

# A morphological study to note the variable patterns of cutaneous innervation on the dorsum of foot in south Indian human foetuses and its clinical implications

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## Abstract

**Background:** Cutaneous nerves on the dorsum of foot are at risk for iatrogenic damage while performing arthroscopy, local anaesthetic block, surgical approach to the fibula, open reduction and internal fixation of lateral malleolar fractures, application of external fixators, elevation of a fasciocutaneous or fibular flaps for grafting, surgical decompression of neurovascular structures, or miscellaneous surgery on leg, foot and ankle. Hence the present study was undertaken to classify the different patterns of cutaneous innervation on the dorsum of foot of foetuses which will help in minimizing iatrogenic damage to the nerves.

**Materials and Methods:** A total of 40 lower limbs from 20 foetuses were dissected and the branching patterns of nerves were noted and specimens were photographed.

**Results:** Four distinct patterns of innervation with additional subtypes were identified and designated as Type 1 a-g; 2 a-d; 3; 4 a-c.

**Conclusion:** Detailed knowledge about the pattern of cutaneous innervation of dorsum of foot may decrease the damage to these nerves during operative procedures near the foot and ankle.

**Key Words:** Abnormalities, forefoot, innervation, surgery, variations

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## INTRODUCTION

The skin on dorsum of foot is innervated by the superficial peroneal nerve (Spn), deep peroneal nerve (Dpn) and the sural nerve (SN), saphenous nerve and nail bed by medial and lateral plantar nerve.<sup>[1]</sup>

It is known that sensory branches in the region of ankle and foot are frequently at risk of injury during various operative procedures performed about this region.<sup>[1]</sup>

The branches of the Spn supply the skin of the dorsal surfaces of all the toes excluding the lateral side of the little toe, and the contiguous sides of the great and second toes, the former being supplied by the lateral dorsal cutaneous nerve from the SN, and the latter by the medial branch of the Dpn. Both branches, mainly the lateral are at danger during the placement of portal incisions for arthroscopy.<sup>[2]</sup>

Iatrogenic damage to the Spn is the most frequently reported complication in anterior ankle arthroscopy.<sup>[3]</sup> Autologous nerve graft is required for bridging a large

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nerve gap following trauma. Cutaneous nerves of the extremities, especially, SN, superficial radial nerve are commonly used for grafting. In several cases where multiple or very long nerve grafts are needed, other cutaneous nerves, Spn may be used.<sup>[4]</sup>

Anatomical variations in the course and distribution of cutaneous nerves are important for clinicians who are planning surgical intervention around leg, ankle and foot.<sup>[5]</sup> Knowledge of the variability of peripheral nerve distribution is clinically important, as SN is commonly used for nerve conduction studies, nerve biopsies, and as a convenient source for nerve grafting.<sup>[6]</sup>

So, the aim of our study was to note and classify the different patterns of cutaneous innervation on the dorsum of the foot in south Indian human foetuses.

## MATERIALS AND METHODS

The study was carried out on 40 lower limbs of 12 male and 8 female foetuses ranging between 16 to 40 weeks of gestation. All of the foetuses were obtained from spontaneous abortion and had no signs of any anomalies. The foetuses were embalmed in 10% formalin and dissections were performed in the Department of Anatomy, KMC, Manipal.

After careful reflection of the skin flap, the trunk of SN was identified in the subcutaneous tissue posteroinferior to the lateral malleolus, Spn or its main branches, in front of the medial malleolus and Dpn in the 1<sup>st</sup> intermetatarsal space. The subcutaneous layer was carefully dissected in every specimen to avoid distortion of the nerve and its anatomic relationship as far as possible. The nerves were then carefully dissected to track their course as far as possible. The specimens were photographed with a Sony digital camera.

