ORIGINAL RESEARCH

Variation In The Tibial Nerve Branching In Foot On Cadaver

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Abstract

Background and Objectives: The tibial nerve, a significant part of the sciatic nerve, originates from the ventral branches (Anterior Division) - L4, L5, S1-S3. It travels through the leg alongside the posterior tibial vessels within the tarsal tunnel, and then branches into the medial calcaneal nerve and the medial and lateral plantar nerves. Responsible for sensory information, the tibial nerve adapts to foot movements and stretching. Compression in the tarsal tunnel can cause tarsal tunnel syndrome. Proper knowledge of its anatomical variations is essential for surgical safety, nerve blocks, and graft procedures.

Materials & Methods: In this cross-sectional study conducted at the Department of Anatomy in a government and a private medical college in central India, lower limbs from 30 embalmed cadavers were included. The mideo-malleolar-calcaneal axis was defined as a reference line of 1 cm width, by connecting two landmarks: the medial malleolus and medial tubercle of the calcaneus. The bifurcation of the tibial nerve was studied with respect to this axis.

Results: The findings demonstrated that the tibial nerve consistently crossed the posterior tibial vessels in all cases. The bifurcation of the tibial nerve was located proximal to the mideo-malleolar-calcaneal axis in 55% of cases, with an average distance of 1.86 cm above the axis, thus belonging to the Type I category. The Type II category, observed in 30% of cases, showed bifurcation occurring at the level of the axis. Additionally, the Type III category, accounting for 15% of cases, displayed bifurcation at an average distance of 1.16 cm below the axis.

Conclusion: A comprehensive understanding of the anatomical variations in tibial nerve branching is essential to prevent surgical complications, enable effective nerve blocks, and facilitate the procurement of tibial nerve grafts. This knowledge enhances clinical practices involving the tibial nerve in various medical interventions.

Key words: Tibial Nerve, Tarsal Tunnel Syndrome, Cadaver, Calcaneus

INTRODUCTION

The tibial nerve, which constitutes the larger portion of the sciatic nerve, originates from the ventral branches (anterior divisions) of the fourth and fifth lumbar and first to third sacral ventral rami. It descends along the posterior aspect of the thigh and the popliteal fossa until reaching the distal border of the popliteus muscle. Subsequently, it passes deep to the gastrocnemius and soleus muscles, and then courses anteriorly to the arch of the soleus muscle, in close proximity to the popliteal artery [1]. Within the leg, the tibial nerve travels in tandem with the posterior tibial vessels, being enveloped within a fibro-osseous structure known as the tarsal tunnel. The medial boundary of this tunnel is defined by the flexor retinaculum, while the lateral aspect is bordered by the posterior facets of the talus and calcaneum, with the medial malleolus marking its anterior limit. Beneath the flexor retinaculum, the tibial nerve divides into the medial and lateral plantar nerves [2]. The medial calcaneal nerve originates at the ankle, pierces the flexor retinaculum, and innervates the posterior and lower surface of the heel. In contrast, the medial and lateral plantar branches supply the medial and lateral plantar regions of the foot, respectively, and convey sensory information from these areas [3]. During lower limb movements, particularly ankle joint dorsiflexion and foot inversion, the tibial nerve may experience stretching, necessitating adaptations through its mechanical properties. It exhibits the ability to endure repetitive forces and move relative to surrounding tissues [4, 5]. Narrowing and compression of the tibial nerve within the tarsal tunnel can result in tarsal tunnel syndrome. Consequently, surgical procedures involving this area, including tibial nerve blocks, demand a thorough understanding of the variations in the nerve's division levels [6]. The present study aimed to examine the topographic anatomy of the tibial nerve and its corresponding branches within the ankle concerning the tarsal tunnel and its clinical implications.

MATERIAL & METHODS

The research was conducted within the Department of Anatomy at both a government and a private medical college in central India. The investigation involved 30 preserved cadavers' lower limbs. These limbs underwent dissection, during which the skin and superficial fascia were removed, starting 30 cm proximal to the medial malleolus and extending to the plantar surface of each foot. Dissection commenced from the popliteal fossa and continued downward along the posterior aspect of the leg until reaching the flexor retinaculum. Each foot was positioned in the anatomical orientation, ensuring a 90° angle between the foot and tibia to maintain measurement consistency. A reference line, 1 cm in width, was established using two identifiable landmarks: the tip of the medial malleolus (MM) and the medial tubercle of the calcaneus (MTC), chosen for their prominence and ease of palpation during physical examination. This line, known as the medio-malleolar-calcaneal (MMC) axis, also corresponded to the lower border of the flexor retinaculum and thus defined the tarsal tunnel. The tarsal tunnel was further delineated by extending 2 cm both proximally and distally from this axis. The classification of the tibial nerve bifurcation was made with reference to this established axis: Type I indicated bifurcation proximal to the axis, Type II indicated bifurcation at the axis, and Type III indicated bifurcation distal to the axis. Precise measurements were taken using a digital Vernier caliper with an accuracy of 0.001 mm, and thorough records of typical findings were documented. Mean values and standard deviations for measurements on the right and left sides of each foot were statistically computed. Statistical analysis was conducted using SPSS (Statistical Package for the Social Sciences) version 20 by IBM Corp. and Microsoft Excel by Microsoft® Corp.

