

ORIGINAL COMMUNICATION

Anatomical Variations of the Human Sural Nerve and Its Role in Clinical and Surgical Procedures

ESSAM M. EID AND AHMED M.S. HEGAZY*

Department of Anatomy, Faculty of Medicine, Benha University, Egypt

The sural nerve is the most commonly nerve used in nerve transplantation, and so the aim of this study was to determine the variations of the sural nerve in the back of the leg, its relations to the calcaneal tendon and lateral malleolus, and determine the patterns of its distribution on the dorsum of the foot. Twenty-four Egyptian legs and feet were dissected. The results showed that the sural communicating nerve connected with the sural nerve in 87.5%. The predominant site of union between these two nerves was in the lower one-third of the leg and ankle region (62%). There was only one right leg that the sural nerve passed through the gastrocnemius. The small saphenous vein passed along the medial side of the sural nerve in 100%. The sural nerve crossed the lateral border of the calcaneal tendon in 50%. The distance between the sural nerve and insertion of calcaneal tendon was $16 + 7$ mm in 91.7%. There were four types of pattern of innervation of the toes by the sural nerve. The predominant pattern was type I (45.8%), where the lateral side of the little toe was supplied by the sural nerve alone. The second pattern was type IV (29.2%), where the lateral 2 ½ toes were supplied by the sural nerve alone. These findings are important for sural nerve biopsy and grafts, surgical repair of the calcaneal tendon, and regional anesthesia of the foot. *Clin. Anat.* 24:237–245, 2011. © 2010 Wiley-Liss, Inc.

Key words: sural nerve; anatomical variations; clinical importance; surgical procedures

INTRODUCTION

The sural nerve (medial sural nerve, L_5 , and $S_{1,2}$) is a cutaneous branch that arises from the tibial nerve in the popliteal fossa. The sural-communicating nerve (fibular communicating nerve, L_5 , and $S_{1,2}$) is a cutaneous branch that arises from the common fibular nerve (common peroneal nerve) in the popliteal fossa. The lateral cutaneous nerve of the calf (lateral sural nerve) also arises from the common fibular nerve in the popliteal fossa (Chummy, 2006; Standring et al., 2008). The sural nerve passes between the two heads of gastrocnemius, pierces the deep fascia half-way down the leg, and receives the sural communicating branch below the bellies of gastrocnemius. It descends close to the small saphenous vein to reach behind the lateral malleolus and runs to the fifth toe. It supplies the posterolateral part of the skin of the lower third of the leg down to the

lateral malleolus as well as the lateral side of the dorsum of the foot to the little toe (Chummy, 2006; Ellis, 2007; Romanes, 1990; Standring et al., 2008). The sural nerve connects on the dorsum of the foot with the superficial fibular nerve (superficial peroneal nerve) and in the leg with the posterior cutaneous nerve of the thigh (Standring et al., 2008). However, the knowledge about the variations of the sural nerve in its course, contributing nerves, and its distribution is lacking. These variations are important in the clinical and surgical procedures.

*Correspondence to: Ahmed Hegazy, Department of Anatomy, Faculty of Medicine, Benha University, Egypt.
E-mail: Ahmed0562301954@yahoo.com

Received 19 November 2009; Revised 20 May 2010; Accepted 30 August 2010

Published online 14 October 2010 in Wiley Online Library (wileyonlinelibrary.com). DOI 10.1002/ca.21068

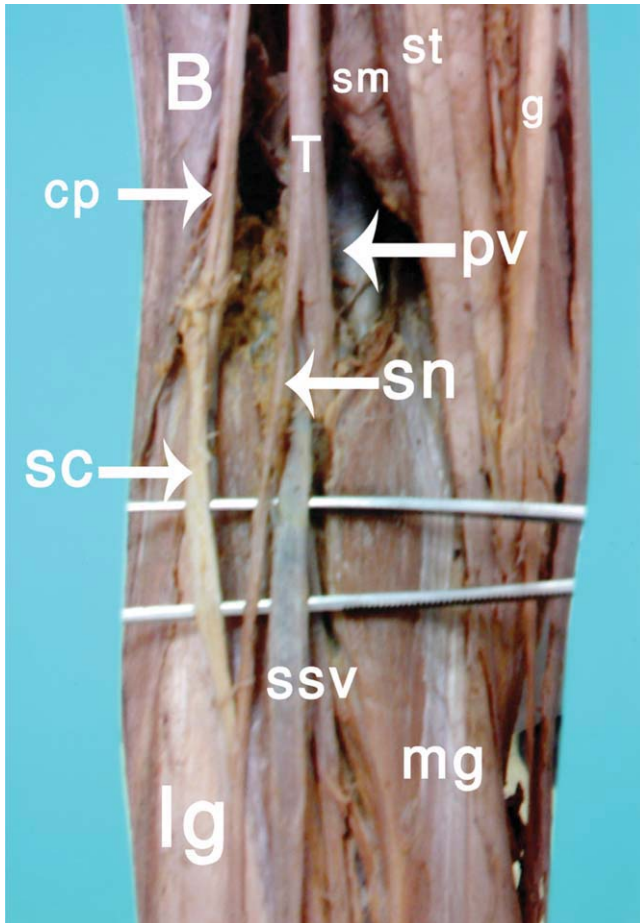


Fig. 1. A photograph of a dissected left popliteal fossa showing: fusion of the sural communicating nerve (sc) with the sural nerve (sn) (9.5%) (this photo has one of two possible variations). The small saphenous vein (SSV) lies medial to the sural nerve (100%). Notice the tibial nerve (T), common peroneal nerve (cp), popliteal vein (pv), gracilis (g), semitendinosus (st), semi-membranosus (sm), biceps femoris (B), lateral (lg), and medial (mg) heads of gastrocnemius. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

So, the aim of this work was to describe the anatomical variations of the sural nerve to identify the sites of connections between the sural nerve and sural-communicating nerve to demonstrate the accurate position of the sural nerve in relation to the calcaneal tendon and lateral malleolus and to determine the patterns of distribution of the sural nerve on the dorsum of the foot.