## RESULTS

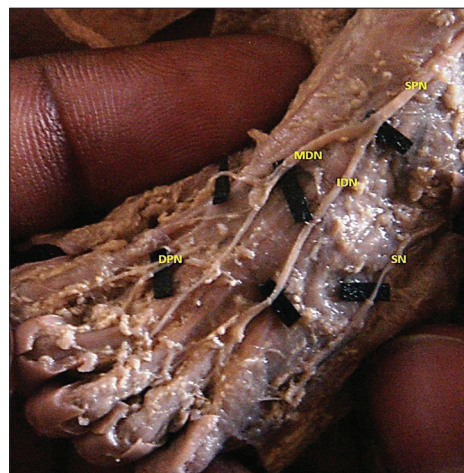
There was considerable variation in the patterns of cutaneous innervation observed over dorsum of foot in different foetuses. Four distinct patterns of innervation with additional subtypes were identified and designated as Type 1 a-g; 2 a-d; 3; 4 a-c [Table 1].

Communications were found between Spn and Dpn in 10 limbs (25% cases). In 5 limbs (12.5% cases) there existed a communication between medial dorsal nerve (Mdn) and intermediate dorsal nerve (Idn) which are branches of Spn. In 6 limbs (15% of cases) there was communication between Spn and SN. In 1 limb (2.5% of cases) there was communication between branches of SN.

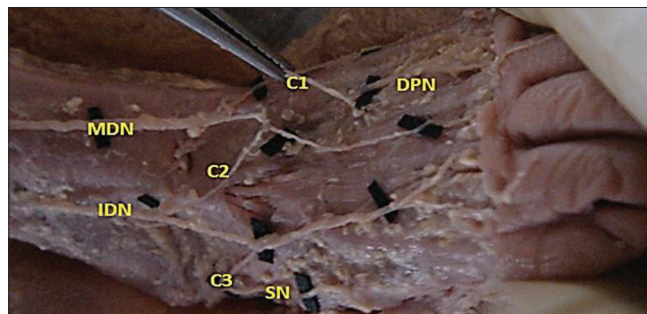
Type 1a [Figure 1] consists of a configuration where Spn divided into Mdn and Idn. Mdn innervated the medial side of great toe and 2<sup>nd</sup> interdigital cleft. Idn supplied 3<sup>rd</sup> and 4<sup>th</sup> interdigital clefts through separate branches for each cleft. The SN passed inferolateral to the lateral malleolus and supplied lateral border of foot and little toe. The first interdigital cleft was supplied by Dpn emerging at the proximal end of dorsal aspect of 1<sup>st</sup> intermetatarsal space.

In Type 1b-Type 1a + Mdn and Idn of Spn pierced the crural fascia independently in the lower leg. Type 1c-1a+ communication between Spn and Dpn. Type 1d-1a+ communication between Mdn and Idn. Type 1e- 1a+ communication between Spn and SN. In type 1f [Figure 2] 1a + communication between Spn, Dpn and SN. Type 1g [Figure 3] 1a + Mdn and Idn of Spn pierced the crural fascia independently in the lower leg and Mdn supplies only the medial border of great toe.

Type 2a consisted of an undivided single trunk of Spn supplying the medial border of great toe and adjacent



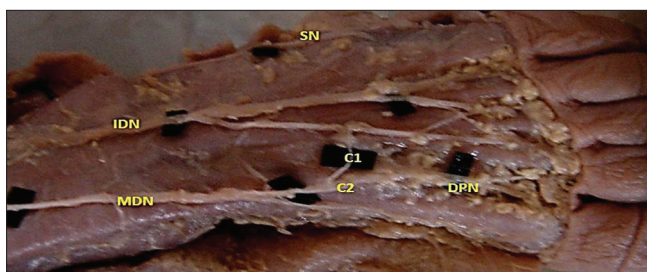
**Figure 1:** Photograph showing variant of type 1a, SPN=Superficial Peroneal Nerve, MDN=Medial Dorsal Nerve, IDN=Intermediate Dorsal Nerve, DPN=Deep Peroneal Nerve, SN=Sural Nerve



**Figure 2:** Photograph showing type 1f. MDN=Medial Dorsal Nerve, IDN=Intermediate Dorsal Nerve, DPN=Deep Peroneal Nerve, SN=Sural Nerve, C1=Communication between DPN and MDN, C2=Communication between MDN and IDN, C3=Communication between IDN and SN

