Review Article

Tarsal Tunnel Syndrome: Anatomical Facts and Clinical Implications

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Abstract

Introduction: Tarsal tunnel syndrome (TTS) associates with the posterior tibial nerve (PTN) entrapment at the medial side of the ankle. TTS is a major cause of heel pain. The diagnosis and treatments have several techniques. For accurate diagnosis and effective treatment, the surgeons need to have detailed anatomical knowledge of the arrangement of PTN. The aim of this present study is to describe anatomical aspects and TTS including its etiology, diagnosis, and treatments. **Material and Methods:** This literature review was done by searching the data from the following databases such as PubMed, Google Scholar, Springer, Elsevier (ScienceDirect), and book chapter. **Results:** This literature review showed anatomical variations of the PTN and its branches that used the malleolar-calcaneal axis for measurement of branching point. Moreover, these studies showed the origin and the number of branches. The diagnosis of TTS can be used numerous techniques such as neurophysiology, electromyography (EMG), ultrasound scanning (US), and magnetic resonance imaging. The treatment for TTS includes conservative approach, open surgery, and endoscopic procedures. **Discussion and Conclusion:** The anatomical knowledge of the neurovascular structures at the medial side of the ankle is not only considered for diagnostic purposes but also it ensures safe and effective operative procedures. This literature review will be beneficial for academics and clinicians.

Keywords: *Anatomy, tarsal tunnel syndrome, tibial nerve*

Introduction

The clinical implications associated with the medial side of the ankle are numerous. The presence of several important structures includes bones, the deltoid ligament, and the tarsal tunnel (TT).[1] Injuries of the ankle include medial malleolar fractures, ligament sprains, ligament tears, nerve entrapment, and impaired blood circulation.[2] At the medial side of the ankle, the TT houses the posterior tibial artery (PTA), the posterior tibial nerve (PTN), and the branches associated with both of nerve and artery.[1] TT syndrome (TTS) is the most common nerve entrapment of the foot. TTS arises from the compression of PTN and its branches.[2] The main causes of TTS have several causes such as space-occupying lesions,[3-8] foot deformities,[9,10] traumatic lesions, and even improper positioning of the foot.[10] Moreover, the peripheral nerve dysfunction causes impaired circulation and nerve compression[11] including partial paralysis of small foot muscles. For the vessels, the distribution and location of the arterial branches can cause of nerve compression.[5] Detailed anatomical knowledge of the relationship between vessels and the nerve is important as regards clinical applications.[12]

The treatment of TTS includes several techniques such as conservative treatment, open surgical treatment, and endoscopic procedures. Nowadays, the endoscopic TT decompression is usually selected for the treatment of TTS in patients because this technique is safer and higher success rate.[13] The lack of anatomical understanding can cause the failure of treatment.[14] This narrative review describes the anatomy of TTS and discusses its treatment and clinical implications which are important to clinicians.

Material and Methods

The analysis of this literature review is done by searching the data from the following databases such as PubMed, Google Scholar, Springer, Elsevier (ScienceDirect), and book chapter.

Anatomy of posterior tibial nerve and its branches

Posterior tibial nerve

The PTN or tibial nerve is larger than the other branches of the sciatic nerve[15] and

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reaches from the archway of the soleus muscle to the calcaneal canal. It is continuous with the sciatic nerve and shifts medially into the tibiotalocalcaneal canal.[16] The PTN divides into three terminal branches such as medial plantar nerve (MPN), lateral plantar nerve (LPN), and medial calcaneal nerve (MCN) in the TT. The bifurcation of PTN had been studied by several researchers. They used the malleolar-calcaneal axis in their studies, as shown in Figure 1 and Tables 1 and 2.[12,15,17-23]

Medial plantar nerve

The MPN is the larger size than LPN.[16] After the PTN has split into the MPN and LPN, the MPN runs into the medial plantar tunnel or abductor tunnel that deeps to the abductor hallucis (AH) muscle.[24] Its terminal branches are medial plantar cutaneous nerves of the hallux and three medial common digital nerves.[25] For distal TT or the area that deeps into the AH muscle, the medial septum makes up the floor. The TT's roof makes with the medial calcaneus and AH muscle's deep fascia, respectively. This tunnel independently separates the medial plantar tunnel and lateral plantar tunnel including tendon and neurovascular structures that can pass in this tunnel to the foot.[26]