MATERIALS AND METHODS

The material of this study included 24 legs and feet of adult Egyptian cadavers (12 right and 12 left). These specimens were obtained from the post-

mortem room of Faculty of Medicine, Benha University. They were preserved in 10% formalin. Each specimen was dissected by removal of the skin and fascia of popliteal fossa, back of leg, and dorsum of the foot. In the superficial fascia, the sural nerve, and its branches, the small saphenous vein, the sural communicating nerve, and the lateral cutaneous nerve of the calf were identified. The distance between these nerves was calculated. The relationships of the sural nerve with the calcaneal tendon were recorded. The distance between the sural nerve and the lower end of the posterior border of the lateral malleolus was calculated. Also, the distance between the sural nerve and the lower end of lateral border of the calcaneal tendon was calculated. On the dorsum of the foot, the digital branches of the

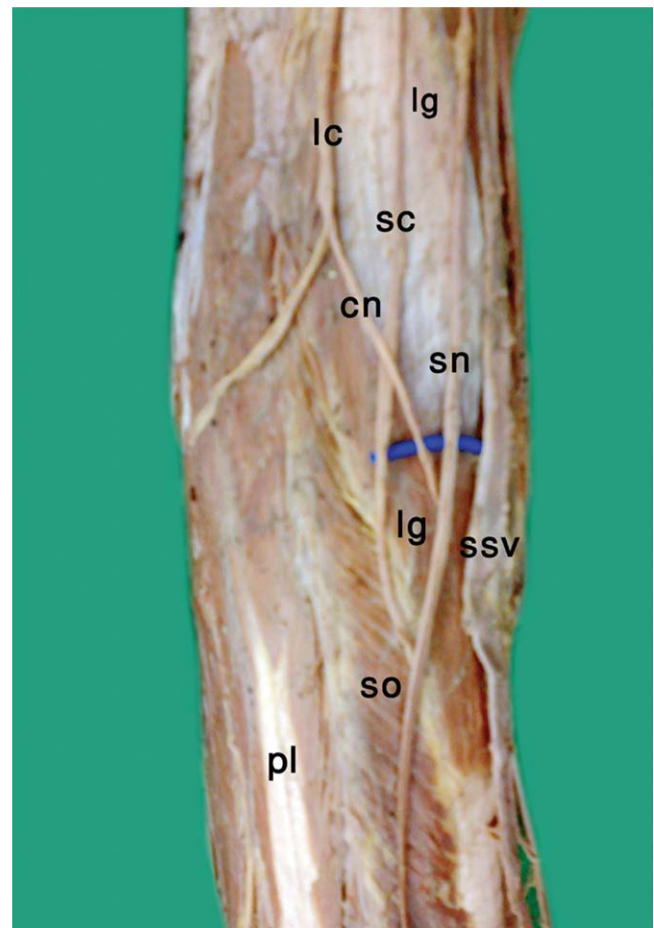


Fig. 2. A photograph of a dissected back of the middle part of the left leg showing: Fusion of the sural communicating nerve (sc) and the lateral cutaneous nerve of the calf (lc) with the sural nerve (sn) (8.3%) (one of two possible variations). Notice the lateral head (lg) of gastrocnemius, soleus (so) fibularis longus (pl), and small saphenous vein (SSV). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

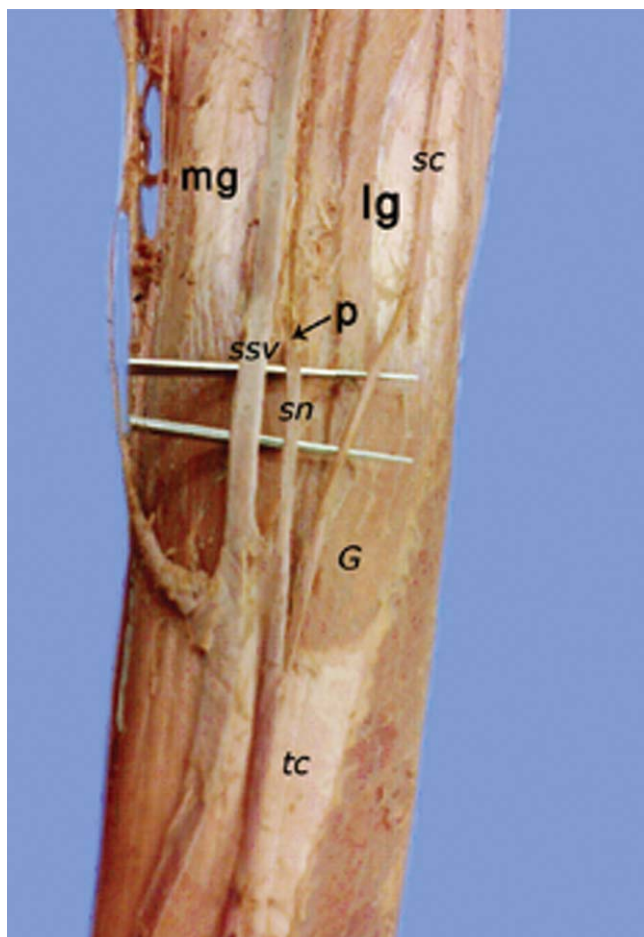


Fig. 3. A photograph of a dissected back of the middle part of the right leg showing: the sural nerve (sn) pierces the gastrocnemius (G) emerging from it (4.2%) (only one specimen). The sural-communicating nerve (sc) fuses with the sural nerve below the bellies of gastrocnemius. Notice the small saphenous vein (SSV), lateral (lg), and medial (mg) heads of gastrocnemius and calcaneal tendon (tc). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

TABLE 1. The Communicating Nerves with the Sural Nerve and Their Percentages

Types of communicating nerve		Number	Percentage
1	s. n. + s. c.	18	75
2	s. n. + s. c. + L. c.	2	8.3
3	s. n. + s. c. + p. c.	1	4.2
4	s. n. only	3	12.5
Total		24	100

s. n., sural nerve; s. c., sural communicating nerve; L. c., lateral cutaneous nerve of the calf; p. c., posterior cutaneous nerve of the thigh.

