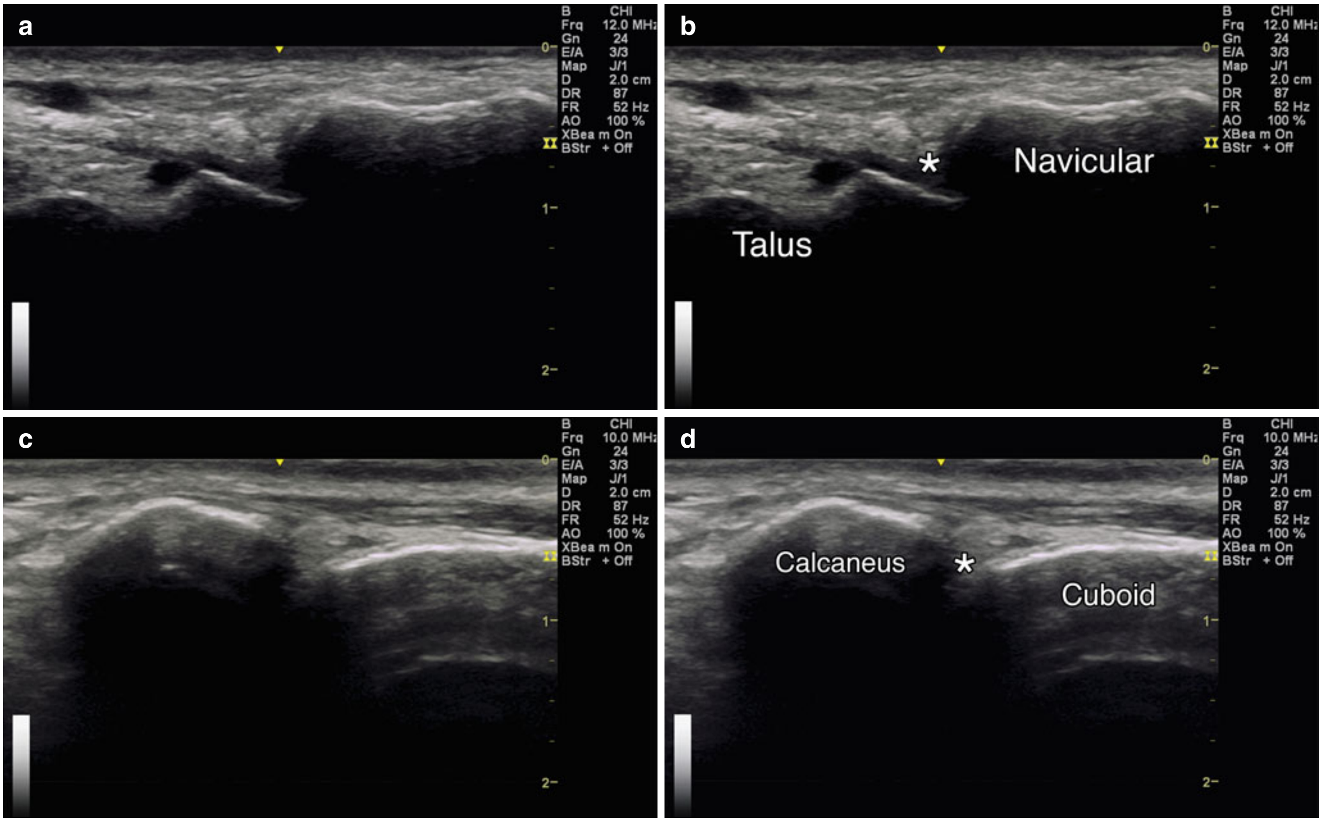

Fig. 7.13 (**a**) Axial view of talonavicular joint. (**b**) *Asterisk* indicates joint space. Talus and navicular labeled. (**c**) Axial view of calcaneocuboid joint. (**d**) *Asterisk* indicates joint space. Calcaneus and cuboid labeled

