Tibial Nerve Entrapment

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Introduction

Patients with foot pain are not uncommon in clinical practice. A recent systematic review revealed that 24 % of older adults (≥45 years) have frequent foot pain; forefoot pain is more common in women and causes at least moderate disability in most patients [1]. Heel pain is also common and has a variety of causes including nerve entrapment [2].

The *tibial nerve* (TN), often called the *posterior tibial nerve* (PTN) as it nears the ankle, is vulnerable to entrapment at two separate anatomic sites. The more well known of these locations is the *tarsal tunnel* (TT), also known as the *tibiotalocalcaneal tunnel*, *calcaneal tunnel*, or *Richet's tunnel* [3], where the PTN travels under the *flexor retinaculum* (previously known as the *lancinate ligament*) of the ankle [4]. Entrapment of the PTN or its branches at this site is called *tarsal tunnel syndrome* (TTS) [5, 6]. We address entrapment of the individual branches of the TN in subsequent chapters (Chaps. 74, 75, 76, and 77).

In 1981, Mastaglia et al. [1] described a proximal entrapment of the tibial nerve at the tendinous arch between the two heads of the soleus muscle behind the knee. This is becoming known as the *soleal sling syndrome* (SSS) [7–9] and can exacerbate TTS symptoms via a "double crush" effect (see Chap. 1). SSS presents with pain in the popliteal fossa and proximal calf (aggravated by active and passive dorsiflexion of the foot), inability to bear weight, weakness of toe flexion, and sensory deficits on the sole of the foot that are aggravated by walking.

The tarsal tunnel is a major corridor at the posteromedial ankle between the distal tibia and the plantar foot, allowing nerves, blood vessels, and tendons to cross into the foot. The taxonomy of the tarsal tunnel can be confusing. In the radiology literature, it has been divided into "upper" (tibiotalar) and "lower" (talo-caneal) tunnels, with the dividing line at the *sustentaculum talus* [2–4]. However, surgeons as a group divide the tarsal tunnel into "proximal," the portion deep to the *flexor retinaculum*, and "distal," the portion deep to the *abductor hallucis* (AbH) muscle [5–7]. In this and subsequent chapters, we will follow the surgical convention.

TTS was thought to be clinically and pathologically comparable to carpal tunnel syndrome [8, 9] (Chap. 37), although the tarsal tunnel is now understood as more analogous to the forearm compartment, while the medial plantar tunnel (Chap. 75) is more equivalent to the carpal tunnel [6, 10].

Clinical Presentation (Table 73.1)

TTS is a relatively common problem, especially in patients with biomechanical faults of intrinsic foot structure that lead to overpronation [13]. Foot pronation increases the pressure in the tarsal tunnel [26] and decreases its volume [27], thereby chronically compressing the nerve. Patients with increased foot pronation may have additional proximal musculoskeletal complaints such as *shin splints*, *patellofemoral syndrome*, or *peritrochanteric hip pain* because the same biomechanical faults can be the root cause of all these conditions.

It is also seen in athletes [18–22] and those with occupations which require extensive standing or walking [8]. There

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Table 73.1 Occupation/exercise/trauma history relevant to tibial nerve entrapment

Compression	Synovial cysts [11, 12]
	Neurilemmoma [12]
	Foot pronation [13]
	Varicose veins [11]
	Talocalcaneal coalition [11]
	Accessory flexor digitorum longus [14]
	Hemodialysis [15]
Inflammation	Thrombophlebitis [16]
	Tenosynovitis [16]
	Osteomyelitis [17]
Trauma	Fracture or dislocation of foot bones [16]
	Posttraumatic edema [16]
	Athletes [18–23], especially in those sports that require repetitive foot dorsiflexion that increases the pressure in the tarsal tunnel
Others	Obesity is associated with a greater incidence of flat foot [24] Diabetes and other peripheral neuropathies [25]

Fig. 73.1 Patient pain complaint from tarsal tunnel syndrome (Image courtesy of Andrea Trescot, MD)

is an even distribution of genders exhibiting TTS [9]. Acute trauma or repetitive microtrauma can generate entrapment and pain. Other contributing triggers may include diabetes or chemotherapy [28].

The symptoms of TTS often include burning pain and paresthesias at the medial ankle, though it may extend through the heel or the sole of the foot, with radiation proximally along the medial calf [10] (Fig. 73.1). Tenderness below the medial malleolus is much more common than on the plantar foot [13] (Fig. 73.2). Depending on the compression site and the specific nerve branch or branches involved, clinical symptoms may vary. Numbness can lead to loss of balance and falls [28], and PTN dysfunction can progress to paresis of the small muscles of the foot.

Fig. 73.2 Pattern of pain from tarsal tunnel syndrome (Image courtesy of Andrea Trescot, MD)

Although it is typically aggravated by activity [10] and relieved by rest, TTS pain often worsens at night and may actually awaken the patient from sleep [13]. Night pain may be the result of venous stasis when the patient is inactive, and patients may obtain relief by getting up or hanging the leg over the side of the bed [9].

In contrast to TTS, patients with SSS have pain in the back of the knee and proximal calf that is exacerbated by active plantar flexion.

Anatomy (Table 73.2)

The TN is the larger of the two terminal branches of the sciatic nerve, traveling down the back of the leg to the foot (Fig. 73.3). It gives off branches to the muscles of the thigh and then crosses the middle of the *popliteal fossa* and under the tendinous arch of the *soleus muscle* to supply the calf and foot flexor muscles in the deep posterior compartment. The TN accompanies the *posterior tibial branch of the popliteal artery* and one or more veins through the popliteal fossa.