TABLE 2. The Sites of Connections Between the Sural Nerve and the Sural-Communicating Nerve and Their Percentage in 21 Specimens

Sites	Number	Percentage
1 In the upper one-third of the leg (in popliteal fossa)	2	9.5
2 In the middle one-third of the leg	6	28.6
3 In lower one-third of leg	11	52.4
4 At the level of ankle joint	2	9.5
Total	21	100

sural nerve and the superficial fibular nerve were identified. The anatomical variations of the sural nerve were photographed by close-up camera under a light source.

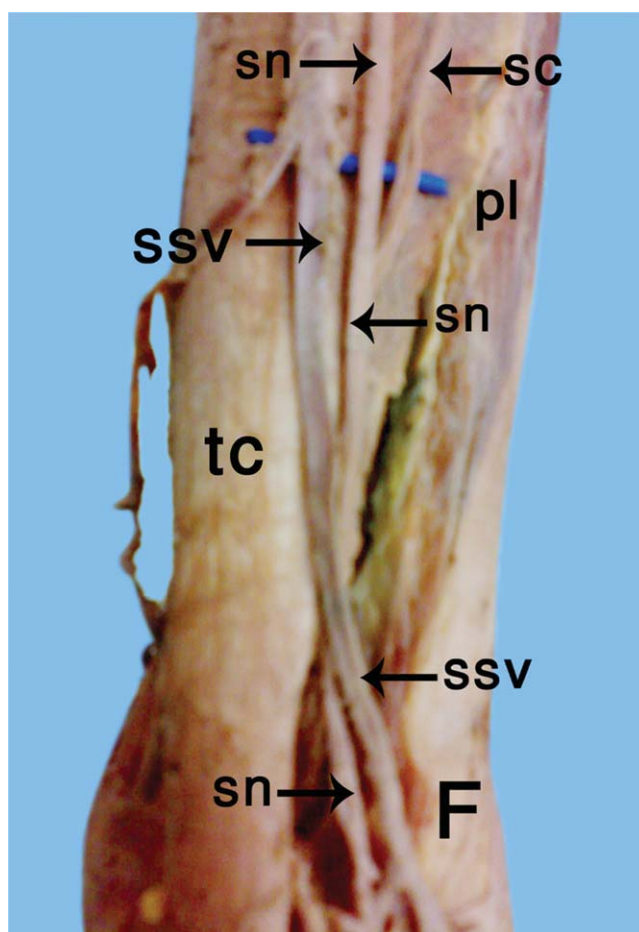


Fig. 4. A photograph of a dissected lower part of the back of the right leg showing: fusion of the sural communicating nerve (sc) with the sural nerve (sn) (52.4%) (1 of 11 possible variations) the sural nerve crosses the lateral border of the calcaneal tendon (tc) (37.5%) (one of nine possible variations) and is crossed by the small saphenous vein (SSV). Notice the fibularis longus (Pl) and the lateral malleolus (F). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

TABLE 3. The Relationships of the Sural Nerve to the Calcaneal Tendon

Relationship of the sural nerve to the calcaneal tendon	Number	Percentage
1 Infront and parallel	10	41.7
2 Crossing lateral border of calcaneal tendon, 2 inches above its insertion	9	37.5
3 Crossing lateral border of calcaneal tendon, 1 inch above its insertion	3	12.5
4 Vertically close to the lateral border of calcaneal tendon	2	8.3
Total	24	100

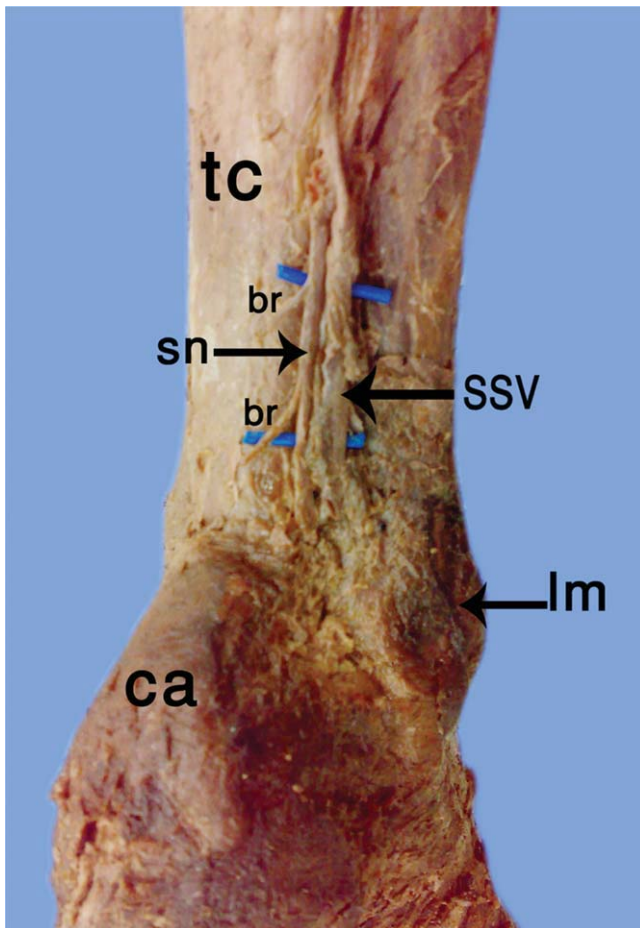


Fig. 5. A photograph of a dissected lower part of the back of the right leg and ankle region showing: the sural nerve (sn) lies in close contact long the lateral border of calcaneal tendon (tc) (8.3%) (one of two possible variations). Notice the cutaneous branches (br) of the sural nerve, small saphenous vein (SSV), lateral malleolus (Lm), and calcaneus (ca). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