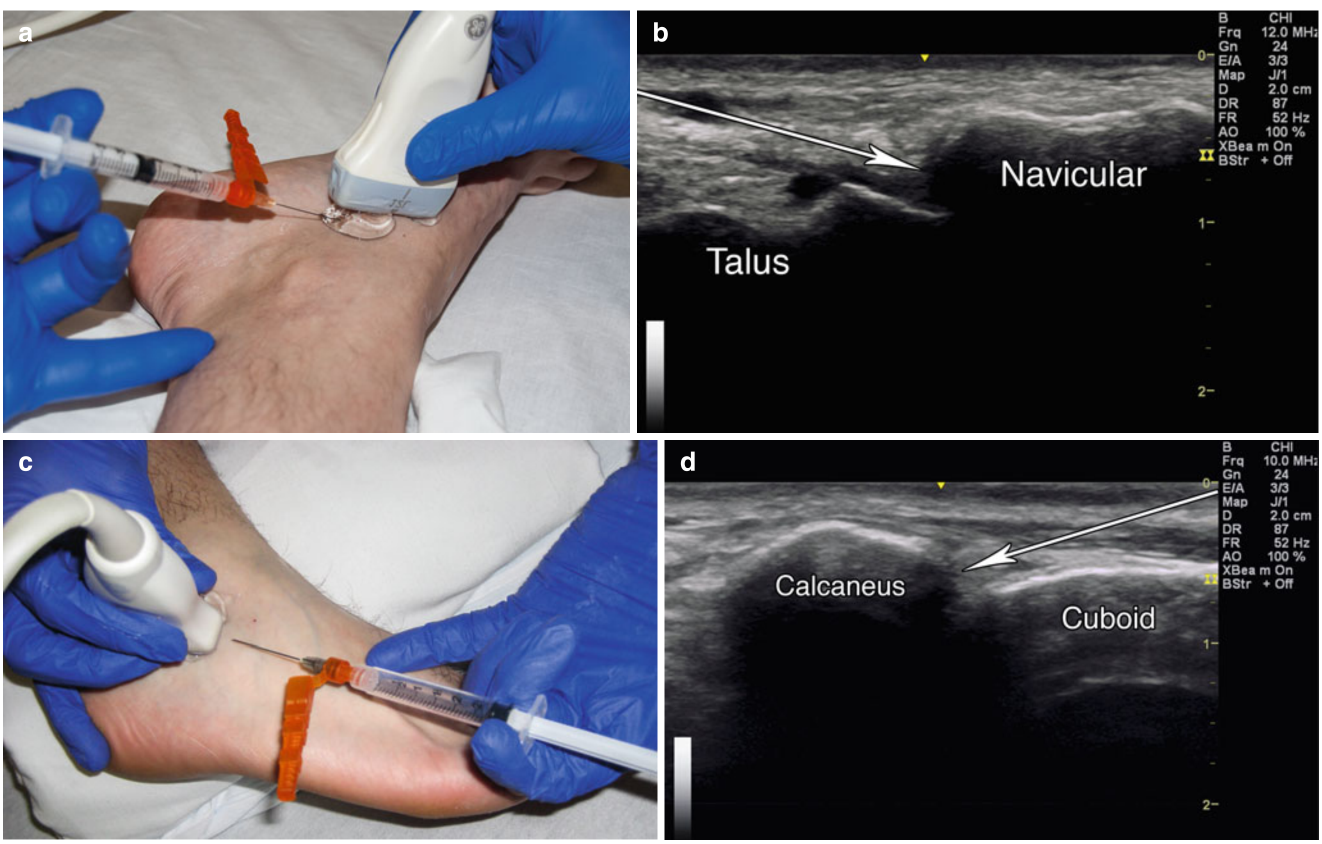

Fig. 7.14 (**a**) Example of axial probe position with gel standoff over talonavicular joint with in-plane needle position. (**b**) *Arrow* indicates needle trajectory into the talonavicular joint. Talus and navicular labeled. (**c**) Example of axial probe position over calcaneocuboid joint with in-plane needle position. (**d**) *Arrow* indicates needle trajectory into the calcaneocuboid joint. Calcaneus and cuboid labeled

Equipment needed:

- High-frequency linear array transducer
- 25G 1.5″ needle
- 0.5 mL of steroid preparation
- 1–3 mL local anesthetic

Morton's Neuroma

Morton's neuroma (interdigital neuroma) is a common cause of forefoot pain and paresthesia, especially in women. It is a nonneoplastic enlargement of the common plantar digital nerve due to trauma, nerve entrapment, endoneurium edema, axonal degeneration, and/or vascular proliferation [30, 39]. The most common site for a Morton's neuroma is the 3rd web space, followed by the 2nd. Mulder's sign, where the examiner places medial and lateral stress compressing the metatarsal heads, displacing a neuroma in the plantar direction, may elicit a palpable click or pain. Ultrasound is both sensitive and specific, diagnosing Morton's neuroma with 95–98 % accuracy [40, 41].

Scanning Techniques and Anatomy to Identify

Place the patient supine with the leg straight and the foot lying comfortably. Position the transducer in the coronal plane, transverse to the metatarsal heads. The neuroma appears as a hypoechoic mass, replacing the normal hyperechoic fat found in the interdigital web space. Masses greater than 5 mm are more likely to be symptomatic [40]. In the sagittal plane, identification of the common plantar digital nerve leading into the neuroma and non-compressibility of the mass both support the diagnosis of neuroma, rather than bursitis (Fig. 7.15) [30].

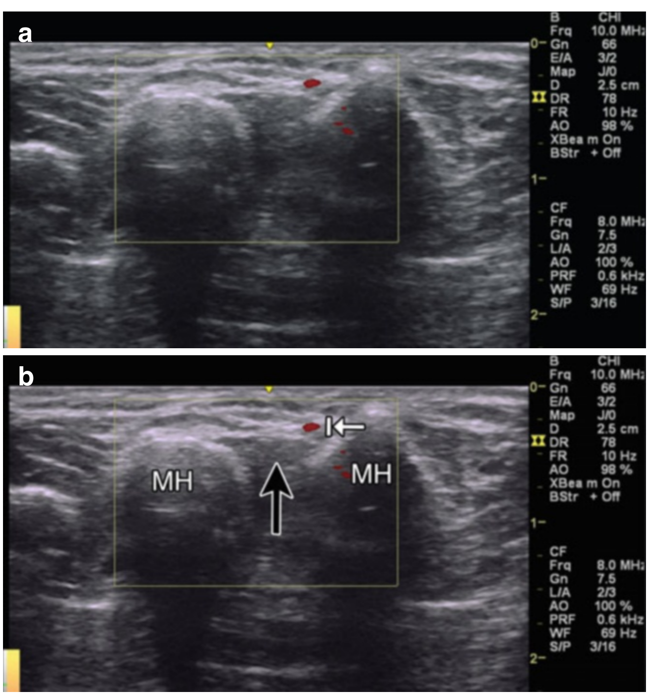

Fig. 7.15 (**a**) Coronal view of Morton's neuroma. (**b**) *Black arrow* indicates location of digital nerve. *White arrow with stop* indicates vasculature. *MH* metatarsal heads

Injection Technique: Out-of-Plane Coronal Approach

Patient positioning: Lay the patient supine with the knee flexed and the foot resting flat on the table.

Probe positioning: Place the probe transversely over the MTP joints. Visualize the neuroma in between the symptomatic MTP joints, and center it on the screen (Fig. 7.16a).

Markings: Identify small arteries.

Needle position: Enter the skin out-of-plane, advancing the needle posteriorly and inferiorly.