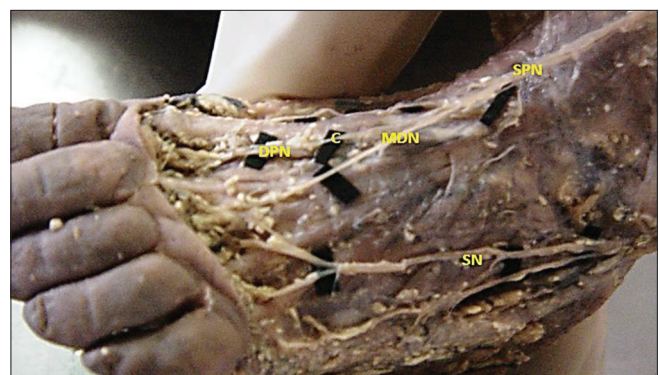
**Table 1: Classifications of patterns of cutaneous innervation of dorsum of foot in foetuses**

Pattern type	No of cases	Distribution (%)	Spn	Dpn	SN	Comments
Type 1a	8	55	Medial side of great toe and 2 <sup>nd</sup> , 3 <sup>rd</sup> and 4 <sup>th</sup> cleft	1 <sup>st</sup> cleft	Lateral border of 5 <sup>th</sup> toe	No communication
Type 1b	1		Medial side of great toe and 2 <sup>nd</sup> , 3 <sup>rd</sup> and 4 <sup>th</sup> cleft	1 <sup>st</sup> cleft	Lateral border of 5 <sup>th</sup> toe	Mdn and ldn emerge separately
Type 1c	5		Medial side of great toe and 2 <sup>nd</sup> , 3 <sup>rd</sup> and 4 <sup>th</sup> cleft	1 <sup>st</sup> cleft	Lateral border of 5 <sup>th</sup> toe	Communication between Spn and Dpn
Type 1d	2		Medial side of great toe and 2 <sup>nd</sup> , 3 <sup>rd</sup> and 4 <sup>th</sup> cleft	1 <sup>st</sup> cleft	Lateral border of 5 <sup>th</sup> toe	Communication between Mdn and ldn
Type 1e	2		Medial side of great toe and 2 <sup>nd</sup> , 3 <sup>rd</sup> and 4 <sup>th</sup> cleft	1 <sup>st</sup> cleft	Lateral border of 5 <sup>th</sup> toe	Communication between Spn and SN
Type 1f	2		Medial side of great toe and 2 <sup>nd</sup> , 3 <sup>rd</sup> and 4 <sup>th</sup> cleft	1 <sup>st</sup> cleft	Lateral border of 5 <sup>th</sup> toe	Communication between Spn, Dpn and SN
Type 1g	2		Medial side of great toe and 2 <sup>nd</sup> , 3 <sup>rd</sup> and 4 <sup>th</sup> cleft	1 <sup>st</sup> cleft	Lateral border of 5 <sup>th</sup> toe	Mdn and ldn emerge separately. Mdn supplies medial border of great toe only
Type 2a	11	35	Medial side of great toe and 2 <sup>nd</sup> , 3 <sup>rd</sup> and 4 <sup>th</sup> cleft	1 <sup>st</sup> cleft	Lateral 2 ½ digits	No communication
Type 2b	1		Medial border of great toe, 2 <sup>nd</sup> cleft	1 <sup>st</sup> cleft	Lateral 2 ½ digits	Communication between Spn and Dpn
Type 2c	1		Medial border of great toe, 2 <sup>nd</sup> cleft	1 <sup>st</sup> cleft	Lateral 2 ½ digits	Communication between Spn and SN
Type 2d	1		Medial border of great toe, 2 <sup>nd</sup> cleft	1 <sup>st</sup> cleft	Lateral 2 ½ digits	Communication between branches of SN and between Dpn and Spn
Type 3	1	2.5	Medial border of great toe, 2 <sup>nd</sup> cleft	1 <sup>st</sup> , 2 <sup>nd</sup> cleft	Lateral border of 5 <sup>th</sup> digit	-
Type 4a	1	7.5	Medial border of great toe, 2 <sup>nd</sup> , 3 <sup>rd</sup> cleft	1 <sup>st</sup> cleft	4 <sup>th</sup> cleft, Lateral border of 5 <sup>th</sup> digit	-
Type 4b	1		Medial border of great toe, 2 <sup>nd</sup> , 3 <sup>rd</sup> cleft	1 <sup>st</sup> cleft	4 <sup>th</sup> cleft, Lateral border of 5 <sup>th</sup> digit	Mdn and ldn emerge separately
Type 4c	1		Medial border of great toe, 2 <sup>nd</sup> , 3 <sup>rd</sup> cleft	1 <sup>st</sup> cleft	4 <sup>th</sup> cleft, Lateral border of 5 <sup>th</sup> digit	Communication between Spn and SN