Lateral plantar nerve

The LPN is the smaller nerve than MPN.[26] The proximal TT, LPN, locates posteriorly to the PTA.[16] After the LPN has left the proximal TT, it ran posteriorly to the MPN and passes through the AH muscle's deep fascia and medial plantar septum[27] to the lateral plantar tunnel that locates between the AH muscle and the calcaneus. Then, the LPN crosses diagonally from the foot to the toes,[25] and it separates into superficial branch and deep branch. The superficial branch divides into the lateral common digital nerves, and these nerves further subdivide into plantar proper digital nerves.

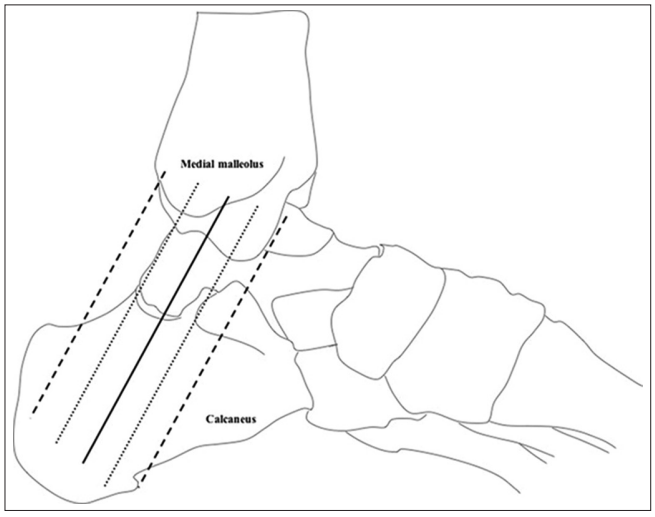

Figure 1: A malleolar-calcaneal axis with ± 1 cm and 2 cm width. This axis was drawn from middle malleolus to middle calcaneus. The solid line (—) represented a malleolar-calcaneal axis. The dashed line (···) represented a malleolar-calcaneal axis with ± 1 cm width. The dashed line (- -) represented a malleolar-calcaneal axis with ± 2 cm width

Medial calcaneal nerve

The MCN can be termed the calcaneal nerve.[28] The MCN can branch from PTN and LPN. Moreover, the MCN that separates from the PTN can branch proximal to TT or within TT.[18] It lies superficially to the AH muscle and may pass through the flexor retinaculum. The MCN branch that separates from the LPN passes through the TT and runs deep to the AH muscle and appears superficially at the lower edge of the AH muscle.[25] The MCN and its branches do not run to the deep structures of the foot and posterior direction. Moreover, the MCN and its branches are more superficial and thicker than the inferior calcaneal nerve (ICN).[29] The MCN is divided into two terminal branches which are anterior and posterior branches. The anterior branch can be called the cutaneous plantar nerve.[19] Moreover, the researchers studied the anatomical variation of MCN, as shown in Figure 1 and Table 3.[12,15,17-20,23,30-34]

Inferior calcaneal nerve

The ICN can be called the numerous names such as Baxter's nerve,[35] the first branch of the LPN, deep calcaneal nerve, and nerve to the abductor digiti minimi (ADM) muscle. The ICN originates from the LPN that splits near the PTN bifurcation or slightly proximal to PTN or from PTN. It runs a vertical direction to lie between the AH and the quadratus plantae (QP) muscles.[36] Then, it runs to lie between the QP and the flexor digitorum brevis muscles and innervates them. After that, it runs horizontally and penetrates the ADM muscle that is near its origin on deep surface. In addition, the ICN runs close to the calcaneus, the medial tubercle of the calcaneus (MTC), and the long plantar ligament. It provides sensory branches to the MTC's periosteum and long plantar ligament. Moreover, the researchers studied the anatomical variation of ICN, as shown in Figure 1 and Table 4.[18,19,21,31,32]

Our experience found the PTN divided into the terminal branches: MPN, LPN, and MCN that divided outside the distal TT. The PTN had branched to the terminal branches before the PTA divided into the terminal branches. For MPN, it had a larger size than the LPN. We found 1–3 branches of MCN. The origin of MCN was mostly PTN. The first branch of MCN separated from PTN in 100%. The second and the third branches separated from PTN followed by MPN. For ICN, it separated below the PTN branching point. This nerve had 1 branch that separated from LPN in 100%.