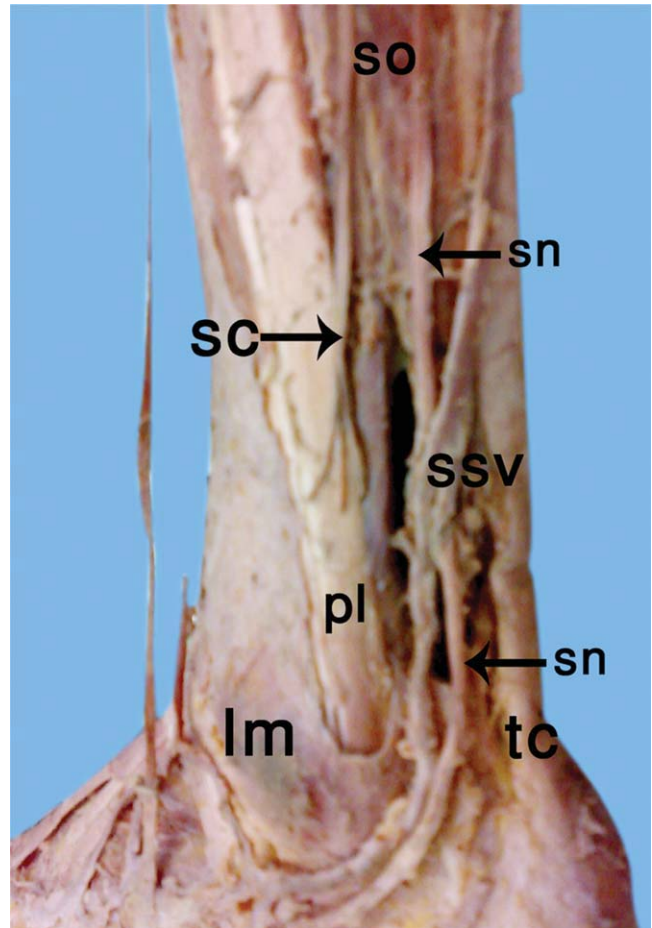


Fig. 6. A photograph of a dissected lower part of the lateral aspect of the left leg and ankle region showing: the sural communicating nerve (sc) not fuse with the sural nerve (sn). (12.5%) (one of three possible variations). The sural nerve lies in front and parallel to the lateral border of calcaneal tendon (tc) (41.7%) (1 of 10 possible variations). The small saphenous vein (SSV) crosses superficial to the sural nerve above the ankle region. Notice the fibularis longus (pl) and lateral malleolus (Lm). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

RESULTS

Variations of the Sural Nerve in the Leg

In 23 specimens (95.8%), the sural nerve descended on the posterior surface of the lateral head of gastrocnemius, lateral to the small saphenous vein, and medial to the sural communicating nerve and lateral cutaneous nerve of the calf (Figs. 1 and 2). In only one right leg (4.2%) the sural nerve descended through the gastrocnemius, pierced this muscle at about its middle, and passed down superficial to it with the small saphenous vein. In this case, the small saphenous vein was not passed through the gastrocnemius with the sural nerve, but passed superficial to it (Fig. 3). The sural-communi-

TABLE 4. The Distances Between the Sural Nerve, The Lateral Border of Calcaneal Tendon at Its Insertion, and the Lower End of the Posterior Border of the Lateral Malleolus

	Distances	Number	Range (mm)	Mean \pm SD (mm)
1	The distance between the sural nerve and the lateral border of calcaneal tendon at its insertion	22	9–23	16 \pm 7
2	The distance between the sural nerve and the lower end of posterior border of lateral malleolus	24	15–25	19 \pm 4
3	The distance between the lower end of lateral border of calcaneal tendon and the lower end of posterior border of lateral malleolus	24	34–38	36 \pm 2

cating nerve descended superficial to the lateral head of gastrocnemius, lateral to the sural nerve, and separated from it by a distance about 32 ± 7 mm. The lateral cutaneous nerve of the calf descended lateral to the sural communicating nerve and separated from it by a distance about 17 ± 4 mm and separated from the sural nerve by a distance about 42 ± 7 mm (Figs. 1 and 2). The communicating nerves with the sural nerve were variable (Table 1). In 21 specimens (87.5%), the sural-communicating nerve was connected with the sural nerve. Although in the other three specimens (12.5%), the sural-communicating nerve remained separate and not fused with the sural nerve (Fig. 6). In 18 specimens (75%), the sural nerve was connected only with the sural communicating nerve. In two specimens (8.3%), the sural nerve connected with the sural communicating nerve and the lateral cutaneous nerve of the calf. In one specimen (4.2%), the sural-communicating nerve and the posterior cutaneous nerve of the thigh were connected with the sural nerve. The sites of union between the sural nerve and the sural communicating nerve were variable (Table 2): 9.5% in the upper one-third of the leg (in popliteal fossa) (Fig. 1), 28.6% in the middle one-third of the leg (Figs. 2 and 3), 52.4% in the lower one-third of the leg (Fig. 4) and 9.5% at the level of ankle joint (Fig. 7). In all specimens, the small saphenous vein passed along the medial side of the sural nerve and separated from it by a distance about 4 ± 2 mm (Figs. 1, 2&3). In the lower one-third of the leg, the small saphenous vein crossed superficial to the sural nerve from behind to in front. The point of crossing was 4–6 cm above the level of lateral malleolus (Figs. 4–7).

Variations of the Sural Nerve in Relations to the Calcaneal Tendon and Lateral Malleolus

The relationship of the sural nerve to the calcaneal tendon was variable (Table 3): In 41.7%, the sural nerve descended in front and parallel to the lateral border of calcaneal tendon (Figs. 6 and 7). In 37.5%, the sural nerve descended superficial to the proximal part of the calcaneal tendon and then inclined toward its lateral border crossing it, two inches above the level of its insertion (Fig. 4). In 12.5%, the sural nerve descended superficial to the major part of the calcaneal tendon and then crossed its lateral border, one inch above its insertion. In

8.3%, the sural nerve descended vertically very close to the lateral border of calcaneal tendon (Fig. 5). In 91.7%, the distance between the sural nerve and the lower end of lateral border of calcaneal tendon was 16 ± 7 mm (Table 4; Figs. 6 and 7).