RESULTS

In this study, a total of 30 lower limb specimens were examined. The tibial nerve demonstrated the expected division into the median and lateral plantar nerves within the tarsal tunnel in all cases, accounting for 100% of the examined specimens. Furthermore, in all cases, the tibial nerve crossed the posterior tibial vessels. Regarding the bifurcation of the tibial nerve, 16 cases (53.33%) exhibited a proximal location with an average distance of 2 cm above the MMC axis, constituting the majority and classified as Type I. Nine cases (30%) fell into the Type II category, where the bifurcation occurred at the level of the axis. Type III category encompassed five cases (16.67%), with the bifurcation positioned at an average distance of 1.10 cm distal to the axis. Notably, the vascular arrangement was normal, and no anomalous branching patterns caused by accessory innervations were observed. Moreover, all muscles showed the usual innervations. Table 1 and Table 2 provide additional details on the measured distances and bifurcation categories..

Table 1: Types of Bifurcation of Tibial Nerve in reference to MMC axis

Types	Frequency	%	Distance from MMC axis (cm) Mean ± SD
Type I	16	53.33	2.00 ± 1.40
Type II	9	30.00	At the axis
Type III	5	16.67	1.10 ± 0.30

Table 1: Distance of Bifurcation of Tibial Nerve in reference to MMC axis

Cadaver No.	Right Lower Limb	Left Lower Limb
1	Type I, 1 cm proximal to axis	Type I, 1 cm proximal to axis
2	Type II, at axis	Type I, 6 cm proximal to axis
3	Type I, 2 cm proximal to axis	Type II, at axis
4	Type I, 2 cm proximal to axis	Type III, 1 cm distal to axis
5	Type II, at axis	Type I, 1.5 cm proximal to axis
6	Type III, 1.5 cm distal to axis	Type I, 1 cm proximal to axis
7	Type II, at the axis	Type I, 1.3 cm proximal to axis
8	Type I, 1 cm proximal to axis	Type II, at axis
9	Type I, 2.5 cm proximal to axis	Type III, 1 cm distal to axis
10	Type I, 1 cm proximal to axis	Type III, 1.6 cm distal to axis
11	Type I, 1 cm proximal to axis	Type III, 1 cm distal to axis

12	Type II, at the axis	Type III, 1.4 cm distal to axis
13	Type II, at the axis	Type III, 1.5 cm distal to axis
14	Type I, 1.5 cm proximal to axis	Type II, at axis
15	Type III, 1 cm distal to axis	Type II, at axis

DISCUSSION

The knowledge of anatomical variations in tibial nerve bifurcation holds significant clinical implications for the diagnosis and treatment of conditions like tarsal tunnel syndrome and for surgical procedures such as external nailing of tarsal bones. Andreasen Struijk et al. conducted a study on functional electrical stimulation systems, which require nerve cuff electrodes to measure sensory information from all three terminal branches of the tibial nerve. They found high dispersion in the branching pattern, with 80% of cases located within the tarsal tunnel [3].

Previous studies by Louisia and Masquelet [10], Dellon and Mackinnon 11], Havel et al. [12], and Davis and Schon [13] have reported varying frequencies of tibial nerve bifurcation within the tarsal tunnel. In the present study, 100% of the branching occurred within the tarsal tunnel. Surgeons need to be aware of these variations to avoid inadvertent cutting of nerve branches during procedures, which could be hazardous. Anomalous medial plantar nerves can lead to compression in the heel region, causing pain, edema, and inflammation of synovial sheaths, resulting in tibial nerve entrapment. Discrepancies between clinical tests and electromyography studies have been observed due to anomalous branching patterns of the tibial nerve above the flexor retinaculum [14]. In this study, the tibial nerve bifurcation was found to be approximately 1.86 cm above the MMC axis. This knowledge is crucial for planning minimal skin incisions during tibial nerve decompression procedures [15]. The association between a high division of the tibial nerve and an accessory flexor digitorum muscle has been noted in previous research, but such findings were not observed in the present study [13]. Iatrogenic injuries to the tibial nerve can occur during fibular graft harvest, high tibial osteotomy, and fascial release procedures. Understanding the topography of the nerve can aid in procuring allogenic vascularized tibial nerve grafts for limb salvage and nerve bank storage for future use [15-20]. This study is the first of its kind in the Central Indian population, and its main limitation is the small sample size due to resource constraints. Future research with larger sample sizes and diverse ethnic groups can further explore statistical significant differences in variations.

CONCLUSION

The tibial nerve plays a critical role in various clinical conditions, including poliomyelitis, nerve compression syndromes, tuberculosis, leprosy, and idiopathic heterotopic ossification. Damage to any of its branches can result in paralysis of the muscles supplied by the nerve. Therefore, having precise anatomical knowledge of its motor branching is crucial for minimizing surgical complications in this region. Moreover, such knowledge can contribute to reducing disparities in clinical and electromyographical correlation studies, leading to more accurate diagnoses and treatment plans. Effective nerve blocks can be expedited with a better understanding of the nerve's branching pattern.

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