TOPOGRAPHIC ANATOMY OF TIBIAL NERVE AND ITS TERMINAL BRANCHES IN RELATION WITH THE POSTERIOR TARSAL TUNNEL WITH CLINICAL CORRELATIONS

Preeti Awari *1, P Vatsalaswamy 2.

1Assistant professor, Department of Anatomy, Dr. Y. Patil Medical College, Hospital and Research centre, Dr. D.Y. Patil Vidyapeeth (Deemed to be University), Pune, Maharashtra, India.
2 Director Academics, Dr. DY. Patil Medical College, Hospital and Research centre, Dr. D.Y. Patil Vidyapeeth (Deemed to be University), Pune, Maharashtra, India.

ABSTRACT

Background: Variations in the level of terminal branching of tibial nerve into medial and lateral plantar nerve in the posterior tarsal tunnel and its relations with posterior tibial artery has tremendous clinical importance. Tibial nerve and its terminal branches are at risk of entrapment in the posterior tarsal tunnel which is called as tarsal tunnel syndrome. The results of surgeries for tarsal tunnel syndrome are variable or suboptimal. The reason could be poor understanding of detailed anatomy of the tarsal tunnel and potential sites of nerve compression. Information regarding the same can help in endoscopic decompression surgeries for tarsal tunnel syndrome with minimal exposure of the region to be operated. Knowledge regarding these variations can also help the anesthetists to give ultrasonography guided ankle block without puncturing the blood vessels.

Materials and Methods: The authors have studied topographic anatomy of tibial nerve and its terminal branches in relation with posterior tarsal tunnel in 50 formalinized cadaveric feet. Authors divided the location of division of tibial nerve in posterior tarsal tunnel (PTT) into seven levels and also categorized the distance between the point of terminal division of tibial nerve (TN) and point of terminal division of posterior tibial artery (PTA) in four categories.

Results and conclusion: Tibial nerve divides relatively higher than the posterior tibial artery in the PTT. Both lie in the same compartment in the tarsal tunnel. The tibial nerve is situated deep to posterior tibial blood vessels .The neurovascular bundle is covered by an unyielding fibrous tissue which could be the reason for the entrapment. Commonest division level of tibial nerve in PTT is level 4 which means the division lies in the range of 6mm to 10mm above the distal border of flexor retinaculum. In 52% of feet the distance between point of division of TN and point of division of PTA is in a range between 0-5mm above the distal border of flexor retinaculum falling under category 1.

KEY WORDS: Posterior tarsal tunnel syndrome, Ankle block, Tibial nerve, Medial plantar nerve, Lateral plantar nerve.

INTRODUCTION

The tibial nerve (TN) enters into the plantar aspect of the foot through the fibro-osseous tunnel called as posterior tarsal tunnel (PTT) which is located on the medial aspect of the foot. Roof of the tunnel is formed by the flexor
retinaculum extending from the medial tubercle of calcaneum posteriorly to the medial malleolus in front. The floor is formed by the posterior aspect of the talus and calcaneus. The anterior wall is formed by the medial malleolus. The distal end is defined by a line joining the tip of the medial malleolus to the medial tubercle of the calcaneus which represents the distal border of the flexor Retinaculum [1]. (figure 1).

Fig. 1: Medial aspect of foot showing posterior tarsal tunnel deep to flexor retinaculum and MMC axis (arrow)

Tibial nerve divides in the PTT into its terminal branches as medial and lateral plantar nerves. The nerve itself and its terminal branches are at risk of entrapment in the posterior tarsal tunnel. This is called as tarsal tunnel syndrome (TTS) [2].

Based on the site of entrapment of tibial nerve or its branches, compression of these structures can lead to a variety of foot and heel pain. Knowledge of topographic anatomy of tibial nerve in relation with the PTT can help to provide patients with needed pain relief by using various conservative or surgical treatment modalities [3-5].

Frequently the tibial nerve entrapment in posterior tarsal tunnel is managed as the heel pain only which denotes that the diagnosis of tarsal tunnel syndrome is much more complicated. This situation makes further study of this region more demanding [2].

Many cases of tarsal tunnel syndrome in India are reported in various journals [6-8] which boosted the authors to take up this region for study.

Many authors conclude that the outcome of decompression surgeries for PTT are variable or suboptimal. The reason could be poor understanding of detailed anatomy of the tarsal tunnel and potential sites of nerve compression [9,10].