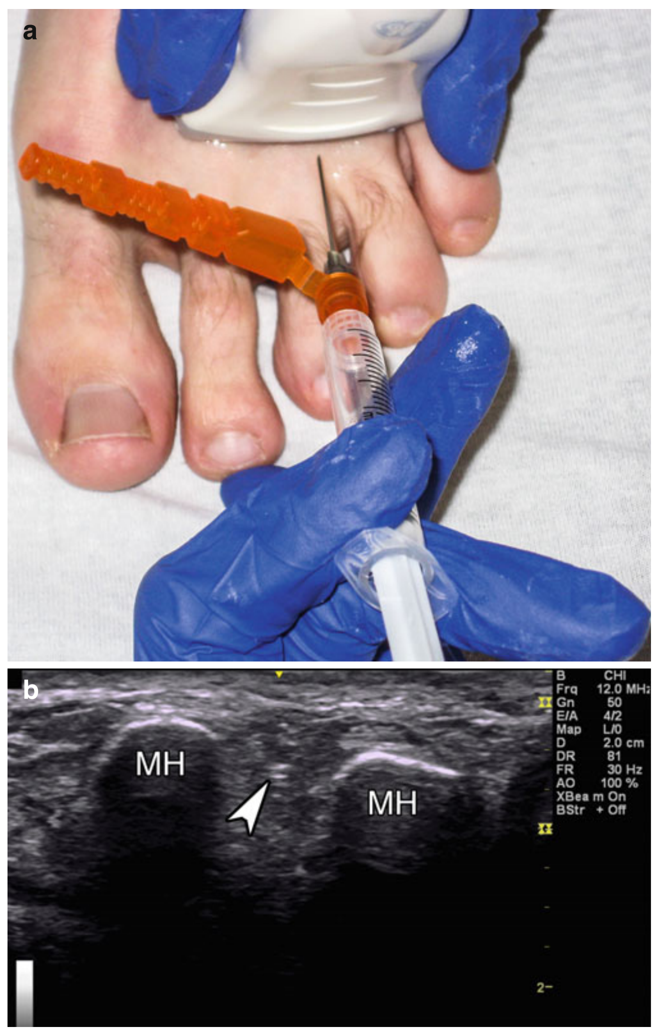

Fig. 7.16 (**a**) Example of coronal probe position over metatarsal heads with out-of-plane needle position. (**b**) Example of out-of-plane injection. *Arrowhead* indicates needle tip, *MH* metatarsal heads

Safety considerations: Advancing too deep can result in perforation of the sole of the foot.

Pearls:

- Power Doppler may be useful in differentiating between symptomatic and noninflamed interdigital neuromas [2].

Equipment needed:

- Medium-frequency linear array transducer (8–12 MHz)
- 22–25G 1.5″ needle
- 0.5 mL of steroid preparation
- 1–3 mL local anesthetic
- 3 mL alcohol or phenol

First Metatarsophalangeal Joint (MTP)

The first metatarsophalangeal (MTP) joint is a common site for forefoot pain. Differential includes gout, osteoarthritis, rheumatoid arthritis (RA), fracture, infection, turf toe, psoriatic arthritis, sesamoiditis, and EHL tendon rupture. Initial treatment includes orthotics with 1st MTP immobilization, rest, ice, compression, elevation (RICE), and activity modification. When pain persists, intra-articular injection of corticosteroid or hyaluronic acid may provide benefit (Table 7.4) [30, 43].

Table 7.4 Accuracy of first metatarsophalangeal joint (MTP) injections

Study – 1st MTP injection	Author	Accuracy (%)
Ultrasound guided (unblinded)	Reach et al. [2]	100
Ultrasound guided (unblinded)	Wempe et al. [42]	100

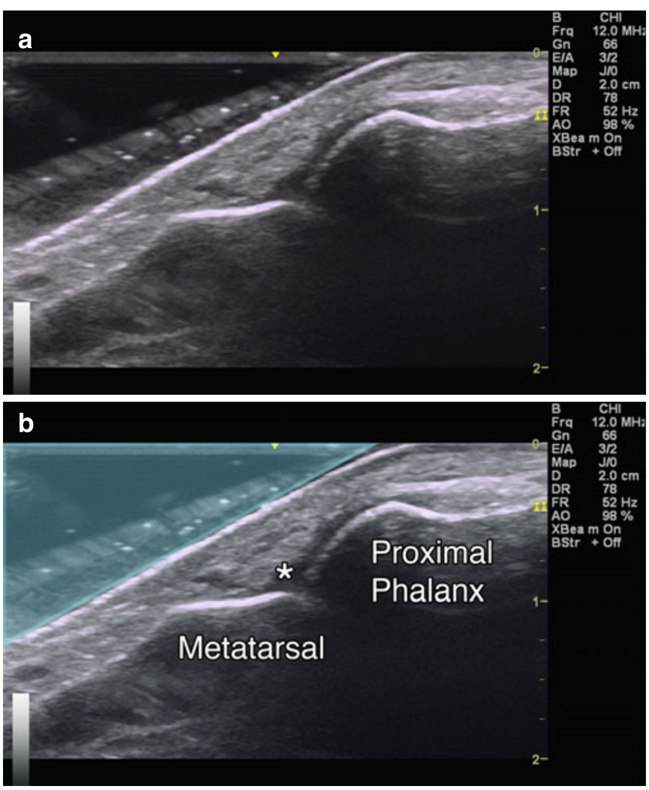

Fig. 7.17 (**a**) Sagittal gel standoff view over MTP joint. (**b**) Teal indicates gel. *Asterisk* indicates joint space. Metatarsal and proximal phalanx labeled

Scanning Technique and Anatomy to Identify

Begin by placing the transducer in the sagittal plane over the EHL tendon. Identify the distal phalanx, proximal phalanx, and 1st metatarsal. Slide the probe medially off of the tendon, and apply light traction and flexion to the toe, further opening up the joint space (Fig. 7.17).

Injection Technique: In-Plane Sagittal Approach

Patient positioning: Place the patient supine with knee flexed. Position the foot so that the forefoot is hanging off the edge, to facilitate manual traction.

Probe positioning: Place the probe in the sagittal plane, just medial to the EHL tendon (Fig. 7.18a).

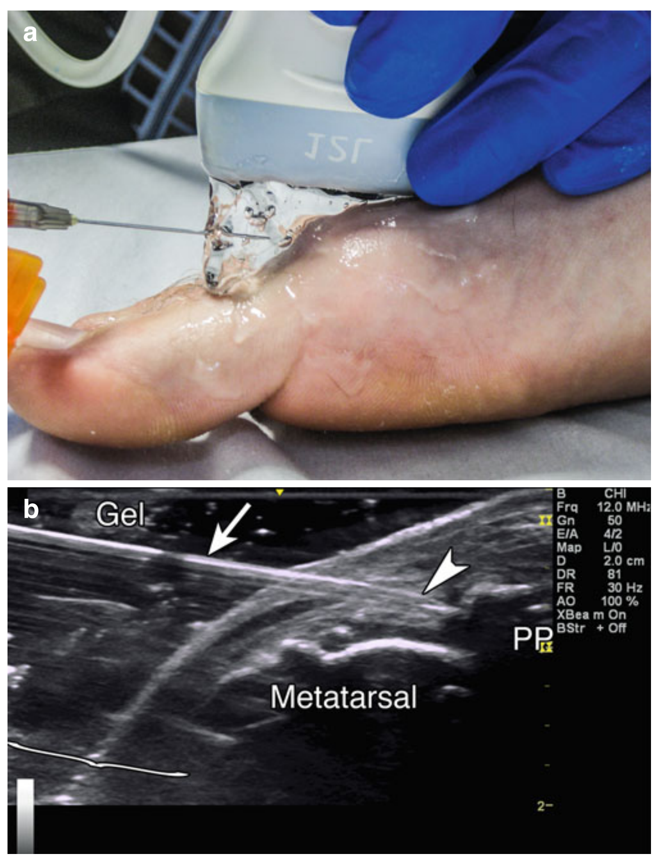

Fig. 7.18 (**a**) Example of sagittal probe position with gel standoff over first MTP joint with in-plane needle position. (**b**) Sagittal gel standoff view of first MTP with *arrowhead* indicating entry into joint. *Arrow* indicates needle. *Bracket* indicates needle reverberation. *PP* proximal phalanx. Metatarsal and gel labeled

Markings: None.