The TN becomes the PTN in the lower leg; it divides into its plantar divisions in or near the fibro-osseous *tarsal tunnel* that stretches from the posteromedial ankle below the *medial malleolus* of the distal tibia down to the medial aspect of the plantar region of the foot (Figs. 73.4 and 73.5). The *malleolar-calcaneal axis* from the center of the medial malleolus to the center of the calcaneus is a useful constant reference point for the center of the tarsal tunnel [30, 31]. The ceiling of the tunnel is the *flexor retinaculum*, and its bony floor consists of the posteromedial *talus*, the medial *navicular*, and the medial *calcaneus* [34]. It contains three tendons: the tibialis posterior (TP), the flexor digitorum longus (FDL), and the flexor hallucis longus (FHL), in addition to the neurovascular bundle of the PTN and

Table 73.2 Tibial nerve anatomy

Origin	L4-S4 ventral rami form the *sciatic nerve*
General route	The sciatic nerve divides in the distal thigh into the *tibial nerve* (TN) and *common peroneal* (*fibular*) *nerve* (CPN) (see Chap. 67); the TN continues down through the deep posterior compartment of the leg, changing its name to the *posterior tibial nerve* (*PTN*)
	The TN divides within (usually) or near the tarsal tunnel behind and inferior to medial malleolus into *the lateral plantar nerve* (LPN), *medial plantar nerve* (MPN), and *medial calcaneal nerve* (MCN)
	Both the MPN and LPN run deep to the *abductor hallucis* (AbH) *muscle* in the direction of the toes within the middle layer of the soft tissues of the plantar side of the foot
	A fibrous septum between the calcaneus and the deep fascia of the AbH separates the MPN from the LPN [6, 10, 22]
Sensory distribution	*LPN*: the skin of the lateral sole, plantar surface, and lateral side of the fourth and all of the fifth toe as well as the anterior calcaneus
	MPN: the skin of the medial sole, the plantar surface, and sides of toes one to three, medial fourth toe, and the tarsal/metatarsal joints
	MCN: the skin and deep structures of the heel
Motor innervation	*Tibial nerve*: popliteus, soleus, gastrocnemius, plantaris, tibialis posterior, flexor digitorum longus, and flexor hallucis longus muscles
	LPN: quadratus plantae (QP), abductor digiti minimi (AbDM), adductor hallucis, flexor digiti minimi brevis, interosseous, and second to fourth lumbrical muscles
	MPN: flexor digitorum brevis (FDB), abductor hallucis (AbH), flexor hallucis brevis, and first and second lumbrical muscles
Anatomic variability	Site of the sciatic nerve branching into TN, the common peroneal nerve
	Relationships between TN and the hamstring tendons, skin, blood vessels, and its own branch points in and near the popliteal fossa [29]
	Site of the tibial N branching into MPN and LPN: in the tarsal tunnel in 93 % of 68 feet dissections, 7 % were more proximal [30, 31]
Other relevant structures	*Soleus muscle*: originates from the posterior fibular head and the soleal line of the tibia; these two origins are connected by a tendinous arch, a potential site of TN entrapment [32]
	Popliteal fossa: an area between the tendons of the hamstring muscles
	Flexor retinaculum: a specialized area of the deep fascia of the leg that runs between the anteromedial medial malleolus and the medial tuberosity of the calcaneus; it forms a tunnel described as oval [5] or conical [6] and continues distally as the fascia surrounding the AbH muscle
	Malleolar-calcaneal axis: the line between the center of the medial malleolus and the center of the calcaneus; a useful reference point since the specialized fascia like the flexor retinaculum blends into the nearby fascia, thereby making exact measurements difficult [30, 31]
	Contents of the tarsal tunnel: the posterior tibial artery and veins (superficial to the nerves), as well as three tendons in their synovial sheaths (tibialis posterior, flexor digitorum longus, and flexor hallucis longus)
	Abductor hallucis (*AbH*) *muscle*: the continuation of the "roof" of the tarsal tunnel; its hypertrophy may contribute to PTN entrapment [33]

the *posterior tibial artery* and veins (Fig. 73.6). The mnemonic "Tom, Dick & Harry" helps one remember the positions of the tendons at the level of the medial malleolus from anterior to posterior, with the "&" representing the neurovascular bundle.

In the classic description, the PTN at the ankle trifurcates into its three terminal branches: the *lateral plantar nerve* (LPN) (Chap. 74), the *medial plantar nerve* (MPN) (Chap. 75), and the *medial calcaneal nerve* (MCN) (Chap. 77), within the tarsal tunnel [34]. Further work has revealed that the MCN may branch from the PTN proximal to the tarsal tunnel [33, 34], from the LPN [35] (see Chap. 74) or the MPN [36] (see Chap. 77). In this chapter, the authors will assume that the PTN bifurcates into the MPN and LPN deep to the flexor retinaculum, within 2 cm of the malleolar-calcaneal axis, as it does in almost all (93–95 %) subjects [30, 31] (Fig. 73.6), and that the MCN origin is variable (thereby accounting for the variable presence of heel pain in TTS).

The MPN and LPN exit the tarsal tunnel to innervate the sole of the foot (Fig. 73.7). As the branches continue distally, deep to the AbH, they become separated by a fascial septum known as the *medial septum* [37] that runs between the medial calcaneus (the tunnel floor) and deep fascia of the AbH (the tunnel roof), and each divides into smaller soft tissue tunnels (Fig. 73.8) [5, 6, 10].

Ultrasound Anatomy of the Tibial Nerve Just Proximal to the Tarsal Tunnel

On ultrasound, the PTN is an approximately 4 mm hyperechoic oval with an internal honeycomb of hypoechoic structures that

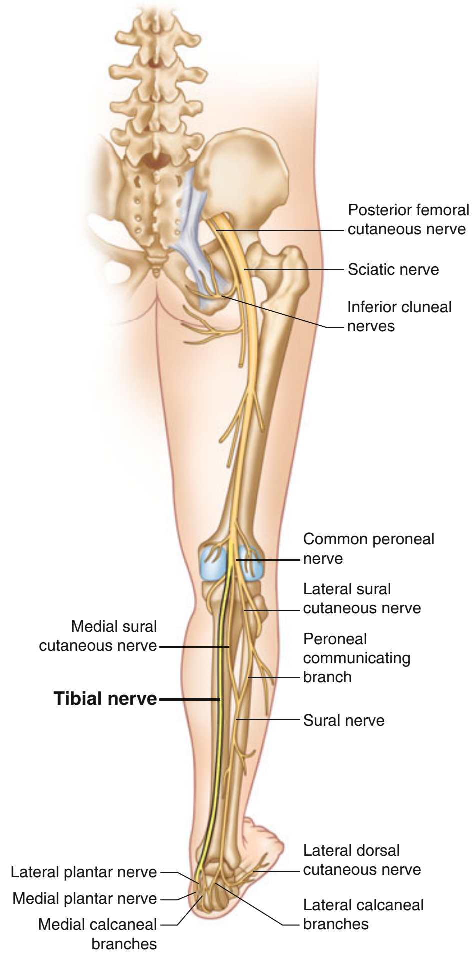

Fig. 73.3 Anatomy of the posterior leg (Image by Springer)

lies posterior to its accompanying blood vessels (Fig. 73.9) [38, 39]. The posterior tibial artery usually has a vein on either side of it, creating a vein-artery-vein configuration. The FHL tendon is also hyperechoic and posterior to the vessels, but it has finer fibrils and will move when the great toe is flexed.