Tarsal tunnel syndrome

The TT is the fibro-osseous tunnel which lies deep to the flexor retinaculum including the posterior and inferior areas to the medial malleolus. The talus, the calcaneus, and the distal tibia form the medial wall of the TT while the flexor retinaculum forms TT roof. The structures that run deep to TT from medial to lateral side compose of the tibialis posterior tendon, flexor digitorum longus

Table 1: The studies of branching point of posterior tibial nerve using malleolar-calcaneal axis (±2 cm)

Authors	Year	Sample	Type of cadavers	Axis	Branching point of posterior tibial nerve							Note
					>−2	−1–−2	0–−1	Axis	0-1	1-2	>2	
Dellon and Mackinnon[17]	1984	31	Embalmed	Malleolar-calcaneal axis			5	17	6	1	2	
Havel *et al*.[15]	1988	68	Embalmed	Malleolar-calcaneal axis±2 cm		1	5	26	21	10	5	
Davis and Schon[18]	1995	20	Embalmed	Malleolar-calcaneal axis±2 cm				18			2	18 cases: within ±2 cm of axis
Louisia and Masquelet[19]	1999	15	Embalmed (13) Fresh (2)	Malleolar-calcaneal axis±2 cm				-				90% in tarsal tunnel
Torres and Ferreira[20]	2012	50	Fresh	Malleolar-calcaneal axis±2 cm		3	8	7	20	6	6	
Iborra *et al*.[21]	2018	12	Fresh	Malleolar-calcaneal axis±2 cm					5	6	1	

Table 2: The studies of branching point of posterior tibial nerve using malleolar-calcaneal axis (width 1 cm)

Authors	Year	Sample	Type of cadavers	Axis	Branching point of posterior tibial nerve			Note
					Distal	Axis	Proximal	
Bilge *et al*.[22]	2003	50	Embalmed	Malleolar-calcaneal axis (width 1 cm)	2	6	42	
Tamang *et al*.[23]	2016	30	Embalmed	Malleolar-calcaneal axis (width 1 cm)	0	3	27	
Yang *et al*.[12]	2017	60	-	Malleolar-calcaneal axis (width 1 cm) Horizontal line (passed tip of tibia)		7	39 (in tarsal tunnel)	At tarsal tunnel border (3) Out of proximal tarsal tunnel (11)

Table 3: The studies of origin and number of branching of medial calcaneal nerve

Authors	Year	Sample	Type of sample	Origin of MCN						Number of branching				
				PTN	Bifurcation of PTN	LPN	MPN	2 nerves	>2 nerves	1	2	3	4	5
Dellon and Mackinnon[17]	1984	20	Patients	18		2				15	5			
Havel *et al*.[15]	1988	68	Embalmed	47		13	1	8		54	14 (>1 branch)			
Davis and Schon[18]	1995	20	Embalmed	15		2	3			8	12 (>1 branch)			
Louisia and Masquelet[19]	1999	15	Embalmed (13) Fresh (2)	10		3		2		2	9	2	2	
Dellon *et al*.[30]	2002	85	Patients	48		56	39			31	35	16	3	
Govsa *et al*.[31]	2006	50	Embalmed	11		7		15	6		1-4 branches			
Torres and Ferreira[20]	2012	50	Fresh	45		1	4			29	17	4		
Kim *et al*.[32]	2015	11	Fresh	7	3	1					None			
Sharma *et al*.[33]	2015	60	Embalmed	21				24	15	21	24	9	5	1
Malar[34]	2016	20	Embalmed	17				3		10	6	4		
Tamang *et al*.[23]	2016	30	Embalmed			17		13		7	16	7		
Yang *et al*.[12]	2017	60	-	/	/	/				16	31	10	2	1

PTN: Posterior tibial nerve, MCN: Medial calcaneal nerve, LPN: Lateral plantar nerve, MPN: Medial plantar nerve

tendon, flexor hallucis longus tendon, PTA, vein, and nerve.[2]