Needle position: Enter the skin in-plane with the transducer, advancing distal to proximal. Maintain a superficial trajectory and use gel standoff for better access.

Safety considerations: Avoid the EHL tendon.

Pearls:

- Applying axial traction may assist in opening up the joint.
- If gout is suspected, consider aspiration and lab work.
- Use a gel standoff to keep the needle parallel to the transducer and facilitate joint entry.

Equipment needed:

- High-frequency linear array transducer
- 25G 1.5″ needle
- 0.5 mL of steroid preparation
- 1–3 mL local anesthetic

Peroneal (Fibular) Tendon Sheath

The peroneus longus runs from the proximal fibula to the base of the first metatarsal and the peroneus brevis from the distal lateral fibula to the fifth metatarsal. Together, they dorsiflex (peroneus longus) and evert (peroneus brevis) the foot at the ankle. Injury to the tendons from repetitive eversion, trauma, or sudden dorsiflexion of the foot can lead to tenosynovitis, subluxation/dislocation, rupture, or chronic tendinopathy. Diagnosis is largely clinical but ultrasound is a useful and expedient alternative to MRI when imaging is indicated [44, 45]. Treatment begins with rest, immobilization, physical therapy, and anti-inflammatory medications. Persistent cases can be treated with injection therapy and surgery. Corticosteroid injections have proven to be useful but must be carefully performed given the close proximity to the sural nerve (Table 7.5) [45, 46].

Table 7.5 Accuracy of peroneal tendon sheath injection

Study – peroneal tendon sheath injection	Author	Accuracy (%)
Palpation	Muir et al. [46]	60
Ultrasound guided	Muir et al. [46]	100

Scanning Techniques and Anatomy to Identify

Lay the patient on their side with the lateral aspect of the affected ankle facing up. A rolled-up towel can be placed under the medial malleolus for comfort. Locate the lateral malleolus and position the transducer in the axial plane posterior to the fibula in the retromalleolar groove, approximately 3–4 cm proximal to the fibular tip. Starting superiorly, the peroneus brevis' muscle belly and tendon will be seen first. More inferiorly, approaching the fibular tip, the peroneus longus tendons may be identified [30, 47]. Follow the tendons in cross section along their course, wrapping around the malleolus. Visualize them just inferior and anterior to the medial malleolus in preparation for injection (Fig. 7.19).

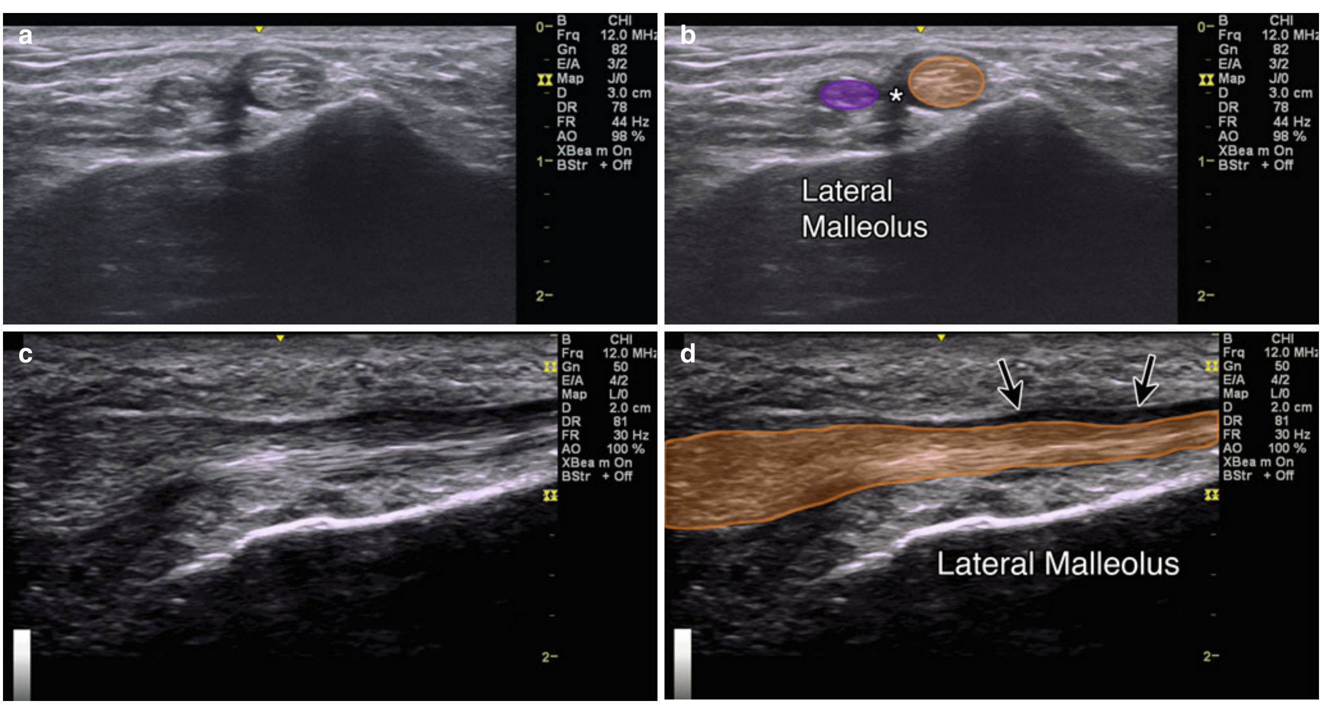

Fig. 7.19 (**a**) Short-axis view of peroneal tendons. (**b**) *Orange* indicates peroneusa brevis. *Asterisk* indicates tenosynovitis. *Purple* indicates peroneus longus. Lateral malleolus labeled. (**c**) Longitudinal view of the peroneus brevis tendon. (**d**) *Orange* indicates peroneus brevis tendon. *Arrows* indicate tenosynovitis. Lateral malleolus labeled