Tibial nerve block at ankle also requires a better understanding of relations of tibial nerve with nearby structures as posterior tibial vessels in the PTT. Anatomical knowledge about the same can also help surgeons to come up with better prognosis of surgical procedures such as external nailing of the tarsal bones, medial displacement osteotomies [11-13].

Few authors also have discussed the topographic anatomy of the tibial nerve in relation with PTT [11-13,16,17,19]. Most of them have classified broadly tibial nerve terminal branching in three types as in the PTT, distal to the tunnel and at the lower edge of the flexor retinaculum.

Authors in this study have classified the location of tibial nerve branching in seven levels with a reference range of 5mm in relation with PTT.

Authors also noted the distance between the point where the tibial nerve divides into medial and lateral plantar nerves and the point where posterior tibial artery divides into medial and lateral plantar arteries.

**MATERIALS AND METHODS**

This is a descriptive type of study. Fifty formalinized cadaveric feet from Dr. D Y Patil Medical College, Hospital and Research Centre, Dr. D Y Patil Vidyapeeth, Pune, Maharashtra, India were used as the study material. To expose the tarsal tunnel and structures within it authors followed the steps given in the Cunningham’s dissection manual [14]. The flexor retinaculum was identified and divided at its anterior end and reflected posteriorly to visualize the structures in PTT. All the structures in PTT were cleaned and photographed.

Authors followed the method of O Bilge et al to study and classify the location of division of the tibial nerve in the posterior tarsal tunnel. O Bilge et al used a reference line extending from the tip of medial malleolus (MM) to medial tubercle of calcaneum (C) called as ‘Medio- Malleolar-Calcaneal axis’ (MMC axis) (figure 1) to classify the location of division of tibial nerve into three types. Type I, II and III signify bifurcations proximal to the reference line but in the tarsal tunnel i.e. within 2cm range, at the line
and distal to the posterior tarsal tunnel respectively [11]. Authors also have added a type IV in the classification (Table 1 and figure 2) for the nerve dividing above the flexor retinaculum i.e. 2cm or more proximal to MMCA. All the measurements were taken with the help of measuring tape in millimeters.

**Fig. 2:** Percentage of cadaveric feet showing various types of division of tibial nerve in relation with MMC axis

As this is the era of minimal invasive surgeries; considering same in mind authors also divided the location of division of TN into seven levels (Table 1) with the reference range of 5mm for the vertical distance between the point of division of TN and the reference line MMCA (figure 3).

Authors also noted the distance between terminal division point of tibial nerve and terminal division point of posterior tibial artery in cases where the tibial nerve was dividing at higher level than the posterior tibial artery. These distances were again divided into four categories (Table 2 and figure 4) with a reference range of 5mm.

Authors observed that the flexor retinaculum as condensed white glistening deep fascia which can be easily visualized as approximately 20mm broad extending from medial malleous to medial tubercle of calcaneum. The observations for the tibial nerve terminal branching in PTT are mentioned in table 1 and pie chart 1.

In 92% of cases the tibial nerve was dividing little higher than the level of division of posterior tibial artery. In 4% of cases both TN and PTA were dividing at the same level. In 4% of cases the posterior tibial artery was dividing little higher than tibial nerve. In all the specimens studied the posterior tibial artery was superficial to the tibial nerve. The tibial nerve flattening was seen before the terminal division in all the specimens.

In pie chart 2 and table 2 authors have shown percentage of feet falling under various categories for the distance between point of terminal division of TN and point of terminal division of PTA. In 52% of feet the distance between point of terminal division of TN and PTA was falling under the category 1 which means the distance between these two division points is falling in the reference range of 0 mm to 5mm.

**Fig. 3:** Percentage of cadaveric feet showing various levels of terminal bifurcation of tibial nerve

**Pie chart 1:** Pie chart showing percentage of feet falling under various levels of terminal bifurcation of tibial nerve in relation with the posterior tarsal tunnel.
Fig. 4: Percentage of feet showing various categories for the distance between point of terminal division of TN and PTA

Fig. 5: Terminal division of tibial nerve into medial plantar nerve and lateral plantar nerve in the posterior tarsal tunnel, A:Tibial nerve, B:Medial plantar nerve, C: Lateral plantar nerve,.......Line represents MMC axis.