**Figure 3:** Photograph showing type 1g. MDN=Medial Dorsal Nerve, IDN=Intermediate Dorsal Nerve, DPN=Deep Peroneal Nerve, SN=Sural Nerve, C1=Communication between MDN and IDN, C2=Communication between MDN and DPN

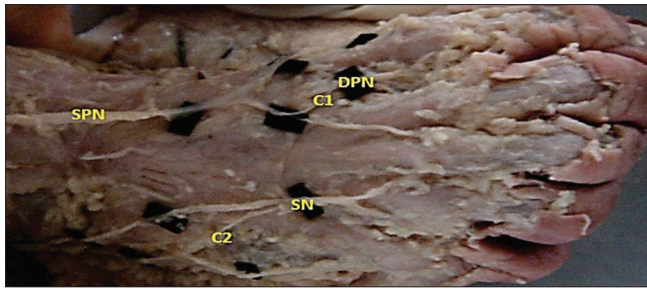
sides of the 2<sup>nd</sup> interdigital cleft. In all these cases, SN after supplying adjacent sides of the 3<sup>rd</sup> and 4<sup>th</sup> clefts through separate branches continued along the lateral border of foot and the 5<sup>th</sup> toe. The 1<sup>st</sup> interdigital cleft was supplied by Dpn. The lateral 2½ digits were supplied by Ldn. In Type 2b [Figure 4]-Type 2a+ communication between Spn and Dpn. Type 2c-2a + communication between Spn and SN. In type 2d [Figure 5]-2a + communication between branches of SN and between Spn and Dpn.



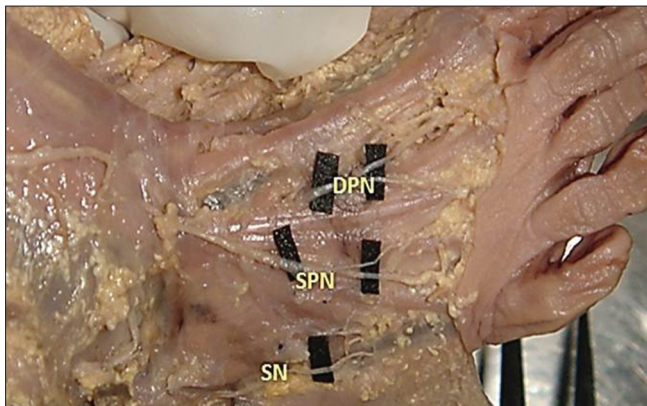
**Figure 4:** Photograph showing type 2b. SPN=Superficial Peroneal Nerve, MDN=Medial Dorsal Nerve, DPN=Deep Peroneal Nerve, SN=Sural Nerve, C=Communication between SPN and DPN

Type 3 [Figure 6] Spn supplying the medial border of great toe, and adjacent sides of 3<sup>rd</sup> and 4<sup>th</sup> clefts. SN supplied the lateral border of little toe. Dpn supplied the 1<sup>st</sup> and 2<sup>nd</sup> clefts.