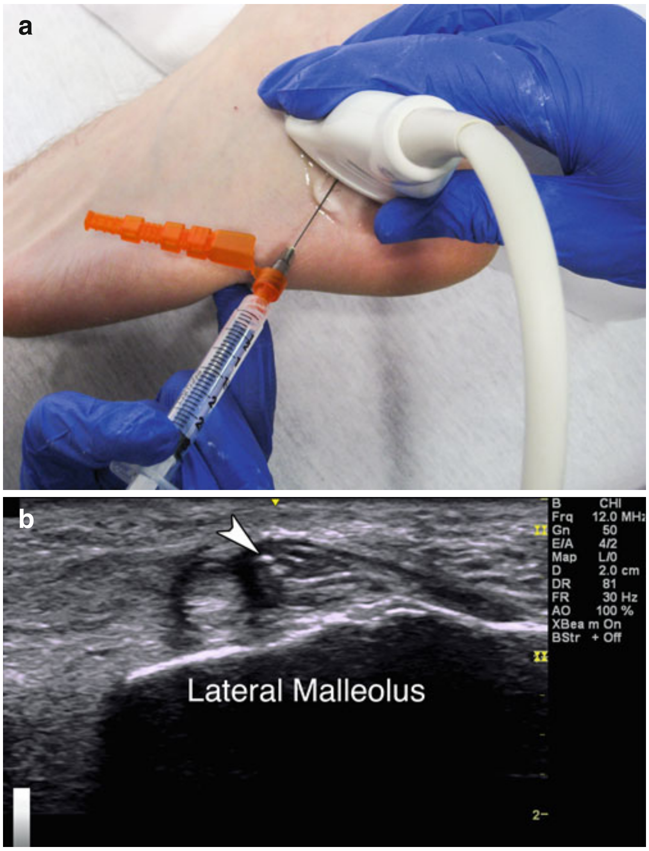

Fig. 7.20 (**a**) Example of short-axis probe position over peroneal tendons with out-of-plane needle position. (**b**) Example of out-of-plane injection. *Arrowhead* indicates needle tip. Lateral malleolus labeled

Injection Technique: Out-of-Plane Short-Axis Approach

Patient positioning: Lay the patient in on their side with the lateral aspect of the affected ankle facing up.

Probe positioning: The probe is placed inferior and anterior to the lateral malleolus, short axis to the tendons (Fig. 7.20a).

Markings:

Needle position: Enter the skin out-of-plane to the probe from either side of it, and advance to the tendon sheath.

Safety considerations: Look for and avoid the sural nerve, although it is not easily visualized.

Pearls:

- To assess for dynamic instability, place the transducer in the axial plane posterior to the distal fibula, and have the patient actively dorsiflex and evert the ankle [30].

Equipment needed:

- Medium-frequency linear array transducer (8–12 MHz)
- 25G 1.5″ needle
- 0.5 mL of steroid preparation
- 1–3 mL local anesthetic

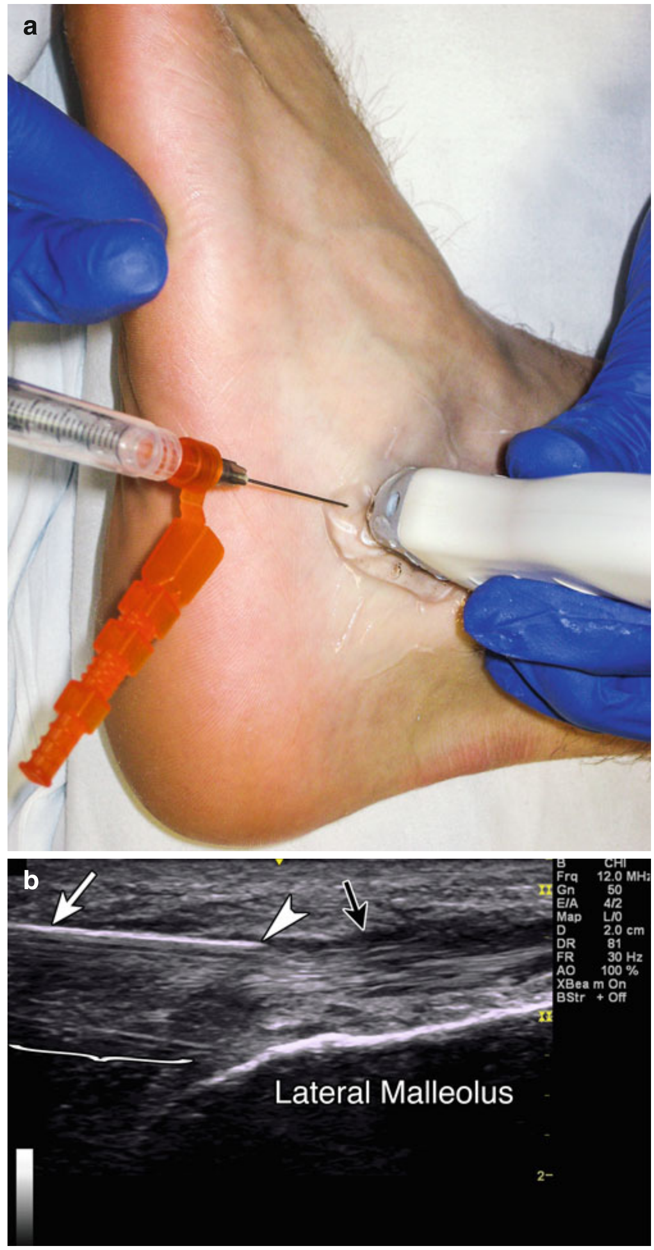

Fig. 7.21 (**a**) Example of longitudinal probe position over peroneal tendons with in-plane needle position. (**b**) Example of in-plane injection. *White arrowhead* indicates needle tip. *White arrow* indicates needle. *Bracket* indicates needle reverberation. *Black arrow* indicates fluid within tendon sheath. Lateral malleolus labeled

Injection Technique: In-Plane Longitudinal Approach

Patient positioning: Lay the patient in on their side with the lateral aspect of the affected ankle facing up.

Probe positioning: The probe is placed inferior and anterior to the lateral malleolus longitudinal to the peroneal tendons (Fig. 7.21a).

Markings:

Needle position: Enter the skin in-plane to the probe from either side of it and advance to the tendon sheath.

Safety considerations: Look for and avoid the sural nerve, although it is not easily visualized.

