Variable patterns of the cutaneous innervation of the dorsum of the foot and its clinical implication

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ABSTRACT

Background: The superficial sensory nerves are at great risk for injury from lacerations and operative incisions. Precise knowledge regarding the course and distribution of sensory nerves over the dorsum of foot is important to avoid iatrogenic damage by surgeons who are planning the surgical intervention around the distal leg, ankle and foot. The objective of the study is to report the variation in the branching pattern and distribution of the cutaneous nerves over the dorsum of foot.

Materials and methods: The study was carried out in 20 formalin fixed adult lower limbs in the Department of Anatomy, KMC Manipal, Manipal Academy of Higher Education, India. After the careful skin reflection, cutaneous nerves were traced.

Results: Six out of twenty (30%) adult limbs had different pattern of cutaneous nerve innervation on the dorsum of foot. Among these five limbs (83.34%) had variation in the sural nerve innervation. In two limbs (33.33%) communications were found between superficial peroneal nerve and deep peroneal nerve. In one adult limb (16.67%) deep peroneal nerve supplied the second interdigital cleft. We grouped these into five types of variation pattern in the cutaneous innervation over dorsum of foot.

Conclusion: We observed five types of variation pattern, out of which variation II is not reported in the literature. The knowledge of these variations will help the surgeons to avoid iatrogenic damage of these nerves during surgeries involving distal leg, ankle and foot, open reduction and internal fixation of fracture, arthroscopy etc.

1. Introduction

The superficial sensory nerves are at risk for injury from lacerations and operative incisions. Injury to a sensory nerve can cause debilitating symptoms and severe postoperative pain and can be difficult to treat [1]. Complications such as loss of cutaneous sensation and the formation of painful neuromas will occur due to iatrogenic damage of the nerves [2]. These problems can be avoided by knowledge of the anatomy of vulnerable cutaneous structures.

The foot is supplied by four nerves; the medial border of the dorsum up to the ball of the great toe is supplied by the saphenous nerve. The area of the first interdigital cleft is innervated by the deep peroneal nerve (DPN). The lateral border is supplied by the sural nerve (SN) and the rest of the portion is supplied by the superficial peroneal nerve (SPN) by its 2 branches the intermediate dorsal cutaneous nerve (IDCN) and medial dorsal cutaneous nerve (MDCN) [1].

The variations of these superficial nerves should be kept in mind when applying external fixators, performing fasciotomies, creating fascio-cutaneous flaps, performing block anaesthesia of the foot and ankle, and evaluating chronic traumatic or atraumatic pain syndromes of leg [3]. Studies by Variation in the distribution of the SPN and the frequency of communications are indications for a longitudinal skin incision and contraindicate a horizontal incision [3]. During the elevations of the flaps, the SPN should be spared to avoid disturbances of sensation over the dorsum of the foot. It is frequently subjected to entrapment syndrome such as lateral compartment syndrome as it pierces the deep fascia of the leg. As SPN supplies the major part of the dorsum of the foot regional block of this nerve, ensure quick anaesthesia. Knowledge of these branching pattern and the quantified relationships may be useful for nerve protection during surgical approaches to this region [2]. Also SN and PN can be used for nerve grafting especially when large graft size is required [5] and the surgical anatomy of the medial branch of MDCN supplying the hallux is important during correction of hallux valgus [6]. Knowledge of such variations are important for orthopaedic and trauma surgeons.

So the present work is an attempt to highlight the variations of the cutaneous nerves and its variant patterns in the dorsum of foot in adult cadavers.
2. Materials and methods

The study was performed on 20 formalin fixed adult cadaveric lower limbs ranging between 25 and 70 years without any limb deformities in the year 2016–17. Dissections were carried out in the Anatomy Department, after obtaining the clearance from the Institutional Ethics Committee (IEC 103/2017). The incision was done according to Cunningham’s Manual of Practical Anatomy. Skin flap was carefully reflected. Subcutaneous tissue was carefully removed without affecting the anatomical position of the cutaneous nerves. The nerves were then carefully dissected to track their course as far as possible. The dorsum of the foot was observed for the variant pattern and distribution of these cutaneous nerves. The variations were compared with the normal anatomical pattern and were noted down. Sketches of the branching patterns of the nerves on the dorsum of the foot were drawn on schematic outlines of the foot. The specimens were painted and photographed with an Sony digital camera.

3. Results

We observed five types of variations in innervation pattern over the dorsum of foot in the adult cadavers.