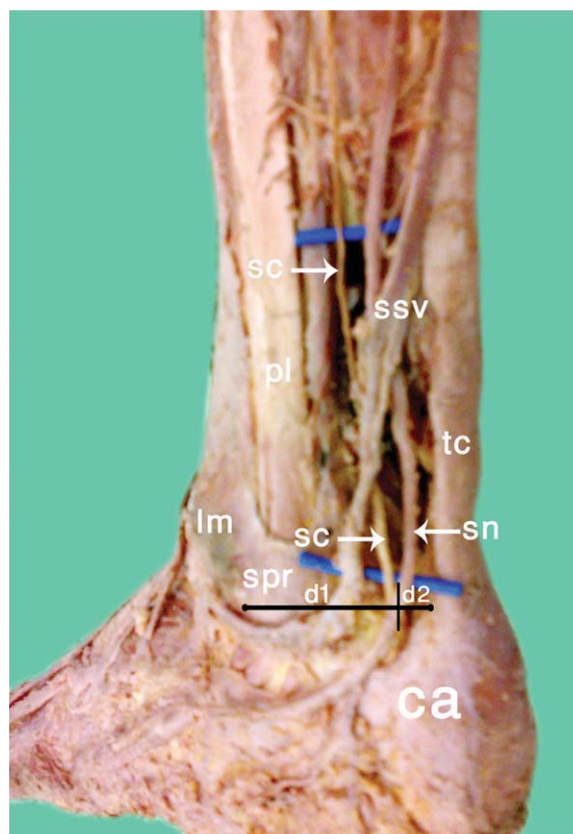


Fig. 7. A photograph of a dissected lower part of the lateral aspect of the left leg and ankle region showing: The sural-communicating nerve (sc) connects with the sural nerve (sn) at the level of ankle joint (9.5%) (one of two possible variations). Notice the distance (d1) between the lower end of posterior border of the lateral malleolus (Lm) and the sural nerve. As well as the distance (d2) between the sural nerve and the lower end of the lateral border of the calcaneal tendon (tc). Notice the small saphenous vein (SSV), fibularis longus (pL), superior fibular retinaculum (spr), and calcaneus (ca). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

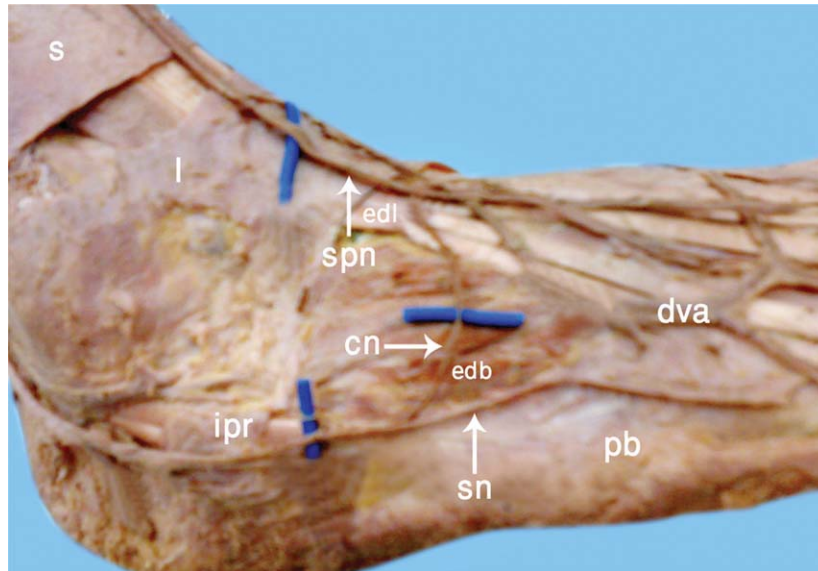


Fig. 8. A photograph of a dissected dorsum of the right foot showing: A nerve (cn) communicates the sural nerve (sn) with the superficial fibular nerve (spn) (29.1%) (one of seven possible variations). The sural nerve crosses the inferior fibular retinaculum (ipr) and fibularis brevis

(pb). Notice the superior (s) and inferior (i) extensor retinacula, extensor digitorum longus (edl), extensor digitorum brevis (edb), and dorsal venous arch (dva). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Although in 8.3%, this distance was 4 ± 2 mm (Fig. 5). In all specimens, the distance between the sural nerve and the lower end of posterior border of lateral malleolus was 19 ± 4 mm. The total distance between the lower end of posterior border of the lateral malleolus and the lower end of lateral border of calcaneal tendon was 36 ± 2 mm (Table 4).

Variations of the Sural Nerve on the Dorsum of the Foot

The sural nerve passed below the lateral malleolus and the small saphenous vein and then crossed the inferior fibular retinaculum and the tendon of fibularis brevis. There was a communicating nerve connected the sural nerve with the superficial fibular nerve (Fig. 8). In 24 specimens, there were four types of patterns of innervation of the toes by the sural nerve and superficial fibular nerve. In type I (45.8%), the lateral side of the little toe was supplied by the sural nerve alone, whereas the adjacent sides of second, third, fourth, and fifth toes were supplied by the superficial fibular nerve alone (Fig. 9). In type II (20.9%), the lateral side of the little toe was supplied by the sural nerve alone, whereas the adjacent sides of the fourth and fifth toes were supplied by the sural nerve along with the superficial fibular nerve (Fig. 10). In type III (4.1%), the lateral 1[1/2] toes were supplied by the sural nerve alone, whereas the adjacent sides of the third and fourth toes were supplied by the sural nerve along with the superficial fibular nerve (Fig. 11). In type IV (29.2%), the lateral 2[1/2] toes were supplied by the sural nerve alone, whereas adjacent sides of sec-

ond and third toes were supplied by the superficial fibular nerve alone (Fig. 12).