Pearls:

- To assess for dynamic instability, place the transducer in the axial plane posterior to the distal fibula, and have the patient actively dorsiflex and evert the ankle [30].

Equipment needed:

- Medium-frequency linear array transducer (8–12 MHz)
- 25G 1.5″ needle
- 0.5 mL of steroid preparation
- 1–3 mL local anesthetic

Plantar Fascia (Aponeurosis)

The plantar fascia arises proximally from the medial tuberosity of the calcaneus and attaches distally at the metatarsal heads of the proximal phalanges of the toes. It provides supports for the foot arch and acts as a shock absorber during weight-bearing activities. A 2003 Cochrane review by Crawford and Thomson described the condition as self-limiting, often resolving within a year's time regardless of treatment type [48]. According to another study by Tsai et al., 80–90 % of those affected respond to conservative treatment [49]. Patients who fail conservative measures may benefit from corticosteroid injections, PRP, or dry needling techniques. However, repeated steroid injections to this area can result in plantar fat pad atrophy or spontaneous plantar fascia rupture [26, 49, 50]. Palpation-guided injections are reported to have anywhere from 31 to 35 % treatment success rate [35]. Ultrasound guidance can decrease the risk of complication by guiding the needle along the plantar margin of the fascia and avoiding fat pad injection. In addition, response to injection therapy can be monitored by serial measurements of the plantar fascia [30].

Scanning Techniques and Anatomy to Identify

Lay the patient prone with their feet hanging off the table or at the end of the examination table with a pillow underneath. Place the transducer in the sagittal plane over the plantar aspect of foot at the level of the calcaneal insertion. Here, the width of the fascia may be measured along its whole course, noting areas of thickening. Normal plantar fascia appears echogenic and striated. Hypoechoic thickening (>4 mm) is an abnormal finding that is often seen at the proximal attachment of the fascia on the calcaneus [30, 33]. With the proximal attachment centered on the screen, rotate the probe 90° to visualize the attachment site in the coronal plane in preparation for injection (Fig. 7.22).

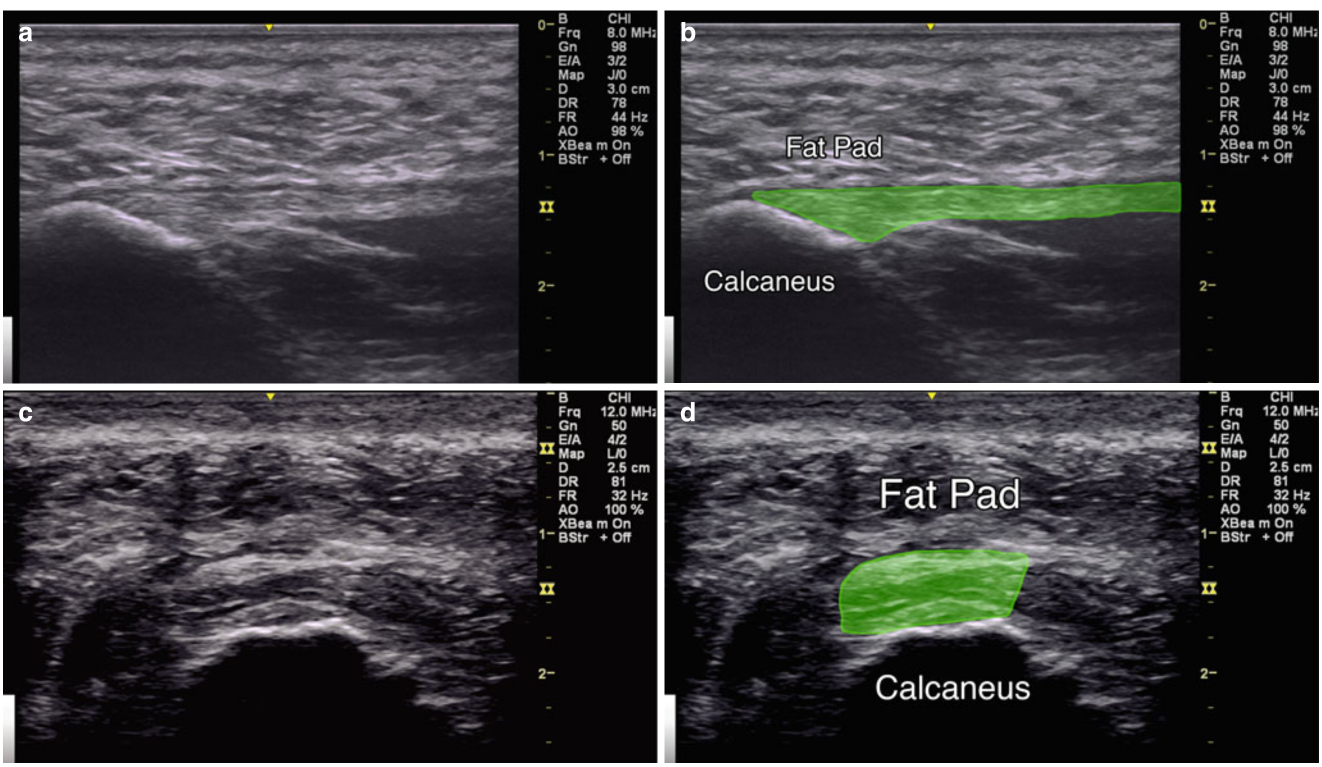

Fig. 7.22 (**a**) Sagittal view of plantar fascia. (**b**) *Green* indicates plantar fascia. Fat pad and calcaneus labeled. (**c**) Coronal view of plantar fascia. (**d**) *Green* indicates plantar fascia. Fat pad and calcaneus labeled

