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The danger zone for the plantar and calcaneal divisions of the tibial nerve - a cadaveric study

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SUMMARY

In this anatomical, cadaveric study we describe a novel method of determining the point of origin of the plantar and calcaneal divisions of the tibial nerve around the tarsal tunnel, in the clinical setting, without requiring the exact path of the nerve to be known.

To this end, we describe an area that arises from the midpoint of the navicular-calcaneal line (MP-NCL), which contains both nerve divisions in the majority of cases. We called this area the danger zone. We identified the size and location of this danger zone by dissecting a total of 50 cadaveric feet. We measured the distance from the origin of each nerve division to both the navicular tuberosity and the calcaneal insertion of the Achilles tendon. From these measurements we were able to calculate the distance of each division from the MP-NCL along two axes, the navicular-calcaneal line (NCL) and a line perpendicular to this crossing at the midpoint.

The danger zone of the tibial nerve, around the tarsal tunnel is a 16.5 cm^2 (5.9 x 2.8 cm) quadrilateral area that passes posterior and proximal from the MP-NCL. This area in our study contained both the plantar and calcaneal divisions of the posterior tibial nerve in 82% of cases. Those divisions that arose outside this area (18%) occurred up to 0.5 cm anterior to the MP-NCL and 1.4 cm distal to the NCL.

Key words: Tibial nerve – Tarsal tunnel – Origin plantar division – Origin calcaneal division medial calcaneal nerve – Medial plantar nerve – Lateral plantar nerve

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INTRODUCTION

The tibial nerve (TN) runs into the plantar aspect of the foot through the fibro-osseous tarsal tunnel. The roof of this tunnel is the flexor retinaculum, the floor is the posterior aspect of the talus and calcaneus and the anterior wall is formed by the medial malleolus. The distal margin is defined by a line drawn from the tip of the medial malleolus to the medial tubercle of the calcaneum (MMCA).

The TN at this level is subject to broad variation (Andreason Struijk et al., 2010; Bareither et al., 1990; Bilge et al., 2003; Davis et al., 1995; Dellon et al.,1984; Havel et al., 1988), but in its simplest form it has two main divisions, the calcaneal division (CD) and plantar division (PD). The PD is the point at which the tibial nerve divides into the medial plantar nerve (MPN) and lateral plantar nerve (LPN) and the CD the point of origin of the medial calcaneal nerve.

Bareither et al. (1990) highlighted that the point of origin of the PD and CD can extend along the length of the tibial nerve from 2.8cm distal, to 14.3 cm proximal to the MMCA. However both Bilge et al. (2003) and Dellon et al. (1984) showed that in the majority of cases, up to 95%, their origin is within +/- 2cm from the MMCA.

The anatomy of the CD is particularly prone to variation. There can be 2 or more calcaneal branches in up to 60% of cases (Davis et al., 1995), and they can arise from the TN, LPN or

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MPN (Andreason Struijk et al., 2010; Davis et al., 1995; Dellon et al.,1984; Havel et al., 1988). When there is more than one calcaneal branch, each branch often has a different point of origin, with up to 9 permutations (Havel et al., 1988). These individual branches can also be seen to originate from either the anterior or posterior parts of the nerve and from within or proximal to the tarsal tunnel.

Studies that describe the point of origin of these nerves in detail usually describe the distance of each nerve division from a fixed point, usually the MMCA, along the length of a dissected tibial nerve. Therefore to locate the origin of these nerve divisions in clinical setting is difficult, as it requires the exact course of the nerve to be known or visualised.

To overcome this requires a method of locating the origin of these nerve divisions in clinical setting that does not require the path of the nerve to be known. We therefore describe an area that is likely to contain both divisions of the tibial nerve and originates from a point that is easy to locate clinically. We call this area the danger zone.

MATERIAL AND METHODS

A total of 50 feet were dissected from 26 cadavers, 24 bilateral and 2 unilateral. There was an equal left-right distribution and the male-female ratio was 7-19. The mean age of the cadavers was 81 with an age range of 51-100 years old.

All cadavers were free from evidence of ischaemic ulceration or gangrene and had been embalmed with Formaline 7%. The skin over the flexor retinaculum was removed and the fascia also removed more proximally. The Achilles tendon was then divided, proximal to its insertion, to enable the foot to be placed in a neutral position (with the longitudinal axis of the 5th metatarsal perpendicular to that of the fibula) so the results would be standardised. The flexor retinaculum was then divided and the tibial nerve isolated *in situ*. The inferior aspect of the medial maleolus (MM), the plantar and calcaneal divisions of the tibial nerve (PD and CD), the centre of the Navicular Tuberosity (NT) and the Calcaneal insertion of the Achilles Tendon (CT) were all located and marked (Fig. 1).