3.1. Variation I

This was observed in two cadavers (10%), where SN supplied the lateral two and a half digits. DPN supplied the first interdigital cleft. The medial side of the hallux was supplied by MDCN and IDCN supplied the second interdigital cleft. This is shown in figure A.1 and a diagrammatic representation of the same is shown in figure A.2.

3.2. Variation II

This was observed in only one cadaver (5%). Here DPN and IDCN together supplied the first interdigital space. IDCN and SN together supplied the second interdigital space. Also, lateral two and a half digits are supplied by SN. The medial side of the hallux is supplied by MDCN. This is shown in figure B.1 and a diagrammatic representation of the same is shown in figure B.2.

3.3. Variation III

This was observed in only one cadaver (5%). MDCN supplied the medial aspect of the big toe and second interdigital cleft, IDCN supplied the third interdigital cleft. SN supplied lateral aspect of the little toe and the last interdigital cleft. DPN and MDCN supplied the first interdigital cleft. The saphenous nerve innervated the medial part of the foot up to the ball of the big toe. This is shown in figure C.1 and a diagrammatic representation of the same is shown in figure C.2.

3.4. Variation IV

This was observed in only one cadaver (5%). Lateral one and half digits are innervated by SN. The first interdigital cleft is innervated by DPN. The medial side of the hallux and the third interdigital space is innervated by MDCN and IDCN respectively. This is shown in figure D.1 and a diagrammatic representation of the same is shown in figure D.2.

3.5. Variation V

This was observed in only one cadaver (5%). Medial one and half digits is supplied by MDCN. The second interdigital space is supplied by DPN. Third and fourth interdigital space is supplied by IDCN. The lateral side of the foot is supplied by SN. This is shown in Figure E.1 and a diagrammatic representation of the same is shown in figure E.2.

4. Discussion

Surgeons should have adequate knowledge of variable patterns of the cutaneous innervation to avoid the iatrogenic damage to the nerves during various operative procedures around the distal leg, ankle and foot. Accidental nerve transection associated with painful neuromas results in fatiguing symptoms. Knowledge of the variable pattern in peripheral nerve innervations helps the surgeons in diagnosing compression neuropathies of the SN, and to determine the biopsy sites [7].

In our study we observed five types of variations. We compared our findings with variable patterns of cutaneous innervations over the dorsum of foot in adults and foetuses reported in earlier literature.

Variation I: SN supplied the lateral two and a half digits. DPN supplied the first interdigital cleft. The medial side of the hallux was supplied by MDCN and IDCN supplied the second interdigital space. The saphenous nerve innervated the medial part of the foot up to the ball of the big toe. This was observed in two cadavers (10%). Studies by Chandini et al. (2012) and Prakash et al. (2010) observed the same variation [8,9]. Studies by Madhavi et al. (2005) and L.B Soloman et al. (2001), observed a similar variation of SN and SPN [10,11].

Variation II: DPN and branches IDCN together supplied the first interdigital space. IDCN and SN together supplied the second interdigital space. Also, lateral two and a half digits is supplied by SN. The medial side of the hallux is supplied by MDCN. The saphenous nerve innervated the medial part of the foot up to the ball of the big toe. This was observed in only one cadaver (5%). This type of variation is not commonly mentioned in the literature.

Studies by Asli et al. (2005); Mamatha H et al. (2016) and Wahee et al. (2010) have reported only on SN variations, they all have found SN supplying the lateral two and a half toes [12–14].

Variation III: MDCN supplied the medial aspect of the big toe and second interdigital cleft, IDCN supplied the third interdigital cleft. SN supplied lateral aspect of the little toe and the last interdigital cleft. DPN and MDCN supplied the first interdigital cleft. The saphenous nerve innervated the medial part of the foot up to the ball of the big toe. This was observed in only one cadaver (5%). The same variation was observed by Kosinski et al. (1926) in 8.3% limbs out of 229. A similar variation of SN and SPN was observed by Madhavi C et al. (2005), in her study she got 92 variations out of 260 limbs (35.38%) [12,13].

Variation IV: Lateral one and half digits are innervated by SN. The first interdigital cleft is innervated by DPN. The medial side of the hallux and the third interdigital space is innervated by MDCN and IDCN respectively. This was observed in only one cadaver (5%). The same variation was observed by authors Chandini et al. (2013); Wahee P et al. (2010) in five out of 60 lower limbs (8.3%). The same variation of SN and SPN was observed by Madhavi et al., 2005, in her study she got 10 variations out of 260 limbs (3.8%) [10].