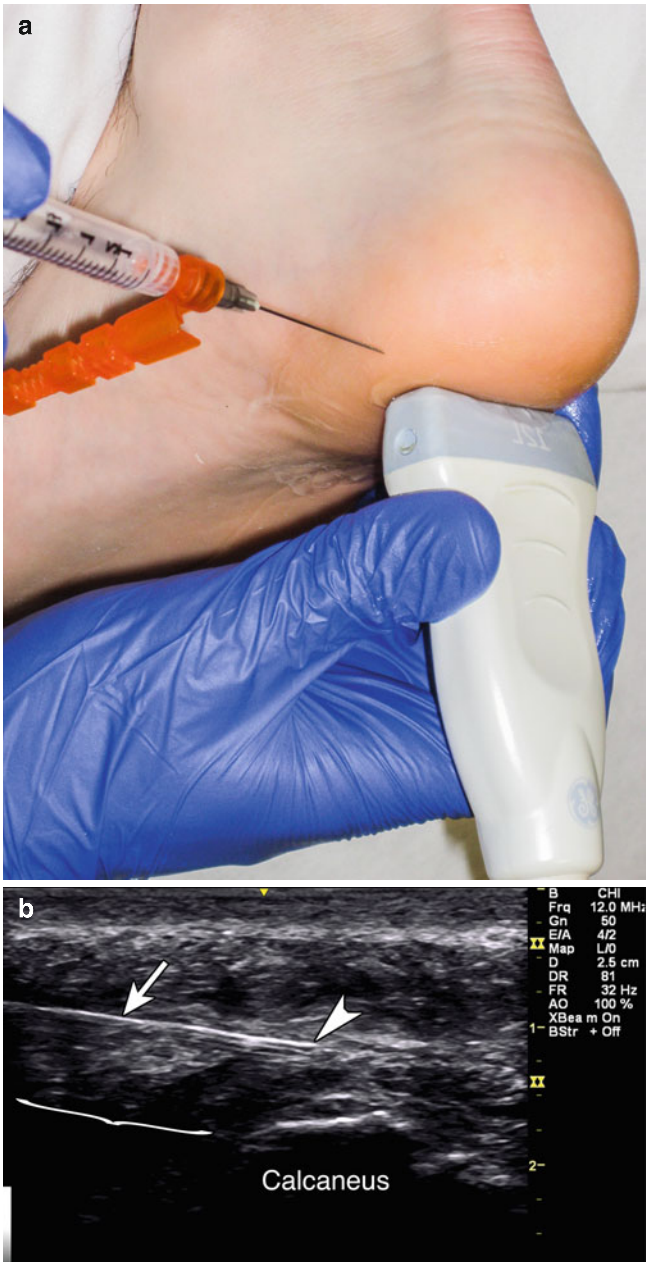

Fig. 7.23 (**a**) Example of coronal probe position over plantar fascia with in-plane needle position. (**b**) Example of in-plane injection. *Arrowhead* indicates needle tip. *Arrow* indicates needle. *Bracket* indicates needle reverberation. Calcaneus labeled

Injection Technique: In-Plane Axial Approach

Patient positioning: Lay the patient prone with the feet hanging over the edge of the table.

Probe positioning: Place the transducer longitudinally over the plantar aspect of foot at the level of the calcaneal insertion. Rotate the probe 90° to visualize the calcaneal attachment in the coronal plane (Fig. 7.23a).

Markings: None.

Needle position: Enter the skin from either the medial or lateral heel, in-plane with the transducer, and guide it to the plantar fascia. Switch to the sagittal plane to visualize the needle out-of-plane, and help guide it to areas of calcification, hypoechogenicity, or thickening. This can be facilitated with a "K" turn, retracting the needle and rotating radially to increase needle coverage without rebreaking skin.

Safety considerations: Avoid injecting the fat pad. When injecting within the fascia, use minimal volume to decrease the risk of rupture.

Pearls:

- With dynamic scanning, active ankle dorsiflexion may help to better visualize the plantar fascia margins.

Equipment needed:

- High-frequency linear array transducer
- 25G 1.5″ needle
- 0.5–1.0 mL of steroid preparation
- 1–3 mL local anesthetic

Tarsal Tunnel Syndrome

The tarsal tunnel is formed by the groove between the posterior calcaneus and medial malleolus. It wraps around the inferior malleolus, following the course of its overlying flexor retinaculum. It contains the tendons of the tibialis posterior, flexor digitorum longus, flexor hallucis longus, and the posterior tibial nerve, artery, and vein. Within the tunnel the posterior tibial nerve bifurcates into the medial and lateral plantar nerves, although this can occur proximal to the tunnel in 5 % of cases [43]. Before the bifurcation, also within the tunnel, the medial calcaneal nerve branches off from the posterior tibial nerve; however, it has been shown to arise from the lateral plantar nerve 25 % of the time [43]. It has also been shown to branch off earlier and bypass the tarsal tunnel superficial to the flexor retinaculum [30]. Ultrasound can be helpful in detecting soft tissue and osseous abnormalities within the tarsal tunnel [51] and is very useful in guiding injections to this crowded region.

Scanning Techniques and Anatomy to Identify

Position the patient on their side with the medial aspect of the affected ankle facing up. Place the probe in the axial plane just superior and posterior to the medial malleolus. From anterior to posterior, identify the tibialis posterior tendon; flexor digitorum tendon; posterior tibial artery, vein, and nerve; and lastly the flexor hallucis longus [34]. The overlying flexor retinaculum should appear hyperechoic and fibrillar. Slide the probe inferiorly and anteriorly following the course of the tunnel while rotating it accordingly to maintain cross-sectional views. Look for the bifurcation into

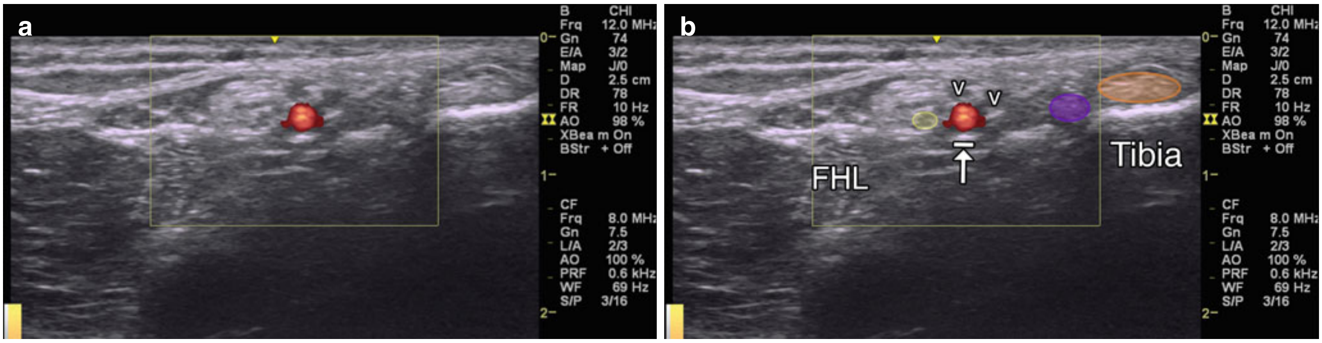

Fig. 7.24 (**a**) Axial view of tarsal tunnel with Doppler utilization. (**b**) *Orange* indicates tibialis posterior tendon. *Purple* indicates flexor digitorum longus. *Arrow with stop* indicates tibial artery adjacent to veins. *Yellow* indicates tibial nerve. *FHL* flexor hallucis longus

the plantar nerves, as well as the emergence of the medial calcaneal nerve. Find the level prior to the bifurcation where the flexor retinaculum is clearly visible, which generally occurs towards the proximal end of the tunnel. Use power Doppler to monitor the vascular distribution in preparation for injection (Fig. 7.24).