Entrapment

The TN is most commonly compressed in the tarsal tunnel, deep to the flexor retinaculum at the medial ankle [40]. Its branches, the MPN and LPN, can be trapped separately in the two tunnels created by the fascial septum deep to the AbH [10], as well as at the medial calcaneal tunnel (Chaps. 74, 75, 76, and 77). Pressure around the PTN is increased significantly with dorsiflexion and hind-foot eversion, as well as with pronation [25, 26, 41]. Changes in ankle position increase the pressure in the medial and lateral plantar tunnels even more than the pressure in the tarsal tunnel itself; therefore, more distal compression is likely [25].

A more proximal entrapment of the TN occurs where it passes through a tunnel between the superficial and deep posterior compartments of the leg at the origin of the soleus muscle [1, 32, 42–44]. Patients report numbness of the sole of the foot and great toe, along with tenderness of the posterior proximal calf. There can be a positive Tinel's sign at the posterior calf approximately 5 cm below the medial tibial plateau. MRI images will show flattening of the TN and thickening of the soleal arch at the site of entrapment [45].

The TN can also be entrapped at the popliteal fossa by a mass such as a Baker's cyst or popliteal artery aneurysm [46]

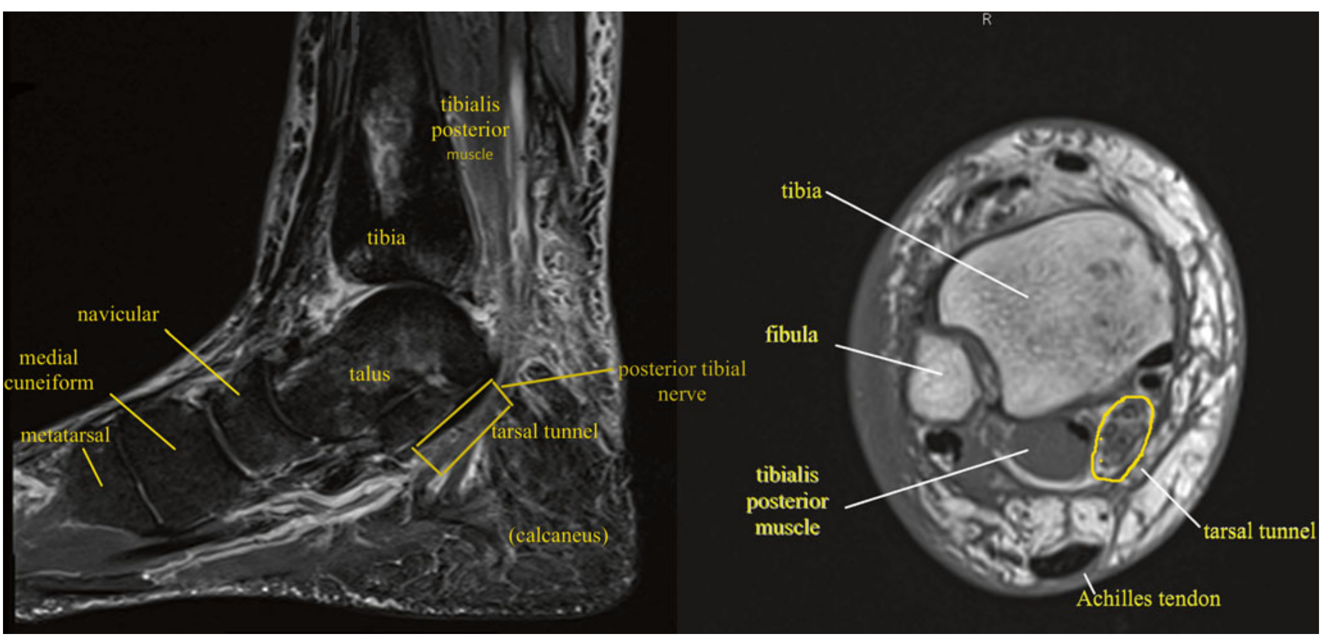

Fig. 73.4 MRI (sagittal and axial) of the tarsal tunnel (Image courtesy of Andrea Trescot, MD)

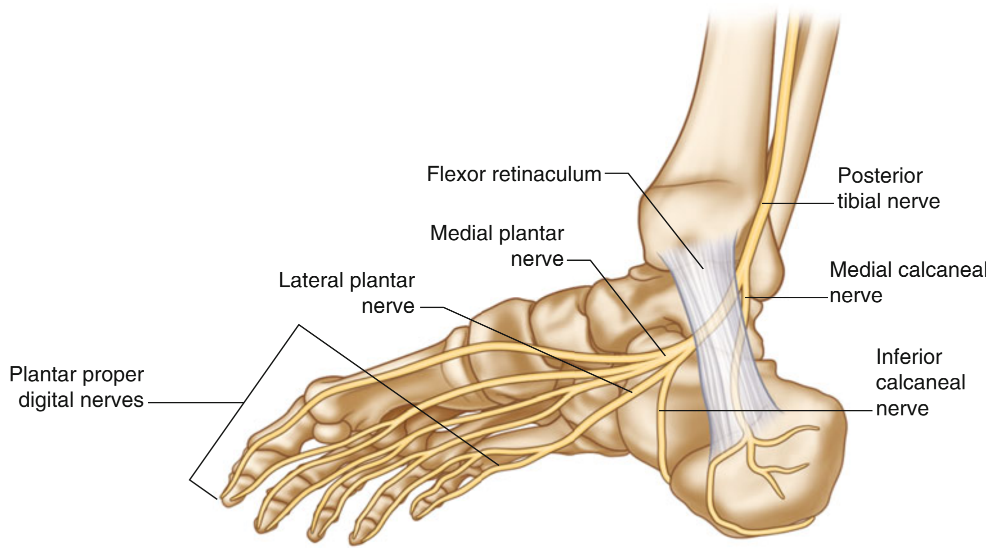

Fig. 73.5 Anatomy of the distal tibial nerve and its branches (Image by Springer)