Fig. 6: Terminal division of tibial nerve into medial plantar nerve and lateral plantar nerve 4.2cms above the MMC axis, A:Tibial nerve, B:Medial plantar nerve, C: Lateral plantar nerve,.......Line represents MMC axis

Fig. 7: Terminal division of tibial nerve (N)(yellow dot) is proximal to terminal division of posterior tibial artery(A)(red dot), tibial nerve flattening is seen just before bifurcation.

Pie chart 2: Percentage of feet falling under various categories for the distance between point of terminal division of TN and PTA.

Table 1: Types of division and levels of division of tibial nerve in the posterior tarsal tunnel with percentage of cadaveric feet showing the same (figure no.2,3)

| Level of terminal division of TN | Location of terminal division of TN in millimeters (mm) in relation with MMCA | Percentage of cadaveric feet showing various levels of division | Type of division | Percentage of feet showing type of division |
|----------------------------------|--------------------------------------------------------------------------------|---------------------------------------------------------------|------------------|--------------------------------------------|
| 1                                | Distal to the MMCA                                                               | 0%                                                           | III (distal to the PTT) | 0%                                         |
| 2                                | At the MMCA                                                                     | 0%                                                           | II (within the PTT)    | 0%                                         |
| 3                                | 1mm to 5mm above MMCA                                                           | 12%                                                          | I (within the PTT)     | 84%                                        |
| 4                                | 6mm -10mm above MMCA                                                            | 32%                                                          |                  | 18%                                        |
| 5                                | 11mm-15mm above MMCA                                                            | 18%                                                          |                  | 22%                                        |
| 6                                | 16mm-20mm above MMCA                                                            | 16%                                                          | IV(proximal to the PTT) | 16%                                        |
| 7                                | More than 20mm above MMCA                                                       | 16%                                                          |                  | 16%                                        |
Table 2: Categorization of the distance between terminal division point of tibial nerve and terminal division point of posterior tibial artery and percentage of cadaveric feet showing the same (in cases where tibial nerve was dividing at higher level than the posterior tibial artery) (Figure 4)

| Category | Distance between terminal division point of TN and terminal division point of PTA in millimeters (mm) | Percentage of cadaveric feet falling under various categories |
|----------|-------------------------------------------------|----------------------------------------------------------|
| 1        | 0 to 5mm                                         | 52%                                                      |
| 2        | 6mm to 10mm                                     | 22%                                                      |
| 3        | 11mm to 15mm                                    | 12%                                                      |
| 4        | 16mm and above                                   | 14%                                                      |

Table 3: Comparison of percentage of feet showing various types of division of tibial nerve in posterior tarsal tunnel amongst various studies.

| Authors                          | Bifurcation in PTT | Bifurcation distal to PTT | Bifurcation proximal to PTT |
|----------------------------------|--------------------|--------------------------|----------------------------|
| Horwitz et al cited by André Leal Gonçalves Torres, [19] | 96%                | -                        | 4%                         |
| Davis et al cited by André Leal Gonçalves Torres, [19] | 94%                | -                        | 6%                         |
| Louisa et al cited by André Leal Gonçalves Torres, [19] | 73%                | -                        | 26%                        |
| Heimkes et al cited by André Leal Gonçalves Torres, [19] | 100%               | -                        | -                          |
| Ndoiye et al cited by André Leal Gonçalves Torres, [19] | 93%                | -                        | 7%                         |
| Bilge et al cited by André Leal Gonçalves Torres, [19] | 90%                | -                        | 10%                        |
| Joshi et al [17]                  | 99.90%             | 0.89%                    | -                          |
| Fernando et al cited by André Leal Gonçalves Torres, [19] | 86.70%             | 3.30%                    | 10%                        |
| A Torres et al cited by André Leal Gonçalves Torres, [19] | 88%                | -                        | 12%                        |
| Alvaro Iborra et al [2]           | 91.70%             | -                        | 8.30%                      |
| Present study                     | (Type I) 84%        | 0%                       | 16%                        |

DISCUSSION

The authors were able to appreciate the flexor retinaculum but it was thinner than the flexor retinaculum in the hand. The tibial nerve fattening was seen at the point of terminal division in all 50 feet. Posterior tibial blood vessels were superficial to it in all dissected specimens. This might be the most common factor for the compression of the tibial nerve. The same findings were described by Michihiro Kohno et al[15], Tamang et a [16], SS Joshi et al [17].

In 92% cases tibial nerve was dividing higher than the PTA. SS Joshi et al [17] found the same in 98% of cases. O Bilge et al [11] and Yang et al [18] have also described a higher level of bifurcation of tibial nerve.