DISCUSSION

In this study, the most common nerve connected with the sural nerve was the sural communicating nerve in 87.5%. The usual site of connection between these two nerves was in the lower one-third of the leg (52.4%). These results are nearly similar to the results of Park et al. (2007) who reported that the site of connection between the sural nerve and the sural communicating nerve in the lower 2/5 of the leg was 53.8%. Mahakkonukrauh and Chomsung (2001) found that the predominant site of connection between the sural nerve and sural-communicating nerve in the lower one-third of the leg and ankle region was 66.7%. From these findings, we suggest that the suitable site for the sural nerve biopsy and graft is in the lower one-third of the leg. This suggestion is supported by Ruth et al. (2004) who described the technique for the sural nerve biopsy and graft in the lower leg. Bevilacqua et al. (2007) suggested that the sural nerve is the most commonly biopsied peripheral nerve for several reasons: It is superficial and easy to locate anatomically. It is a pure sensory leaving no loss of motor function. Its sensory distribution is located on the dorsolateral aspect of the foot; hence, permanent anesthesia in this area will not likely predispose a patient to a planter ulcer. Clinically, the sural nerve is widely used for nerve biopsy to diagnose most of the peripheral neuropathies. Also, it is used to determine the nerve conduction velocity (Chentanez et al., 2006; Mcleod,

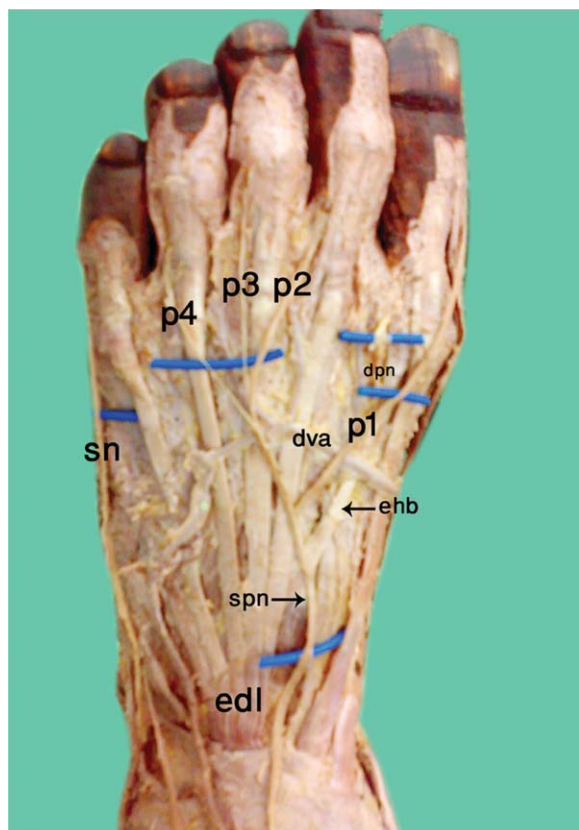


Fig. 9. A photograph of a dissected dorsum of the left foot showing: type I, where the sural nerve (sn) supplies the lateral side of the little toe (45.8%) (1 of 11 possible variations). The superficial fibular nerve (spn) gives four branches (p_1 , p_2 , p_3 , and p_4). Notice the extensor digitorum longus (edL), extensor hallucis brevis (ehb), deep fibular nerve (dpn), and dorsal venous arch (dva). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

2000; Zehr et al., 1998). Therapeutically, the sural nerve grafts remain the gold standard for bridging larger nerve defects. It is commonly used for nerve grafting at the time of radical prostatectomy to restore the potency (Lee et al., 2008; Mancuso and Rashid, 2008). We suggest that the sural-communicating nerve may be used as nerve biopsy and graft as well as the sural nerve, where the sural communicating nerve lies on the lateral side of the sural nerve and separated from it by a distance about 32 ± 7 mm. In this study, there was only one right leg that the sural nerve passed through the gastrocnemius, pierced this muscle, and continued its normal course.

This finding is similar to the results of Fabre et al. (2000) and George and Nayak (2007). Fabre et al. (2000) reported 18 cases where the sural nerve passed through the gastrocnemius. Amoridis et al. (1987) reported that the sural nerve is considered to be a sensory nerve, and motor fibers have been found in 4.5% of nerves. In these cases, the sural

nerve gave motor branches to the gastrocnemius as it passed through it. The entrapment of the sural nerve in gastrocnemius is important in sport medicine and physiotherapy. This abnormal course of the sural nerve can produce pain up on the contraction of the gastrocnemius or altered sensation over the area of its distribution.

In this study, the small saphenous vein passed very close to the medial side of the sural nerve in 100%. In the lower leg, the small saphenous vein crossed superficial to the sural nerve, 4–6 cm above the level of lateral malleolus. This close relation of the small saphenous vein to the sural nerve could be used as a guide to the sural nerve during the nerve ultrasonography, nerve conduction velocity studies, sural nerve biopsy, and graft. But the damage to the sural nerve may arise from surgical stripping or thermal ablation of the small saphenous vein. Ricci et al. (2009) reported that the ultrasonography of the sural nerve can be used to prevent the damage to the sural nerve during surgical stripping of the small saphenous vein. In this study, the sural nerve descended superficial to the calcaneal tendon and then crossed its lateral border in 50%. Whereas the other 50%, the sural nerve, descended parallel and in front (37.5%) and vertically close to the lateral border of the calcaneal tendon (12.5%). These findings may explain the high risk for the sural nerve injury during the surgical repair of the calcaneal tendon. Apaydin et al. (2009) reported that the sural nerve was intersecting with the lateral border of the calcaneal tendon at the 55% of the mid-tendon line. So, they suggested that the sutures placed on the calcaneal tendon distal to the 55% of the mid-tendon line. This decreases the iatrogenic nerve injury.