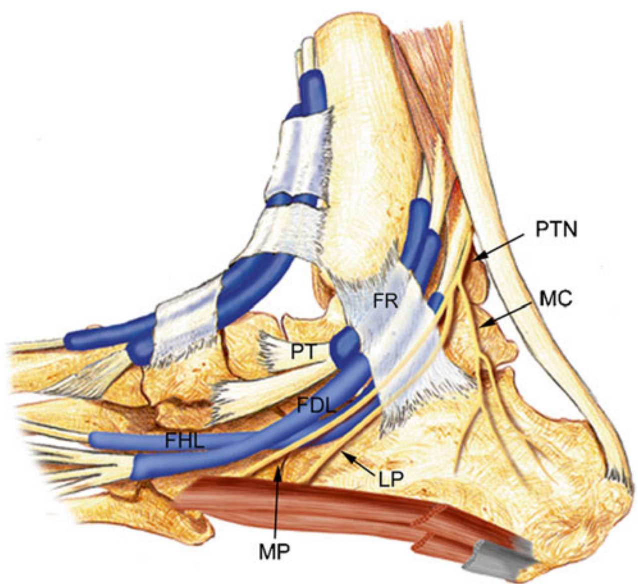

Fig. 73.6 Anatomy of the medial foot. *PTN* posterior tibial nerve, *MC* medial calcaneal nerve, *LP* lateral plantar nerve, *MP* medial plantar nerve, *PT* tibialis posterior tendon, *FDL* flexor digitorum longus tendon, *FHL* flexor hallucis longus tendon, *FR* flexor retinaculum. Note the parallel courses of the PTN and the FHL tendon (From Beltran et al. [65]. Reprinted with permission from Thieme)

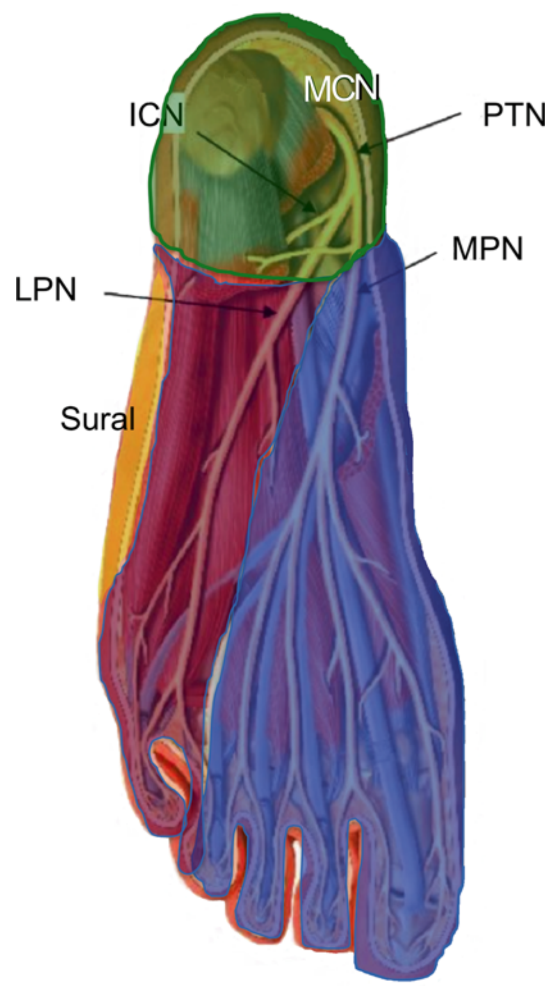

Fig. 73.7 Schematic representation of the plantar nerves and their cutaneous territories. *LCN* lateral calcaneal nerve, *MCN* medial calcaneal nerve, *PTN* posterior tibial nerve, *MPN* medial plantar nerve, *LPN* lateral plantar nerve, *ICN* inferior calcaneal nerve, *PF* plantar fascia (Image courtesy of Michael Brown, MD)

and more distally by the lower edge of the gastrocnemius muscle [47] or by synovial cysts in the tarsal tunnel (Fig. 73.10).

Physical Examination

If TTS is suspected, begin with the surface anatomy of the foot (Fig. 73.11). There can be local tenderness at the medial ankle over the tarsal tunnel [9] (Video 73.1) (Fig. 73.12c),

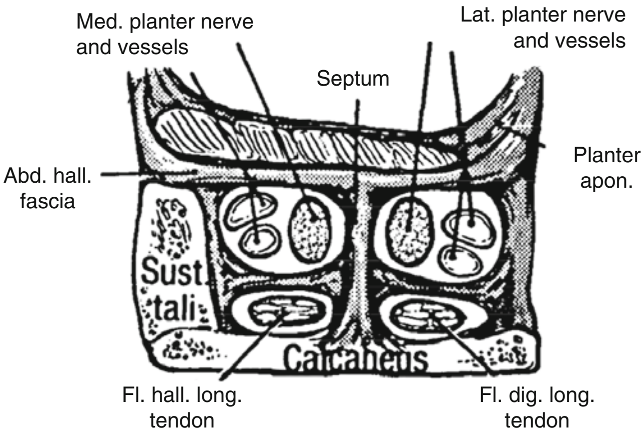

Fig 73.8 Cross section through the region immediately distal to the proximal tarsal tunnel. The medial and lateral plantar tunnels are separated by a septum between the tunnel roof (the deep abductor hallucis fascia) and the tunnel floor (the calcaneus). *Apon* aponeurosis, *dig* digital, *fl* flexor, *hall* hallucis, *lat* lateral, *long* longus, *med* medial, *sust* sustentaculum (From Dellon [10]. Reprinted with permission from Elsevier Limited)

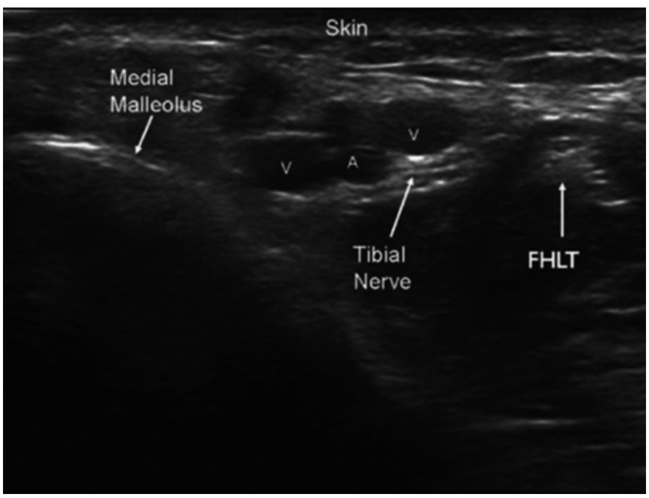

Fig. 73.9 Ultrasound anatomy of the tarsal tunnel at the level of the ankle (short axis view). *A* posterior tibial artery, *FHLT* flexor hallucis longus tendon, *V* vein. Screen right is posterior, and screen left is anterior. Note the vein-artery-vein configuration near the nerve and the proximity of the flexor hallucis longus tendon (FHLT); the latter can be distinguished from the nerve by watching it move when the great toe is flexed (From Redborg et al. [38]. Reprinted with permission from Wolters Kluwer Health, Inc)

with sensory loss over the bottom of the foot. A Tinel's sign may be elicited with the fingers (Fig. 73.12a) or a reflex hammer (Fig. 73.12b) over the PTN at this site [13]; if it is present, it provides an 88 % positive predictive value of a good to excellent response to surgery [10]. However, its absence may indicate an even greater degree of injury [28].