The NT and CT then used to define the navicular -calcaneal line (NCL) and its midpoint (MP-NCL). The MP-NCL is easy to locate clinically and therefore was defined as the point of origin of our Danger zone. Two axes were then created. The x axis represented the NCL and the y axis a line perpendicular to the NCL crossing at the MP-NCL (Fig. 2). These axes define 4 quadrants:

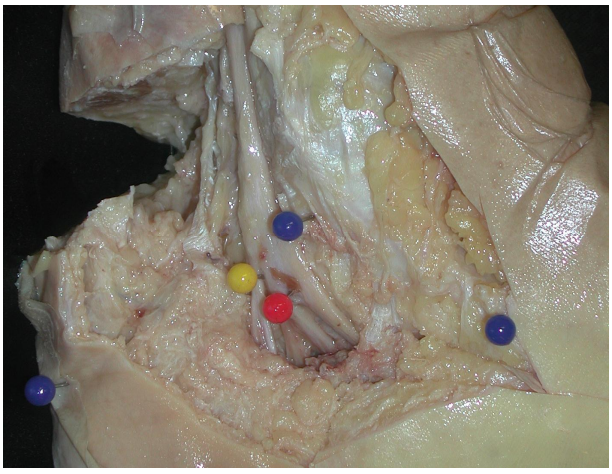
1. Posterior & proximal
2. Anterior & proximal
3. Posterior & distal
4. Anterior & distal

The danger zone is defined as the quadrant that contains both divisions (CD and PD) in the majority of cases. This quadrant or danger zone would be easy to locate clinically as it

Originates from the midpoint of the navicular-calcaneal line (MP-NCL).

Extends along the two perpendicular axis (x,y) (Fig. 2).

The distance between the NT, CT and both



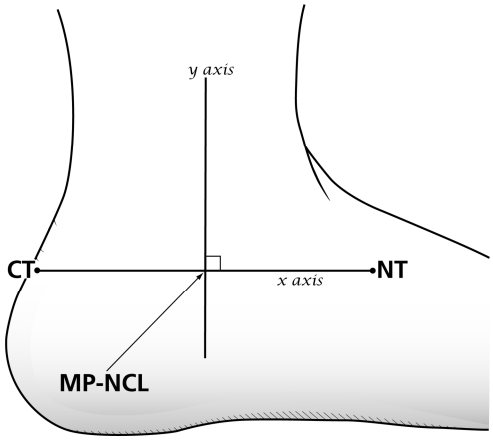


Fig. 1 (Left). Dissected tarsal tunnel and tibial nerve. Pins identify the point used for measurements. Blue pins = Medial maleolus (MM), Navicular Tuberosity (NT) or Calcaneal insertion of the Achilles tendon (CT). The red pin = bifurcation of the tibial nerve (PD) and the yellow pin = origin of the calcaneal division (CD).

Fig. 2 (Right). Diagram showing the medial view of the ankle, illustrating the navicular calcaneal line (NCL), its midpoint (MP-NCL) and the x,y axis. Calcaneal insertion of the Achilles Tendon (CT) and Navicular Tuberosity (NT).

nerve divisions (CD & PD) were measured. All measurements were in cm to one decimal place, using vernier callipers (Silverline Tools Ltd, Somerset, UK).

Measurements were used to calculate a set of co-ordinates (x,y) for the exact location for the origin of each division (PD and CD). A branch proximal to the NCL was given positive (y) co-ordinate. A branch posterior (towards to the CT) to the MP-NCL was given a negative (x) co-ordinate. The spread of data for each co-ordinate is illustrated using ranges and confidence intervals about the mean with p=0.01 (Table 1). For the purpose of this study the areas calculated will refer to both the PD and CD combined.

The Total Area of Origin (TAO) is defined as the area over which the origin of both divisions is spread. This will be calculated using the formula below:

TAO =(X) x (Y)

X = distance between minimum and maximum x co-ordinates (PD and CD)

Y = distance between minimum and maximum y co-ordinate (PD and CD)

The size of the Danger Zone (DZ) will be calculated using the formula below:

DZ = (xmax) x (ymax)

Xmax = largest x co-ordinate in the danger zone (PD and CD) ; Ymax = largest y co-ordinate in the danger zone (PD and CD)

RESULTS

The spread of data is shown in Fig. 3 and summarised in Table 1. The PD, in our study, was most likely to arise -0.8 cm from the MP-NCL (99% CI -1.0 to -0.6) and 0.7 cm from the NCL (99% CI 0.2 to 1.2). Similarly the CD was most likely to arise -1.2 cm from the MP-NCL (99% CI -1.5 to -1.0) and 0.7 cm from the NCL (99% CI 0.4 to 1.1).