Injection Technique: Out-of-Plane Axial Approach

Patient positioning: Lay the patient in the lateral decubitus position with the medial aspect of the ankle facing upwards.

Probe positioning: Place the probe in the axial plane just superior and posterior to the medial malleolus. Slide the probe distally until the flexor retinaculum is clear. Try to stay proximal to the bifurcation of the posterior tibial nerve (Fig. 7.25a).

Markings:

Needle position: Enter the skin out-of-plane with the probe, from either proximal to distal or distal to proximal. Use power Doppler to plan the trajectory towards the nerve while avoiding the vascular structures.

Safety considerations: Avoid the posterior tibial artery and vein.

Pearls:

- Hydrodissection around the nerve is recommended to loosen any adhesions that may be present.

Equipment needed:

- High-frequency linear array transducer
- 25G 1.5″ needle
- 0.5 mL of steroid preparation
- 1–3 mL local anesthetic

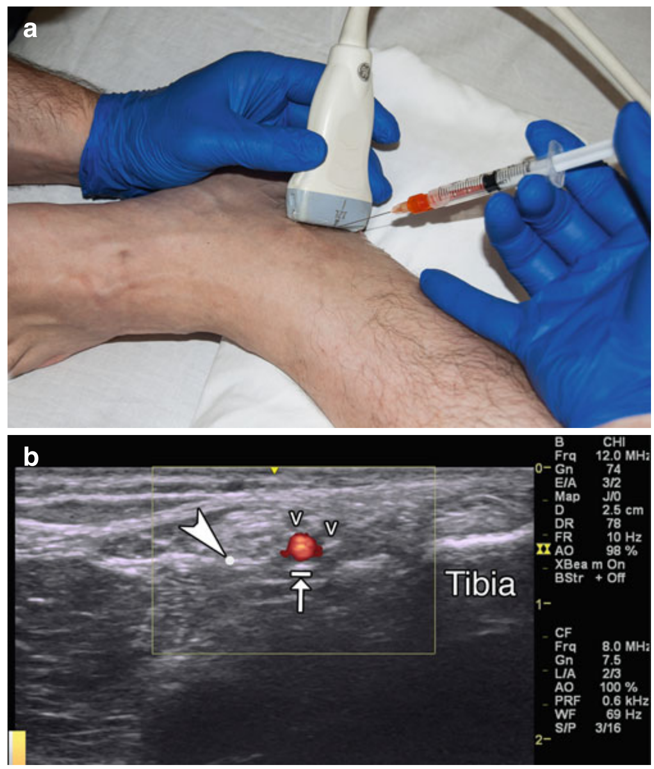

Fig. 7.25 (**a**) Example of axial probe position over tarsal tunnel with out-of-plane needle position. (**b**) Example of out-of-plane injection. *Arrowhead* indicates needle tip. *Arrow with stop* indicates tibial artery. Tibia labeled

Injection Technique: In-Plane Axial Approach

Patient positioning: Lay the patient in the lateral decubitus position with the medial aspect of the ankle facing upwards.

Probe positioning: Place the probe in the axial plane just superior and posterior to the medial malleolus. Slide the probe distally until the flexor retinaculum is clear. Try to stay proximal to the bifurcation of the posterior tibial nerve (Fig. 7.26a).

Markings:

Needle position: Enter the skin in-plane with the probe, from anterior to posterior. Use power Doppler to plan the trajectory towards the nerve while avoiding the vascular structures.

Safety considerations: Avoid the posterior tibial artery and vein.

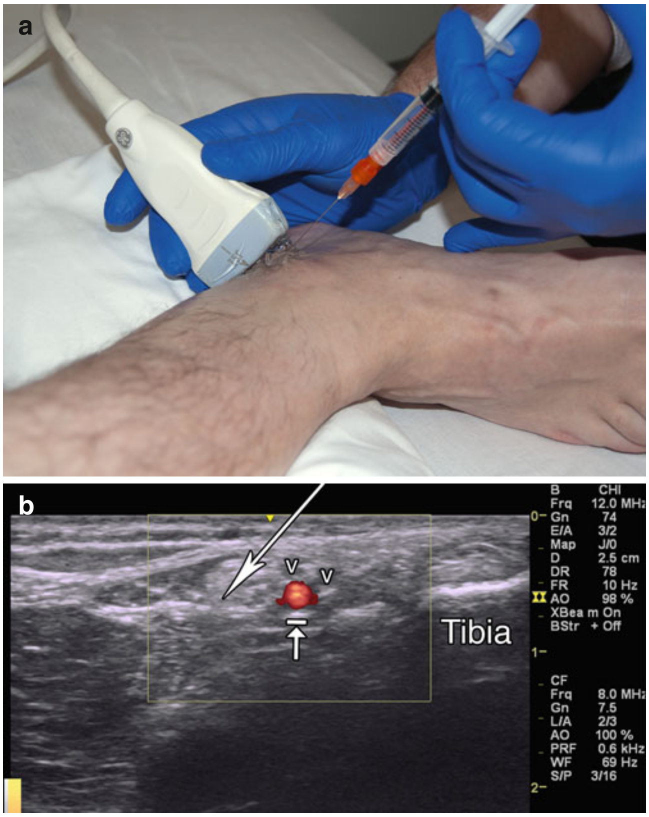

Fig. 7.26 (**a**) Example of axial probe position over tarsal tunnel with in-plane needle position. (**b**) Example of in-plane injection. *Arrow* indicates needle trajectory with gel standoff technique avoiding the medial tendons and vessels. *Arrow with stop* indicates tibial artery. Tibia labeled

Pearls:

- If the medial malleolus is prominent, it may interfere with the needle guidance. In this case rotate the probe so that its anterior edge is just above the malleolus, leaving a clear path.
- Hydrodissection around the nerve is recommended to loosen any adhesions that may be present.

Equipment needed:

- High-frequency linear array transducer
- 25G 1.5″ needle
- 0.5 mL of steroid preparation
- 1–3 mL local anesthetic

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