The *triple compression stress test* (TCST) (also known as *dorsiflexion/eversion test*) is a provocative test for TTS. Place

Fig. 73.10 T2 sagittal MRI image showing a synovial cyst impinging the tarsal tunnel (*white arrow*) (Image courtesy of Andrea Trescot, MD)

the ankle in full dorsiflexion, evert the foot, and apply digital pressure over the PTN to replicate paresthesias and pain (Fig. 73.12d) [26, 41]. The TCST has been shown to have a sensitivity of 85.9 % and specificity of 100 % for TTS diagnosis [48]. Symptoms may also be increased by a blood pressure cuff inflated to create venous occlusion [9].

Biomechanical assessment of the intrinsic structure of the foot, including the subtalar position and the *pes planus foot*, *rear foot,* and *forefoot position*, gait analysis, and the cause of foot pronation may be helpful in revealing possible causes of increased PTN tension in the tarsal tunnel. One should evaluate whether or not the patient has maintained the ability to abduct the fifth toe (a function of the *abductor digiti minimi* (AbDM)) or abduct the greater toe (a function of the AbH). There may be weak toe flexion and sensory changes over the sole of the foot. Frank motor weakness, however, is a late finding [9]. If the AbH is compressing a nerve or part of one, the patient's symptoms may be reproduced by tensing it [33].

Evaluation of the TN near the popliteal fossa is also an important part of the examination, as impingement at this level may exacerbate TTS. A very tender spot is found on deep palpation of an area about one fifth of the way down the back of the leg. A Tinel's test at this point may travel to the medial plantar foot; if it goes to the lateral foot, the sural nerve may also be entrapped (Chap. 71) [32].

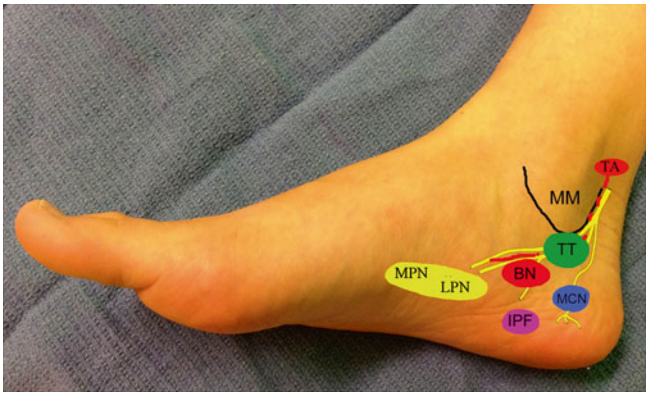

Fig. 73.11 Surface anatomy of the medial ankle. *MM* medial malleolus, *TT* proximal tarsal tunnel, *BN* Baxter's *nerve* inferior calcaneal nerve, *MCN* medical calcaneal nerve, *MPN* medial plantar nerve, *LPN* lateral plantar nerve, *TA* tibial artery, *IPF* insertion of the plantar fascia (Image courtesy of Michael Brown, MD)

Differential Diagnosis (Tables 73.3 and 73.4)

The differential diagnosis of TTS includes plantar fasciitis, Achilles tendonitis, retrocalcaneal bursitis (Fig. 73.12), and infection (e.g., calcaneal osteomyelitis) [17]. Passive dorsiflexion and eversion will provoke pain, tingling, numbness, and burning, which typifies tarsal tunnel syndrome. TTS may present as a complex regional pain syndrome (CRPS) as a complication of trauma. As discussed in Chap. 3, CRPS may be triggered by nerve entrapment; this is not actually a differential diagnosis, but rather an etiology.

Diagnostic Tests (Table 73.5)

Imaging

Plain radiography, supplemented as needed with CT, is useful for evaluating the patient's underlying foot structure and assessing other bony abnormalities that can cause compression [51]. MRI of the foot and ankle (Fig. 73.13) can also be useful in identifying suspected space-occupying soft tissue lesions within the tarsal tunnel [51, 52]. Ultrasound is another way to evaluate the PTN and potential sources of entrapment [11], and it is an excellent way to guide placement of local anesthetic around the PTN or its branches (see below).

EMG/NCV

Electrodiagnostic studies can help diagnose and quantify the severity of entrapment neuropathies. Goodgold et al. [16] published a normal range of TN conduction velocities