The most common nerve pathology at the medial side of the ankle is TTS which is the nerve entrapment.[37] TTS was associated with the entrapment of the PTN and its branches.[2] The symptoms are burning pain, paresthesia, and numbness at the medial side of the ankle extending to the heel or sole including the medial calf.[26] The symptoms vary depending on the compression of the specific branches of the PTN. The patients may have worse symptom experience during standing and walking or at night, but the symptoms can be reduced by leg rest and elevation. For TTS, the examination of Tinel's sign at the foot and ankle region uses the dorsiflexion and eversion,[2] but the entrapment of ICN uses supination.[1]

Etiology

The most common etiology of TTS can be classified into three types such as space-occupying lesions, deformities of the foot, and traumas of the foot and ankle. The space-occupying lesions are a result of pathology of the accessory or abnormal of the bone, retinaculum, tendons, osteophytes, artery, and accessory muscle. The accessory

Table 4: The studies of origin and number of branching of inferior calcaneal nerve

Authors	Year	Sample	Type of sample	Origin of MCN					Number of branching		Note
				PTN	Bifurcation of PTN	LPN	MPN	2 nerves	1	2	
Davis and Schon[18]	1995	20	Embalmed			20					
Louisia and Masquelet[19]	1999	15	Embalmed (13) Fresh (2)			14	1			15	ICN branching below PTN branching
Govsa *et al*.[31]	2006	50	Embalmed	41	5	2		2	50		
Kim *et al*.[32]	2015	11	Fresh			11			11		
Iborra *et al*.[21]	2018	12	Fresh			11					Trifurcation in 1 case

PTN: Posterior tibial nerve, MCN: Medial calcaneal nerve, LPN: Lateral plantar nerve, MPN: Medial plantar nerve, ICN: Inferior calcaneal nerve

bone of sustentaculum tali is os sustentaculi which projects to sustentaculum tali of the calcaneus. It can compress PTN or its branches and become TTS.[3] The other causes of bone are talus bipartitus which is a rare cause of abnormal anatomical of the talus. This bone fragment has prominence to the medial side of the ankle. It may cause PTN entrapment within TT.[4] For artery cause, the PTA penetrates through the nerve that might be fixed and disrupted the sliding and stretching of the nerve in TT. It becomes TTS from compression of PTA.[5] In our dissection, we found that the branch of PTA perforates through the PTN in some cases of healthy sample. For accessory muscle, the flexor digitorum accessory longus (FDAL) muscle is superficial to the neurovascular structures.[38] The PTN in TT can be compressed from this muscle because the vigorous exercise causes hypertrophy or edema of FDAL muscle.[7] Moreover, the arthroscopic surgery can be cause of nerve injury, especially the posteromedial portal of arthroscope. This portal increases PTN and calcaneal nerve injury.[8] Other space-occupying lesions result from ganglia, lipoma, varicose veins, and neurilemmoma which compress the PTN inside or outside the TT.[9]

The deformities of the foot occur from several causes such as varus and valgus foot that involve with flat foot,[9] failure of longitudinal arch of the foot,[10] and excessive foot pronation in athletes and the prolonged weight-bearing on standing and walking person. Increasing pressure on the PTN causes alteration of the position of the foot, especially as dorsiflexion and hindfoot eversion or pronation. The foot positions can cause increasing pressure on the MPN and LPN at the medial and lateral plantar tunnels.[39] Moreover, these causes can increase the pressure to PTN including stretching the PTN, which develop to the TTS.[40]

The ankle traumatic lesions result from the bone fracture, the deltoid ligament injury, and flexor tenosynovitis. The fracture of the bone surrounding the ankle and deltoid ligament injury can reduce the TT area. The reducing area of TT can compress the PTN. For flexor tenosynovitis, this cause can compress the proximal area of the PTN.[40]

Diagnosis

The diagnosis and treatment need proper understanding and anatomical knowledge of the PTN and its branches and TT.[17] The diagnosis of TTS can use several techniques such as neurophysiology, ultrasound scanning (US), and magnetic resonance imaging (MRI).