Variation V: Medial one and half digits are supplied by MDCN. The second interdigital space is supplied by DPN. The third and fourth interdigital space is supplied by IDCN. The lateral side of the foot is supplied by SN. This was observed in only one cadaver (5%). A same variation was observed by authors Wahee P et al. (2010) in one out of 60 lower limbs (1.7%) [1].

So in conclusion we observed five variant patterns out of which variation II is not reported in the literature. Six out of 20 (30%) adult limbs had variations of cutaneous nerve innervation on the dorsum of the foot. Among these five limbs (83.34%) had variation in the saphenous nerve innervations. In two (33.33%) communications were found between SPN and DPN. In one adult limb (16.67%) DPN nerve supplied the second interdigital cleft.

The major strength of the study is type II variation is reporting for the first time in the literature. The limitation of the study includes 1) study was limited to a sample of 20 cadaveric legs, rather we could have increased the sample size. 2) Also we could have explored the variation based on the sex difference.
Knowledge of these variations would be useful in the diagnosis of the sensory nerve entrapment syndromes and associated distal sensory loss. For example in SN entrapment syndrome expected sensory loss may vary from lateral one and a half to two and a half toes. DPN usually gets entrapped below the extensor retinaculum, and expected sensory loss will be over the first interdigital cleft.

5. Conclusion

We observed five types of variation pattern, out of which variation II is not reported in the literature. The knowledge of these variations will help the surgeons to avoid iatrogenic damage of these nerves during surgeries involving the distal leg, ankle and foot, open reduction and internal fixation of fracture, arthroscopy etc. Also, variable patterns of these nerves help deciding the surgical incisions and the design of neurovascular free flaps over dorsum of foot determins the safe placement of arthroscopy portals, nerve harvesting and avoid iatrogenic damage during the various surgical procedures.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Ethical approval

The research was conducted after obtaining the approval from institutional ethical committee Kasturba Medical College, Manipal, with the reference number IEC 103/2017.

Sources of funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jamsu.2021.102404

Appendices.

Figure A.1 and A.2.

Variation I: SN supplied the lateral two and half digits. DPN supplied the first interdigital cleft. The medial side of hallux was supplied by MDCN and IDCN supplied the second interdigital cleft (SN: sural nerve, DPN: deep peroneal nerve, MDCN: median dorsal cutaneous nerve and IDCN: intermediate dorsal cutaneous nerve).

Figure B.1 and B.2.

Author contribution

Aswathi Cheredath was conducted the experiment and prepared the outline of the manuscript. Vrinda Hari Ankolekar and Antony Sylvan D’Souza helped to create an outline for the work and revised the manuscript.

Registration of research studies

Not applicable, study not involved any human subject.

Name of the registry:

Unique Identifying number or registration ID:

Hyperlink to your specific registration (must be publicly accessible and will be checked):

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Declaration of competing interest

The authors declare that they have no conflict of interest.

Acknowledgements

I thank all my colleagues and teaching staff for their support and encouragement throughout the study.
Variation II: DPN and IDCN together supplied the first interdigital space. IDCN and SN together supplied the second interdigital space. Also lateral two and half digits is supplied by SN. Medial side of hallux is supplied by MDCN (SN: sural nerve, DPN: deep peroneal nerve, MDCN: median dorsal cutaneous nerve and IDCN: intermediate dorsal cutaneous nerve).

Figure C.1 and C.2.

Variation III: MDCN supplied the medial aspect of the big toe and second interdigital cleft, IDCN supplied the third interdigital cleft. SN supplied lateral aspect of little toe and the last interdigital cleft. DPN and MDCN supplied the first interdigital cleft. Saphenous nerve innervated the medial part of foot up to the ball of big toe (SN: sural nerve, DPN: deep peroneal nerve, MDCN: median dorsal cutaneous nerve and IDCN: intermediate dorsal cutaneous nerve).

Figure D.1 and D.2.

Variation IV: Lateral one and half digits is innervated by SN. The first interdigital cleft is innervated by DPN. Medial side of hallux and the third interdigital space is innervated by MDCN and IDCN respectively (SN: sural nerve, DPN: deep peroneal nerve, MDCN: median dorsal cutaneous nerve and IDCN: intermediate dorsal cutaneous nerve).

Figure E.1 and E.2.

Variation V: Medial one and half digits is supplied by MDCN. Second interdigital space is supplied by DPN. Third and fourth interdigital space is
supplied by IDCN. Lateral side of foot is supplied by SN (SN: sural nerve, DPN: deep peroneal nerve, MDCN: median dorsal cutaneous nerve and IDCN: intermediate dorsal cutaneous nerve).

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