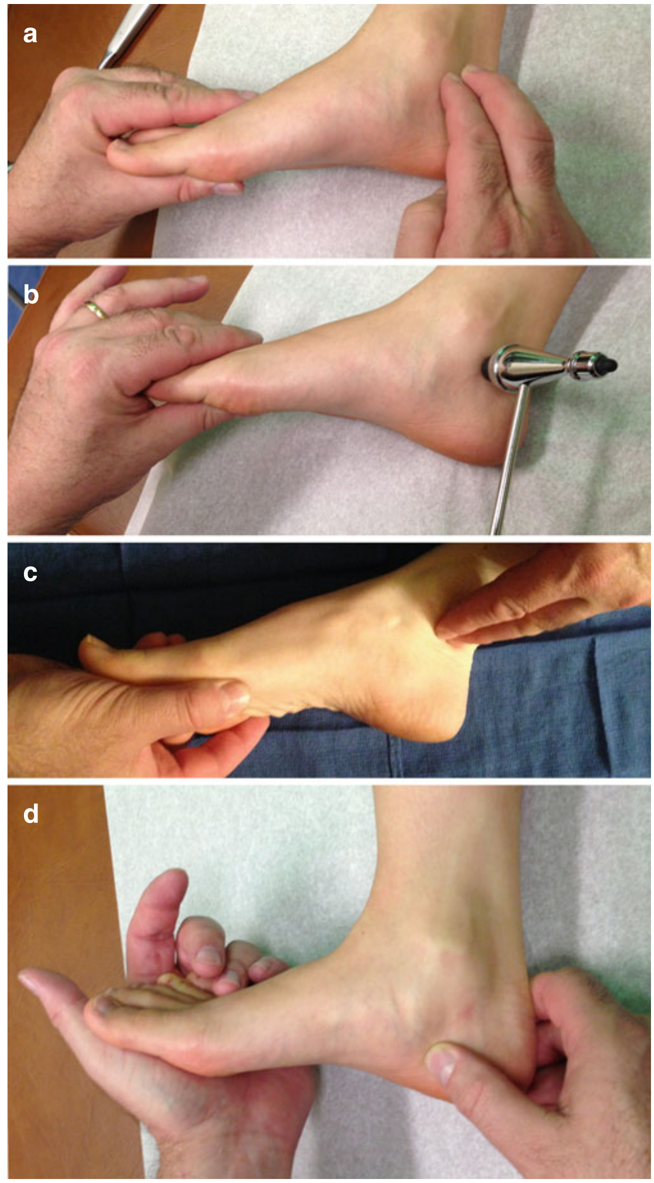

Fig. 73.12 Physical exam of tarsal tunnel syndrome. (**a**) Tinel's sign elicited with fingers; (**b**) Tinel's with a reflex hammer; (**c**) palpation of the tarsal tunnel; (**d**) triple compression stress test (Image courtesy of Michael Brown, MD)

in 1965. More recently, an "*electrophysiologic severity scale*" to grade TTS has been proposed [53]. These may be useful, but a systematic review has revealed that the level of evidence (as of 2005) is weak [54]; some authors think that they are not reliable, particularly because many patients without TTS have abnormal results [10]. In complex situations, however, they may be useful to rule out a radiculopathy [32].

The *pressure-specified sensory device* (PSSD) is an objective, non-painful method to measure nerve function; the pressure required for a person to distinguish one from two static points is the most sensitive gauge of nerve dysfunction

Table 73.3 Differential diagnosis of plantar pain and paresthesias

	Potential distinguishing features
Plantar fasciitis	Tenderness at the attachment of the flexor retinaculum on the calcaneus
Achilles tendonitis	Tenderness more posteriorly at the Achilles tendon attachment
Retrocalcaneal bursitis	Tenderness on palpation at medial and/or lateral Achilles attachment
Osteomyelitis	Fever, elevated WBC, increased ESR, + culture
Ganglion cyst [49]	MRI or ultrasound showing cystic structure
Interdigital neuroma [50]	See Chap. 70
Infection (osteomyelitis) [17]	Bone scan or MRI showing increased uptake and edema
Varicosities	US evaluation
Tenosynovitis	Tenderness along the tendon sheath

Table 73.4 Comparison of plantar pain from common causes

Etiology	Distinguishing characteristics	Location of pain and tenderness
Plantar fasciitis	Insidious onset	From the anterior calcaneus as far as the MTP joints
	Decreased range of motion of the great toe	
	"First step" pain	
Tarsal tunnel syndrome	Pain worse at night	The heel and entire plantar surface, although the heel may be spared if the MCN diverges proximal to the flexor retinaculum
Medial calcaneal nerve dysfunction	History of trauma to the medial border of the calcaneus	Anterior to the medial heel
		Tenderness over the medial calcaneus possibly referred to the anterior calcaneus
Medial plantar nerve dysfunction	Pain aggravated by arch supports	May spread to the AbH origin on the posteromedial calcaneus
Lateral plantar nerve dysfunction	Rare motor dysfunction	Pain and numbness to lateral foot
Soleal sling	Numbness at the sole of the foot	Pain at the back of the knee, approx. 5 cm below the medial tibial plateau
	Tinel's sign at the mid-calf	

from chronic compression [55]. Data for the MPN (big toe) and MCN (heel) has been recently reported in normal subjects and patients diagnosed with tarsal tunnel syndrome [56], and it may be a useful adjunct to diagnosis and treatment [57, 58].

Table 73.5 Diagnostic tests for tibial nerve entrapment

	Tarsal tunnel syndrome	Soleal sling
Physical exam	Clinical symptoms, sensory abnormalities, and provocative tests are the gold standard for diagnosis [10]	Foot and heel pain and numbness plus calf pain
		Tenderness and positive Tinel's sign of the tibial nerve under the soleal sling, ~5 cm distal to the popliteal fossa
Provocative tests	Passive dorsiflexion and eversion cause pain	Increased calf pain with active plantar flexion
	Triple compression stress test (TCST)	
Injection	Resolution of pain after diagnostic injection at the tarsal tunnel	Resolution of pain after diagnostic injection at the soleal sling
X-ray	Best for assessing bony abnormalities that can cause compression [51]	None
Ultrasound	Can show small mass lesions or bony abnormalities [11]	Not reported
	May show compression of the nerve	
	Use high-resolution techniques [51]	
MRI/MR neurography	May show mass lesions, bony abnormalities, or compression of the nerve [2, 64]	May show flattening of the TN and thickening of the soleal arch [45]
Arteriography	Not useful	Not useful
Electrodiagnostic studies	Needle EMG of foot muscles may show denervation	To rule out radiculopathy [32]
	False negative results may lead to underdiagnosis [40]	

Identification and Treatment of Contributing Factors

The cause of a particular patient's TTS should be sought in order to plan a management strategy. According to Ahmad et al. [40], causes can be divided into intrinsic factors involving localized compression or inflammation and extrinsic factors such as ill-chosen footwear [3], foot abnormalities,

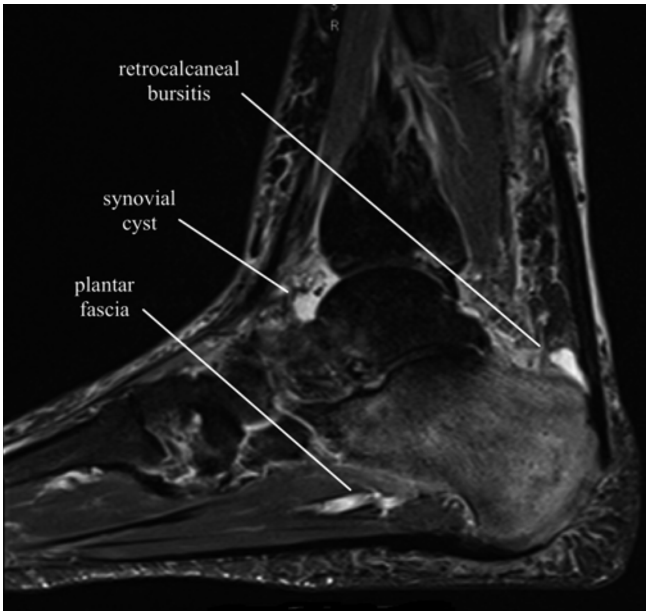

Fig. 73.13 STIR MRI sagittal image of the ankle showing retrocalcaneal bursitis, a synovial cyst, and plantar fascial irritation (Image courtesy of Andrea Trescot, MD)

Fig. 73.14 Landmark-guided tarsal tunnel injection (Image courtesy of Andrea Trescot, MD)

and edema due to pregnancy or venous congestion, systemic diseases, and trauma, including postsurgical scarring (Table 73.1) [40].