Nerve conduction velocity (NCV) is a technique for examination that is separated to sensory and motor NCV. For TTS, the MPN and the LPN will be examined sensory NCV. This technique is a difficult technique for applying of patients. Besides, it has a low amplitude of the response to stimulation. Moreover, the old-age patients have polyneuropathies that affect to the interpretation.[41] Motor NCV records the distal motor latency of the muscle. This technique often records the distal motor latency of the AH muscle because it is easily recorded. However, this method is less sensitivity. The interpretation of this method observes increasing of distal motor latencies and reducing of motor potential amplitude. The sensory and motor NCV should be tested bilaterally for comparing of interpretation.[42]

Electromyography (EMG) records motor latency of the muscle that is supplied by the branches of the PTN such as MPN and LPN. The result shows the prolonging of distal latencies of the AH muscle and ADM muscle for MPN and LPN entrapments, respectively.[43]

US is an equipment that can show the whole PTN and its branches. It can be used for the identification of space-occupying lesions in TT.[44] For the high-resolution US, it has the efficiency like the dissection that can expose the anatomical variation of PTN. The knowledge of accuracy location of the nerve and its branches is important for patients. During operation, the using US guided with operation can decrease the complication of patients.[21]

MRI is a helpful equipment for identifying the cause of TTS. This technique enables the identification of the causes in about 88% of patients and can also be used in surgery to confirm prognosis in approximately 90% of cases.[45] Moreover, the methods for diagnosis have other methods: plan weight-bearing radiographs and/or computed tomography are used for the abnormal structure from bony abnormality[46] and qualitative sensory testing is used for measurement of sensory impairment using the functional assessment of small and large sensory nerve fiber.[47]

Treatment

The treatment of TTS begins with conservative treatment such as rest, modified shoes, physical therapy, medication, and ultrasound investigation. The meditation has numerous kinds for injection to the patients such as nonsteroid anti-inflammatory drug,[9] corticosteroid. This technique has the caution and the contraindication for treatment of the patients. The nonsteroid anti-inflammatory drug should be used the short term, especially tenosynovitis patients.[9] Another meditation, corticosteroid drug technique, is avoiding the injection of tibialis posterior tendon[9] because corticosteroid drug may make the tendon rupture. Other conservative treatments are foot orthosis, orthopedic insole, and medial longitudinal arch supports. The foot orthosis is selected to be the initial conservative treatment[42] because it decreases the effective treatment for flexible deformity cases.[48] The orthopedic insole and medial longitudinal arch supports help control the excessive foot pronation, especially flexible valgus heel that has a successful result.[48]

If the conservative treatment is unsuccessful treatment and the surgeons know the actual nerve entrapment location, the surgeons plan to use operation for decompression of TT as the next option. The surgeons decide to use the middle incision that is between the medial malleolus and the Achilles tendon because this incision is not damaged the posterior branch of the saphenous nerve.[1] The open decompression usually uses for the space-occupying cases that show successful results. Although open surgery has good results with success rates varying from 44% to 96%, this technique has complications such as Tinel's sign and sensory deficit in the patients following surgery.[2]

Over the last decade, endoscopic procedure has become a considerable tool of clinicians for the diagnosis and treatment of various TTS-related pathologies. Endoscopic TT decompression is an alternative treatment for TTS. The usage of endoscopic technique has reached significant improvement in orthopedic operation because these procedures use a small incision to pass the instruments into deep tissue areas for treatment. The specialist knowledge of anatomy is particularly important for clinicians because it can prevent or decrease the risk of complications. This technique uses the less-invasive approach that also has various benefits such as earlier mobilization and rehabilitation, less wound complications, and a decrease postoperative morbidity,[49] but the space-occupying cannot use the endoscopic technique.[50] The treatment results for this technique are excellent to good results in about 85.7%. Hence, the endoscopic technique is usually selected for treatment of TT decompression in patients because this technique is safer and higher success rate.[13]

Conclusion

TTS is one of the most common injuries of the ankle joint. It causes pain on the medial side of the ankle. Nerve compression and muscle atrophy can cause of pain in the patients of TTS. Recently, diagnosis and treatment have shown promising results. The study of the origin, pathway, bifurcation, and number of branches is important for diagnosis and treatment of any clinical condition. Hence, the detailed anatomical knowledge of the nerve and understanding of the involved mechanisms at the medial side of the ankle area will ensure surgeons that can form an accurate diagnosis and effectively treat patients.

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Conflicts of interest

There are no conflicts of interest.

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