In this study, the distance between the sural nerve and insertion of calcaneal tendon was 16 ± 7 mm (91.7%). Also, the distance between the sural nerve and the lateral malleolus was 19 ± 4 mm. These findings are nearly similar to results of Hromadka et al. (2009) who reported that the distance between the sural nerve and insertion of calcaneal tendon was 18.8 ± 4 mm, whereas the distance between the sural nerve and lateral malleolus was 18.3 ± 1.9 mm. These distances are important during the surgical repair of the calcaneal tendon and localization of the sural nerve for regional anaesthesia of the foot. Flavin et al. (2007) reported a clinical technique for preoperatively identifying the sural nerve. This technique is the patient is placed in prone position with the knee flexed at right angle. The ankle is dorsiflexed, and the foot is inverted. This maneuver leads to the tightening of the sural nerve between the two heads of the gastrocnemius and the posterior-inferior border of the lateral malleolus, and the taut nerve can be palpated along its length. A limitation to this technique is the detecting of the sural nerve in close contact along the lateral border of the calcaneal tendon. In this study, there were four types of patterns of innervation of the toes by the sural nerve and superficial fibular nerve. The predominant patterns were type I

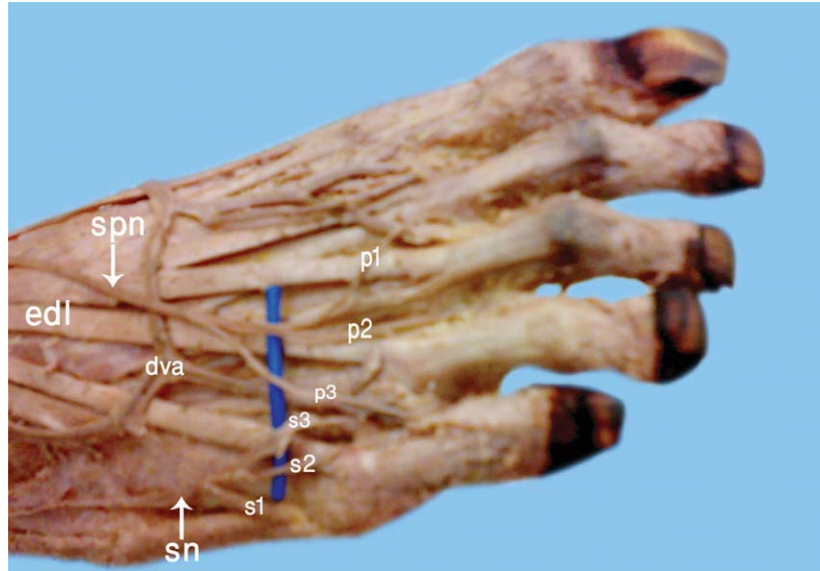


Fig. 10. A photograph of a dissected dorsum of the right foot showing: type II, where the sural nerve (sn) is divided into three digital branches (S_1 , S_2 , and S_3) for supplying the lateral 1[1/2] toes (20.9%) (one of five possible variations). The superficial fibular nerve (spn)

divides into three branches (P_1 , P_2 , and P_3). P_3 associates with S_2 and S_3 . Notice the dorsal venous arch (dva) and tendons of extensor digitorum longus (edl). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

(45.8%) and type IV (29.2%). In type I, the lateral side of the little toe was supplied by the sural nerve alone. In type IV, the lateral 2[1/2] toes were supplied by the sural nerve alone. These observations are in agreement with the findings of

Madhavi et al. (2005) who reported that the predominant patterns of innervation of the toes were types I and IV. But the percentages were different: type I was (35.38%) and type IV was (24.61%). We support the suggestion of Madhavi

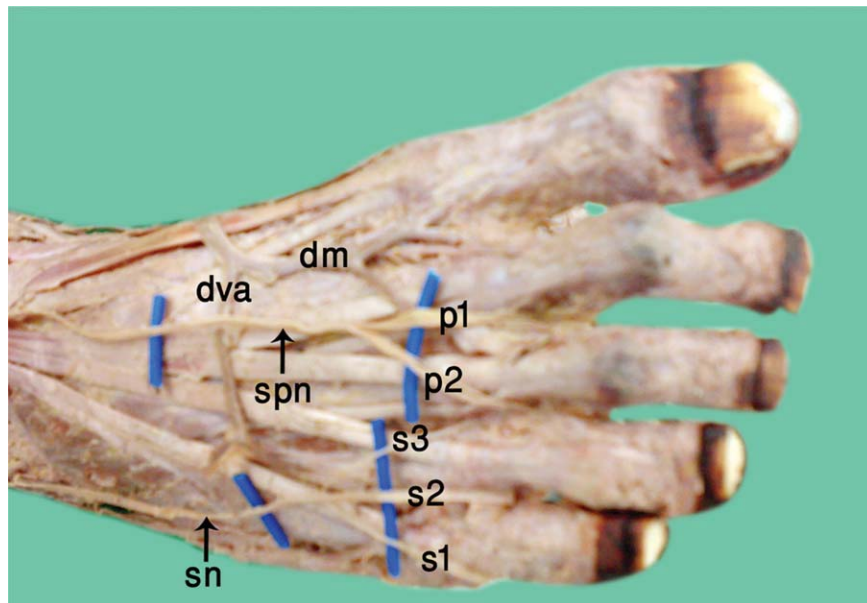


Fig. 11. A photograph of a dissected dorsum of the right foot showing: type III, where the sural nerve (sn) is divided into three branches (S_1 , S_2 , and S_3) for the lateral 2[1/2] toes (4.1%) (only one specimen). The superficial fibular nerve (spn) is divided

into two branches (P_1 and P_2). P_2 associates with S_3 . Notice the dorsal venous arch (dva) and first dorsal metatarsal vein (dm). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