The pain is idiopathic in 40 % of the cases [59]. Early diagnosis is necessary to minimize injury [51]. It is best to fix the entrapment before the onset of motor involvement [50]. Treatment of underlining perpetuating factors predominately involves the pathomechanics of gait, and correcting rear foot and forefoot position with orthotics can reduce the tension placed on the nerve through the tarsal tunnel and may do a better job of resolving the problem long term than surgery. Injection therapy can be a component of short-term symptomatic management, while treatment of the underlying biomechanical faults and contributing factors will provide better long-term resolution.

Injection Techniques

Landmark-Guided Injection

The patient is placed in a lateral position with the medial side of the foot facing upward. After a sterile skin-prep and drape, palpate the posterior tibial artery pulse between the medial malleolus and the Achilles tendon (Fig. 73.11). Using a 27- or 25-gauge, 1.5 inch needle, direct the needle from the region just behind the artery anteriorly toward the pulse and insert it 1–2 cm (Fig. 73.14) (Video 73.2). The nerve may be encountered posterior to the artery, and paresthesias may occur if the needle tip touches the nerve. Typically, if the purpose of the injection is a field block, use 3–5 cc of local anesthetic if a paresthesia is encountered and 7–10 cc if it is not. If the injection is a diagnostic or therapeutic one, a volume less than 2 cc should be used.

Ultrasound-Guided Injection

The patient is placed supine with the knee flexed and the hip externally rotated or lying on their side to expose the medial side of the foot. The *malleolar-calcaneal axis* (MCA) from the center of the medial malleolus to the center of the calcaneus is a useful constant reference point for the center of the tarsal tunnel [30, 31]. A 7.5–15 MHz linear probe is placed obliquely along the MCA, with the notch toward the medial malleolus (Fig. 73.15) and the other end directed toward the heel. You should see the pulsation of the posterior tibial artery with veins on either side of it (Fig. 73.9). Anterior to the three vessels are two tendons, the PT and FDL, along with the muscular portion of the FHL. The nerve is usually just posterior or medial to the vein, and the transducer can be slightly tilted back and forth to pick up its usual honeycomb appearance. If the nerve has already branched, one will see at least two nerves (the MPN and LPN); the LPN is the most posterior.

Direct a 27- or 25-gauge needle toward the nerve in the tarsal tunnel using an in-plane or out-of-plane approach. The in-plane approach provides a means of coming behind the vascular structures, if the nerve is found posterior to the vein

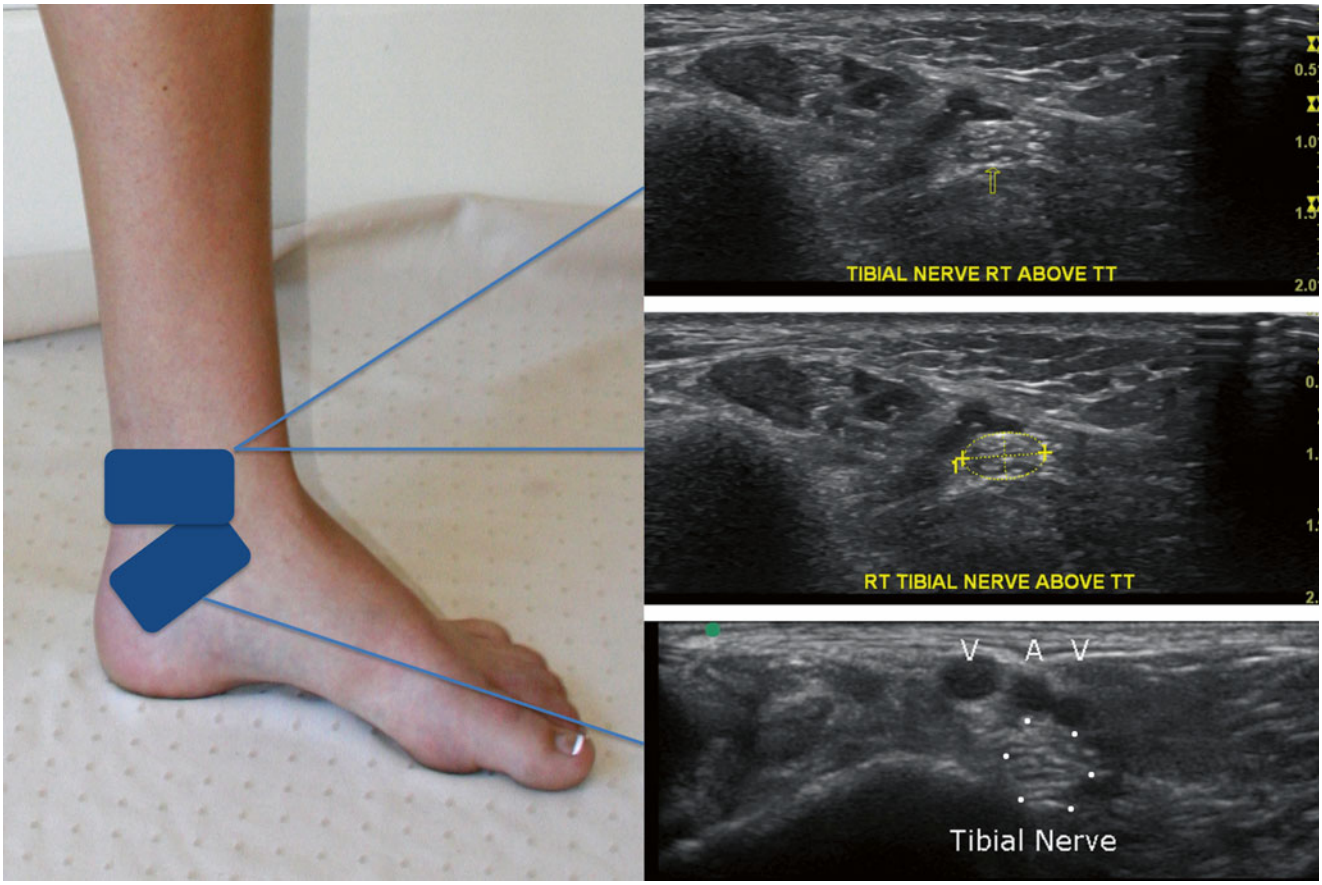

Fig. 73.15 Ultrasound evaluation of the tarsal tunnel (Image courtesy of Michael Brown, MD)

(Fig. 73.16). An out-of-plane approach is satisfactory if the nerve is found next to the vein.