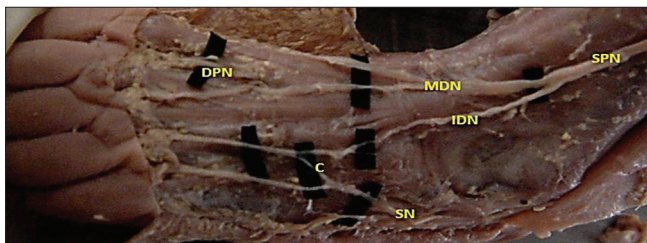
In type 4a Mdn innervated the medial side of great toe and 2<sup>nd</sup> cleft and the ldn through a single digital branch supplied the adjacent sides of the 3<sup>rd</sup> interdigital



**Figure 5:** Photograph showing type 2d. SPN=Superficial Peroneal Nerve, DPN=Deep Peroneal Nerve, SN=Sural Nerve, C1=Communication between SPN and DPN, C2=Communication between branches of SN



**Figure 6:** Photograph showing type 3. SPN=Superficial Peroneal Nerve, DPN=Deep Peroneal Nerve, SN=Sural Nerve



**Figure 7:** Photograph showing type 4c. SPN=Superficial Peroneal Nerve, MDN=Medial Dorsal Nerve, IDN=Intermediate Dorsal Nerve, DPN=Deep Peroneal Nerve, SN=Sural Nerve, C=Communication between IDN and SN

cleft. SN supplied lateral 1½ digit through a branch for 4<sup>th</sup> cleft and another for lateral border of the 5<sup>th</sup> toe. Dpn innervated adjacent sides of the 1<sup>st</sup> cleft. Type 4b- 4a+ with Mdn and Idn of Spn pierced the crural fascia independently in the lower leg. In type 4c [Figure 7]-4a+ communication between Spn and SN.

## DISCUSSION

Knowledge about variations in cutaneous innervation patterns on dorsum of foot improves understanding of the variability of distal sensory loss in nerve entrapments and iatrogenic nerve injury. The nerves over the dorsum of foot also influence surgical incisions and the designing of neurovascular free flaps in this region.<sup>[1]</sup>

Pratima Wahee *et al.* (2009) have classified the cutaneous innervation of foot into 6 types.<sup>[1]</sup>

Type 1 (53.3%): Dpn supplied the 1<sup>st</sup> cleft lateral dorsal cutaneous nerve, supplied the lateral border of little toe and the remaining part on the dorsum of the foot is supplied by Spn.

Type 2 (28.3%): Dpn supplied the 1<sup>st</sup> cleft, Spn supplied the medial border of big toe, 2<sup>nd</sup> cleft and lateral 2½ digits supplied by the lateral dorsal cutaneous nerve.

Type 3 (8.3%): Dpn supplied the 1<sup>st</sup> cleft, lateral 1½ digits supplied by the lateral dorsal cutaneous nerve and the remaining dorsum by Spn.

Type 4 (3.3%): Dpn supplied the 1<sup>st</sup> and 2<sup>nd</sup> clefts; Spn supplied the medial border of great toe and lateral 2½ digits were supplied by lateral dorsal cutaneous nerve.

Type 5 (5%): Dpn supplied 1<sup>st</sup> and 2<sup>nd</sup> clefts, lateral border of the little toe by lateral dorsal cutaneous nerve and remaining part of the dorsum of foot by Spn.

Type 6 (1.7%): Dpn supplied 2<sup>nd</sup> cleft, lateral border of little toe supplied by the lateral dorsal cutaneous nerve and the remaining area by Spn.

Our type 1 and 2 was same as their study. We got that in 55% and 35% of cases and they got that in 53.3% and 28.3% of cases. And our type 3 and 4 corresponds to their type 5 and 3. We got that in 2.5% and 7.5% of cases and they got that in 5% and 8.3% of cases. In our study there was no specimen who correspond to their type 4 and 6. In our study we got communication between the branches of Spn and between the branches of SN which was not seen in their study.