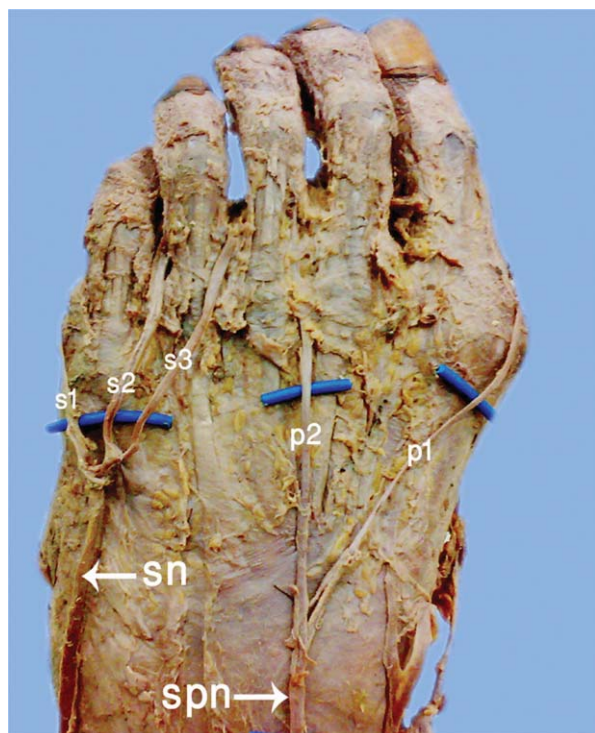


Fig. 12. A photograph of a dissected dorsum of the left foot showing: type IV, where the sural nerve (sn) is divided into three branches (S_1 , S_2 , and S_3) for the lateral 2[1/2] toes. (29.2%) (one of seven possible variations). The superficial fibular nerve (spn) divides into two branches (P_1 and P_2) and does not associate with the sural nerve. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

et al. (2005) who said that the sural nerve may supply a wider area of the skin of the toes than is usually described in textbook. This information may explain the loss of sensation on the lateral 2[1/2] toes in some people when the sural nerve is damaged or anesthetized.

It is concluded that the sural nerve is highly variable. The possibility of the anatomical variations should be considered when the clinical studies and surgical procedures are performed on the sural nerve. This study differs from the previous reports in having a complete data on the variations of the sural nerve from its beginning to its termination.

Finally, when studies are made on the variations of the sural nerve, a higher number of cadavers could be dissected to discover a more variations and more applications.

REFERENCES

- Amoridis G, Schols L, Ameridis N, Przuntek H. 1987. Motor fibers in the sural nerve of humans. *Neurology* 49:1725–1728.
- Apaydin N, Bozkurt M, Loukas M, Vefali H, Tubbs RS, Esmer AF. 2009. Relationships of the sural nerve with the calcaneal tendon: An anatomical study with surgical and clinical implications. *Surg Radiol Anat* 31:775–780.
- Bevilacqua NJ, Rogers LC, Malik RA, Armstrong DG. 2007. Technique of the sural nerve biopsy. *J Foot Ankle Surg* 46:139–142.
- Chentanez V, Cha-oumphol P, Kaewsema A, Agthong S, Huanmanop T. 2006. Accuracy of the three-window sampling method in morphometric analysis of human sural nerve. *J Neurosci Methods* 157:154–157.
- Chummy SS. 2006. *Last's Anatomy, Regional and Applied*, 11th Ed. London: Churchill Livingstone. p 418–419.
- Ellis H. 2007. The nerves of the leg and foot. *Anaesth Intens Care Med* 8:148–150.
- Fabre T, Montero C, Gaujard E, Gervais-Dellion F, Durandeaun A. 2000. Chronic calf pain in athletes due to sural nerve entrapment: A report of 18 cases. *Am J Sports Med* 28:679–682.
- Flavin R, Gibney RG, O'Rourke SK. 2007. A clinical test to avoid sural nerve injuries in percutaneous Achilles tendon repairs. *Injury* 38:845–847.
- George BM, Nayak S. 2007. Sural nerve entrapment in gastrocnemius muscle—A case report. *Neuroanatomy* 6:41–42.
- Hromadka R, Bartak V, Popelka S, Jahoda D, Pokorny D, Sosna A. 2009. Regional anaesthesia of the foot achieved from two cutaneous points of injection: An anatomical study. *Acta Chir Orthop Traumatol Cech* 76:104–109.
- Lee YH, Chung MS, Gong HS, Chung JY, Park JH, Baek GH. 2008. Sural nerve autografts for high radial nerve injury with nine centimeter or greater defects. *J Hand Surg Am* 33:83–86.
- Madhavi C, Isaac B, Antoniswamy B, Holla SJ. 2005. Anatomical variations of the cutaneous innervation patterns of the sural nerve on the dorsum of the foot. *Clin Anat* 18:206–209.
- Mahakkanukrauh P, Chomsung R. 2001. Anatomical variations of the sural nerve. *Clin Anat* 15:263–266.
- Mancuso P, Rashid P. 2008. Nerve grafting at the time of radical prostatectomy: Should we be doing it? *ANZ J Surg* 78:859–863.
- McLeod JG. 2000. Sural nerve biopsy. *J Neurol Neurosurg Psychiatry* 69:431–435.
- Park HD, Kwak HH, Hu KS, Han SH, Fontaine C, Kim HJ. 2007. Topographic and histologic characteristics of the sural nerve for use in nerve grafting. *J Craniofac Surg* 18:1434–1438.
- Romanes GJ. 1990. *Cunningham's Manual of Practical Anatomy. Upper and Lower Limbs*. 15th Ed. Vol. 1. New York: Oxford University Press. p 164.
- Ricci S, Moro L, Incalzi RA. 2010. Ultrasound imaging of the sural nerve: Ultrasound anatomy and rationale for investigation. *Eur J Vasc Endovasc Surg* 39:636–641.
- Ruth A, Schulmeyer FJ, Roesch M, Woertgen C, Brawanski A. 2005. Diagnostic and therapeutic value due to suspected diagnosis, long-term complications, and indication for sural nerve biopsy. *Clin Neurol Neurosurg* 107:214–217.
- Standing S, Borley NR, Collins P, Crossman AR, Gatzoulis MA, Healy JC, Johnson D, Mahadevan V, Newell RLM, Wigley CB. 2008. *Gray's Anatomy. Pelvic Girdle and Lower Limb*. Section (9). 40th Ed. London: Churchill Livingstone. p 1427.
- Zehr EP, Stein RB, Komiyama T. 1998. Function of sural nerve reflexes during human walking. *J Physiol* 507:305–314.