Tibial Nerve Hydrodistention (See Chap. 7)

Before contemplating surgical decompression of the tarsal tunnel, perineural hydrodistention can be considered. The authors report this technique based on positive clinical experience; its efficacy for tarsal tunnel entrapment neuropathies will need to be verified in controlled trials.

Because of the vascular structures in this area, it is important to use US guidance. Identify the structures in the proximal tarsal tunnel, and inject a small aliquot of buffered lidocaine with a 30-gauge, 0.5 inch needle for skin anesthesia. Attach a 10 cc syringe filled with 7 cc D5W, 2 cc 1 % lidocaine, and 1 cc dexamethasone 30 mg/cc onto a 22- or 25-gauge needle. Slide the needle just posterior to the PTN (or the MPN and LPN, if the TN bifurcates proximally), and rapidly inject 3–4 cc, watching the fluid fill the space around the PTN. Reposition the needle anterior to the nerve, behind the vein-artery-vein bundle (Fig. 73.16), and repeat the procedure, taking care to avoid injuring the vascular structures.

Fluoroscopic-Guided Injections

In the authors' opinion, fluoroscopy provides little benefit for PTN injections, since there are no good bone landmarks.

Neurolytic Technique

Cryoneuroablation

Cryoneuroablation is not performed on the PTN, since it is a large mixed nerve, innervating multiple intrinsic foot muscles. However, cryoneuroablation can be used to treat smaller, more distal branches such as *inferior calcaneal nerve* (Chap. 76) or pure sensory nerves such as the *sural* (Chap. 71) or *distal saphenous* (Chap. 59) nerves of the foot.

Fig. 73.16 Ultrasound-guided needle placement behind the tibial nerve (Image courtesy of Michael Brown, MD)

Pulsed Radio Frequency (RF)

No specific pulsed RF procedures to treat TTS have been described.

Neuromodulation

Although no specific neuromodulation techniques have been described for the tarsal tunnel, peripheral nerve stimulation for the lower extremities has been rapidly expanding [60, 61]. Dr. Porter McRoberts noted good relief with stimulation of the tarsal tunnel (personal communication) (Fig. 73.17).

Surgical Technique

Surgical treatment of TTS involves release of the PTN and its branches [10, 62]. Patients with coexisting radiculopathy or generalized neuropathy are more likely to have a poor outcome [63].

Barker et al. [25] measured proximal and distal TT pressures in cadavers placed in a variety of ankle positions. Dividing the flexor retinaculum decreased TT pressure in all positions; excising the septum between the medial and lateral plantar tunnels led to optimum pressure change. The same group [63] also described 44 patients (46 ankles) who had undergone prior, unsuccessful surgical release of the TT. These patients were treated with division of the roof of the medial and lateral plantar tunnels and of the septum between them. They underwent neurolysis of the MPN and

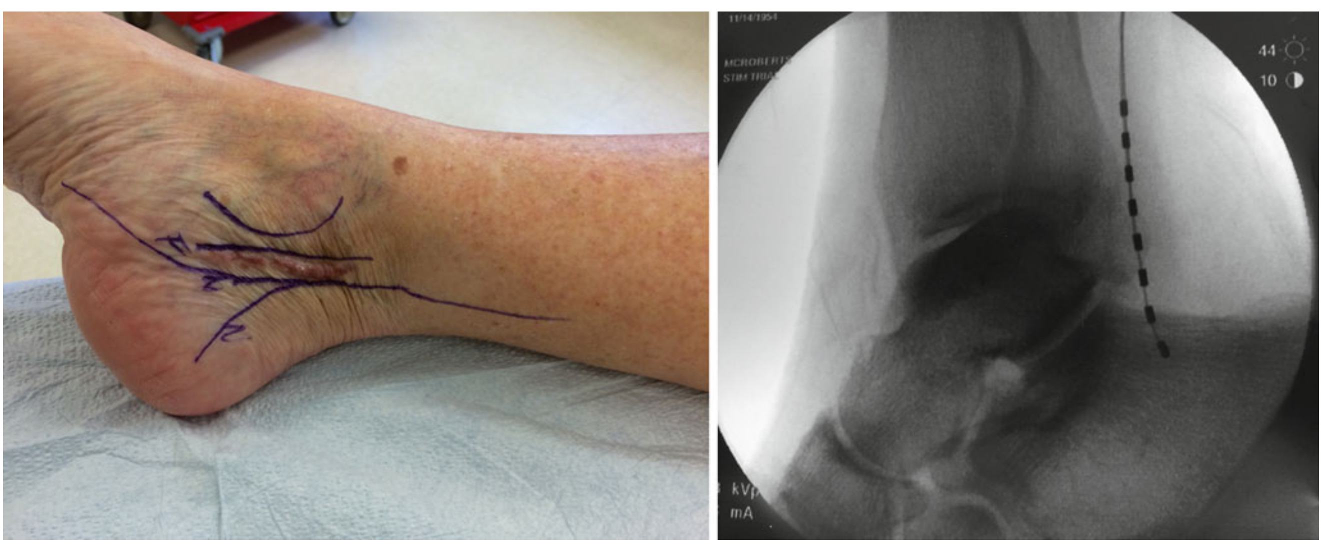

Fig. 73.17 Electrode placement for peripheral nerve stimulation (Image courtesy of W. Porter McRoberts, MD)

LPN as needed and were then followed for an average of 2.2 years. Fifty-four percent rated their pain relief as “excellent,” 24 % noted “good” relief, and 9 % had “poor” outcomes.

Complications

As with any procedure, there are risks of infection, hematoma, vascular puncture, or nerve injury. The most common associated problem is incomplete nerve release or ablation leading to increased pain. In this circumstance, repeating the procedure may lead to resolution of symptoms. The skin is very thin at this site, so injections or surgery can result in skin injury or atrophy.

Summary

Tibial nerve entrapment can cause a variety of foot and heel pains, depending on the site of entrapment. Knowledge of the clinical presentation, the anatomy, and the treatment options can provide patients with needed pain relief.

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