Thick strands of fibrous tissue extending from under surface of flexor retinaculum to the bones forming medial wall of the tunnel were dividing the PTT in individual compartments for tendons and neurovascular bundle. The tibial nerve and the blood vessel were in a same compartment separated from the flexor tendons. These findings match with the findings of Joshi et al [17], Dellon et al [5], Havel et al [19].

Because of the unyielding nature of this fibrous tissue surrounding the neurovascular bundle; the tibial nerve becomes immobile and prone to traction injuries or compression by space occupying lesions [5,19].

From table number three; it can be observed that the most common type for terminal division of tibial nerve is within the tarsal tunnel.

Authors are the first to divide the location of terminal division of TN into seven levels. For the same reason it was not possible to compare the results of the same with any other study. In 32% of feet the division of TN was taking place in a range of 6mm-10mm above the MMCA falling under level 4. In 16% of cases division was taking place above the PTT falling under level 7. Knowledge about common and rare levels of terminal division of TN may help the surgeons to localize tibial nerve and its branches precisely in nerve entrapment cases for endoscopic release with minimal handling of surrounding structures.

In 52% of feet the distance between point of terminal division of TN and point of terminal division of PTA was falling in a range between 0-5mm above the MMCA i.e. category 1. This kind of categorization may help the anesthetists to find safe zone to give ankle block without puncturing the posterior tibial artery [13].

Authors hope that anatomical details discussed in this study can fill the gaps in the knowledge regarding the topographic anatomy of terminal branching of tibial nerve up to certain degree. Parameters studied may be added as one of the factor assisting surgeons for endoscopic release of PTT syndrome with minimal tissue handling. Same can be one of the factor helping anesthetists in giving ankle block without damaging PTA.

CONCLUSION

The tibial nerve divides relatively higher than
the posterior tibial artery in the PTT. The tibial nerve and posterior tibial vessels lie in the same compartment in the tarsal tunnel. The tibial nerve lie deep to posterior tibial blood vessels which could be one of the reasons for the compression of the tibial nerve in tunnel. The neurovascular bundle lie in an unyielding fibrous tissue which could be another reason for the entrapment neuropathy.

Most common level of division of tibial nerve is in the tarsal tunnel was level 4 which means the division was located in the range of 6mm to 10mm above the MMCA.

In 52% of feet the distance between point of terminal division of TN and point of terminal division of PTA was in a range between 0-5mm above the MMCA falling under category 1.

In the era of minimal invasive surgeries and regional blocks the precise knowledge of topographic anatomy of tibial nerve in relation with the posterior tarsal tunnel can help the anaesthetists and surgeons to reduce the time duration of the hospital stay for the patient by optimum handling of the region to be operated.

**ACKNOWLEDGEMENTS**

The authors thank the scholars whose articles are included in references of this manuscript. We thank to the authors, editors and publishers of the articles, journals and books from where the literature for the manuscript has been reviewed. We also thank the teaching and non teaching staff of Department of Anatomy Dr. D Y Patil Medical College, Hospital and Research Centre Pune, Maharashtra, India for providing help and support while doing the research. Our sincere thanks to Dr. Maitreyee Mutalik (Assistant professor Department of Anatomy Dr. D Y Patil Medical College, Pune, India) and Dr. Pallavi Bajpayee (Assistant professor Department of Anatomy Dr. D Y Patil Medical College, Pune, India) for encouraging and supporting while doing the research work.

**Source of funding:** The study was carried out in the department of Anatomy of Dr. D Y Patil Medical college, Pimpri, Pune. So there was no separate financial support provided for the same.