Narendiran K. *et al.* have found a case of abnormal distribution of the Spn. They found that the nerve after supplying the peroneal muscles of lateral compartment gave a Mdn branch and a Idn branch. Mdn branch supplied the skin of medial side of the great toe, the medial side of the 1<sup>st</sup> metatarsal region and the 1<sup>st</sup> web space including the adjacent sides of great and second toes. The Idn branch divided into medial and lateral terminal branches to supply adjacent sides of the 2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup> and 5<sup>th</sup> toes. On the other hand, the Dpn after supplying the muscles of anterior compartment of leg continued on dorsum of foot without dividing into terminal branches and without supplying the skin of first web space and adjacent sides of great and second toes. It ended by supplying the extensor digitorum brevis muscle.<sup>[2]</sup> But we didn't have such case in our study.

Sithiporn Agthong *et al.* classified the branching pattern

of Spn into 2 types-Type 1 (penetration of the main trunk of Spn from the deep fascia) or Type 2 (separate penetration of the Mdn and Idn).<sup>[4]</sup> They found type 1, 2 in 71.8%, 28.2% of cases, Blair JM and Ucerler H found that in 72%, 28% and 73.3%, 26.7% of cases, Prakash *et al.* and Domagała *et al.* found type 1 in 68.33% and 54% of specimens.<sup>[3,5,7,8]</sup> In our study we got type 1 and 2 in 90% and 10% of cases.

Prakash *et al.* found that in 68.33% of specimens the sensory division of Spn branched into the Mdn and Idn distal to its emergence from the deep fascia and proximal to its relation to the extensor retinaculum but in our study we found that in 90% of cases.<sup>[5]</sup>

C. Madhavi *et al.* found six patterns of innervation of the toes by the SN.<sup>[6]</sup>

Type I-lateral side of the little toe was supplied by the SN alone and the adjacent sides of the 2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup>, and 5<sup>th</sup> toes by the Spn alone (35.38%).

Type II-lateral side of the little toe was supplied by the SN alone and the adjacent sides of the 4<sup>th</sup> and 5<sup>th</sup> toes by the SN along with the Spn (10%).

Type III-lateral side of the little toe was supplied by the SN alone and the adjacent sides of the 3<sup>rd</sup>, 4<sup>th</sup>, and 5<sup>th</sup> toes by the SN along with the Spn (21.15%).

Type IV-lateral 1½ toes were supplied by the SN alone and the adjacent sides of the 3<sup>rd</sup> and 4<sup>th</sup> toes by the Spn alone (3.85%).

Type V-lateral 1½ toes were supplied by the SN alone and the adjacent sides of the 3<sup>rd</sup> and 4<sup>th</sup> toes were supplied by the SN along with the Spn (5%).

Type VI-lateral 2½ toes were supplied by the SN alone (24.61%).

In their study the predominant patterns were Type I (35.38%), Type VI (24.61%), and Type III (21.15%). Our type 1 was same as their type 1 and we got that in 55% of cases. Our type 2 corresponds to their type 6. And we got that in 35% of cases. Our type 4 was same as their type 4 and we got that in 7.5% of cases.<sup>[6]</sup>

Somayaji Nagabhooshana *et al.* found 1 case of Spn where it's both branches Mdn and Idn emerge separately and SN supply lateral 1½ digits on dorsum of foot which was similar to our type 4b.<sup>[9]</sup>

Devi Sankar K *et al.* found 1 case of SN where it supplies lateral 1½ toes in our study we also found that in type 4.<sup>[10]</sup>

Z Asli Aktan Ikiz *et al.* found that in 26.7% of cases SN supplies the lateral two and a half toes. In our study we got that in 35% of cases.<sup>[11]</sup>

## CONCLUSION

Entrapment of the SN at the lateral side of the ankle and foot has been reported. In such cases, it is possible that some patients may complain of pain and sensory loss over the lateral one-fourth of the dorsum of foot and lateral 1½ toe to 2½ toes. It is important that neurologists and surgeons consider SN involvement in cases of pain or sensory deficit over the lateral one-fourth of the dorsum of foot and lateral 1½ or 2½ toes. Awareness of the extent of the function of the SN in innervating the dorsum of the foot in various races would facilitate an accurate diagnosis when this area is affected.<sup>[6]</sup>

A detailed knowledge of the branching patterns of the Spn and SN and their variations will help to decrease iatrogenic injury to these nerve.

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