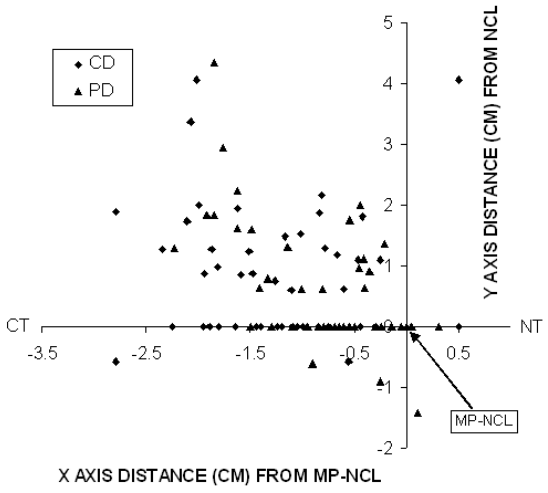


Fig. 3. Scatter plot showing the location of each nerve division on their x,y axis.

Table 1. Spread of data for the co-ordinates of the Plantar and Calcaneal divisions

Co-ordinate	Mean (cm)	Range (cm)	99% confidence intervals (cm)
PD x	-0.8	-2.2 to 0.3	-1.0 to -0.6
PD y	0.7	-1.4 to 5.9	0.2 to 1.2
CD x	-1.2	-2.8 to 0.5	-1.5 to -1.0
CD y	0.7	-0.5 to 4.1	0.4 to 4.1

Overall the TAO was just over 23 cm² (TAO = 3.2 x 7.3). Nerve divisions were seen to originate from 5.9 cm proximal to 1.4 cm distal to the NCL (7.3 cm) and from 2.8 cm posterior to 0.5 cm anterior to the MP-NCL (3.2 cm).

The danger zone is the posterior & proximal quadrant, defined by our axes and illustrated in Fig. 3. In 41 out of 50 of the cadaveric dissections (82%) the nerve divisions arose posterior to the MP-NCL and proximal to the NCL (Fig. 3). From the largest x and y values within this proximal & posterior quadrant (2.8 x 5.9 cm) we can calculate the area of the danger zone = 16.5 cm².

DISCUSSION

This study highlights a TAO of 23 cm² with divisions (PD or CD) occurring up to 5.9cm proximal and 1.4 cm distal to the NCL. Andreason Struijk et al. (2010), Bareither et al. (1990), Davis et al. (1995) and Dellon et al. (1984) all noted that division occurred up to 9cm, 9cm, 5cm proximally from the MMCA respectively. Bareither et al. (1990) noted the greatest variation with divisions occurring from 2.8cm distal to 14.3 cm proximal to the MMCA. However, in contrast to these other studies, our study also highlights that the point of origin varies in the antero-posterior plane, from 0.5 cm anterior to 2.8 cm posterior to the MP-NCL.

The danger zone of the tibial nerve passes 2.8 cm posterior and 5.9 cm proximal to the MP-NCL along our axes and contains both divisions of the tibial nerve in 82% of our cases (Fig. 3).This is similar to the studies by Andreason Struijk et al. (2010), Bilge et al. (2003), Davis et al. (1995), who illustrated that in the majority of their cases, 80%, 96% and 90% respectively, the tibial nerve bifurcated into the medial and lateral plantar nerves within 2cm of the MMCA. Dellon et al. (1984) found a similar majority (90%) but noted that they bifurcated within 1cm of this axis.

Whilst the TAO demonstrates an area over which both divisions of the tibial nerve occur, it does not originate from an easily definable landmark so is not useful clinically. The danger zone that we have described arises from the MP-NCL, which is easily definable and therefore provides a useful clinical guide to the area of origin of these important nerve divisions. It gives the clinician a useful method of locating the area where both nerve divisions are likely to occur, without having to know the exact course of the tibial nerve. This will be of clinical use when diagnosing and treating tarsal tunnel syndrome and also in performing tibial nerve anaesthesia.

A minority (18%) of divisions (PD or CD) do sit outside our danger zone but still within the TAO. They are illustrated in Fig. 3 as the divisions with a positive x co-ordinate (anterior to the MP-NCL) and/or a negative y co-ordinate (inferior to the NCL). Such cases should not be ignored as clinically they may provide explanation for morbidity or poor outcome in procedures around the tarsal tunnel.

In this study we chose the NT and the CT as they are both palpable clinically as are the landmarks for the MMCA used in other studies. The limitation of using such points to define our danger zone on cadavers is the accuracy of locating such points in the clinical environment.

Care should be taken in marking the axes defined in this study. Fig. 2 illustrates the axes as vertical and horizontal lines and this would not necessarily be the case for each individual.

Conclusion: The danger zone of the tibial nerve is 16.5 cm², contains both nerve divisions in 82% of cases and runs posterior and proximal from the MP-NCL along the NCL and a line perpendicular to it.

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