**Conflicts of Interests:** None

**REFERENCES**

[1]. Malin D. Wijeratna Nick R. Evans and Philip D. Vaughan, Original article; The danger zone for the plantar and calcaneal divisions of the tibial nerve - a cadaveric study. Eur. J. Anat. 2014;18(2):81-84.
[2]. Alvaro Iborra, Manuel Villanueva, Stephen L. Barrett, Edgardo Rodriguez-Collazo, Pablo Sanz, Anatomic Delineation of Tarsal Tunnel Innervation via Ultrasonography. J Ultrasound Med 2018;37:1325–1334.
[3]. Brown M.N., Pearce B.S., Trescot A.M., Karl H.W. Tibial Nerve Entrapment. In: Trescot A.M. (eds) Peripheral Nerve Entrapments. Springer 2016, Cham, page 816-831.
[4]. Dellon AL, Mackinnon SE. Tibial nerve Branching in the Tarsal Tunnel. Arch Neurol 1984;41:645-46.
[5]. Erickson SJ, Quinn SF, Kneeland JB, et al. MR imaging of the tarsal tunnel and related spaces: normal and abnormal findings with anatomic correlation. AJR Am J Roentgenol 1990;155:323–328.
[6]. Wani I H, Salaria A Q, Jan M A Ganglion Cyst at the Foot Causing Tarsal Tunnel Syndrome Detected by Magnetic Resonance Imaging. WebmedCentral. Case Report Article ID: WMC001130 ISSN 2046-1690; http://www.webmedcentral.com on 28-Jan-2012, 10:25:48 AM.
[7]. Bhat AK, Madi S, Mane PP, et al. Bilateral tarsal tunnel syndrome attributed to bilateral fibrous tarsal coalition and symmetrical hypertrophy of the sustentaculum tali Case Reports 2017:bcr-2017-220087.
[8]. Pranav Kothiyal Puneet Gupta Kunal Vij Akhilesh Singh Kushwaha; Osteochondroma of the talus presenting with tarsal tunnel syndrome - A case report; Journal of Indian Orthopaedic Rheumatology Association 2018;4(1):36-39.
[9]. Bailie DS, Kelikian AS. The tarsal tunnel syndrome: surgical technique and functional outcome. Foot Ankle Int. 1998 Feb;19(2):65-71.
[10]. Conor O’Brien, Rob Byrden. Tarsal Tunnel Syndrome—A New Way to Diagnose an Old Problem, World Journal of Neuroscience, 2017;7:172-180 http://www.scirp.org/journal/wjns ISSN Online: 2162-2019, ISSN Print: 2162-2000, DOI: 10.4236/ wjns.2017.71012 February 9, 2017.
[11]. Okan Bilge, Mehmet Asim Ozer, Figen Govaş. Neurovascular branching in the tarsal tunnel. Neuroanatomy, 2003;2:39-41.
[12]. D Malar a study of tibial nerve bifurcation and branching pattern of calcaneal nerve in the tarsal tunnel int j anat res 2016;4(1):2034-36. issn 2321-4287 doi: http://dx.doi.org/10.16965/ijar.2016.139
[13]. Deog-Im Kim, Yi-Suk Kim, Seung-Ho Han Topography of human ankle joint: focused on posterior tibial artery and tibial nerve Original Article http://dx.doi.org/10.5115/acb.2015.48.2.130 piiSSN 2093-3665 eISSN 2093-3673.
[14]. G J Romans; Cunningham’s manual of practical Anatomy; Volume 1Upper and Lower Limbs 15th edition; south asia edition; printed in India by Thomson press; The leg and the foot: pages 196 - 206.
How to cite this article:

Preeti Awari, P Vatsalaswamy. TOPOGRAPHIC ANATOMY OF TIBIAL NERVE AND ITS TERMINAL BRANCHES IN RELATION WITH THE POSTERIOR TARSAL TUNNEL WITH CLINICAL CORRELATIONS. Int J Anat Res 2020;8(1.3):7371-7377. DOI: 10.16965/ijar.2020.106

[15]. Michihiro Kohno, Hiroshi Takahashi, Hiromu Segawa, Keiji Sano Neurovascular decompression for idiopathic tarsal tunnel syndrome: technical note Neurol Neurosurg Psychiatry 2000;69:87–90.

[16]. Tamang P.K., Sinha P., Bhutia K.L., Sarda R.K. Neurovascular relation and origin of medial calcaneal nerve in the tarsal tunnel in embalmed cadavers of Eastern India. Ann Int Med Dent Res 2016;2:19 22.

[17]. Joshi S S, Athavale S A, Anatomy of tarsal tunnel and its applied significance, journal of anatomical society of India 2006;55(1).

[18]. Yang Y, Du M.L., Fu Y.S., Liu W., Xu Q., Chen X., et al. Fine dissection of the tarsal tunnel in 60 cases. Sci Rep 2017;7:46351. [doi: 10.1038/srep46351]. Available from: http://www.nature.com/scientificreports, [Last cited on 2018 Apr 07].

[19]. André Leal Gonçalves Torres, Marcus Castro Ferreira. Study of anatomy of tibial nerve and its branches in the distal medial leg. Acta ortop Bras. 2012;20(3):157-64.