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Formation of the sural nerve in foetal cadavers

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The purpose of this study was to provide a morphologic description and assessment on the formation level of the sural nerve (SN) and its components. Also we aimed to reveal histological features of the SN components. An anatomical study of the formation of the SN was carried out on 100 limbs from 50 embalmed foetuses. The results showed that the SN was formed by the union of the medial sural cutaneous nerve (MSCN) and the peroneal communicating branch (PCB) in 71% of the cases (Type A); the MSCN and PCB are branches of the tibial and common peroneal nerve (CPN) or lateral sural cutaneous nerves (LSCN), respectively. Formation level of the SN was at the distal third of the leg in 43% of the cases, at the middle third of the leg in 46% of the cases, and at the upper third of the leg in 11% of the cases. The PCB originated in the CPN in 68% and the PCB originated in the LSCN in 3% of the cases. The SN was formed only by the MSCN in 20% of the cases (Type B). Type C was divided into four subgroups: in the first group the PCB and fibres of the posterior femoral cutaneous nerve joined the MSCN in 4% of cases; in the second group the MSCN, PCB, and sciatic nerve did not unite and coursed separately in 1% of cases; in the third group the SN arose directly from the sciatic nerve alone and the MSCN made a little contribution in 2% of cases; and in the fourth group the PCB, fibres of the sciatic nerve, and the MSCN formed the SN in 1% of the cases. The SN was formed only by the PCB in 1% of the cases (Type D). Distances of the formation level of the SN to the intercondylar line and the lateral malleolus were measured and also noted. A detailed knowledge of the anatomy of the SN and its contributing nerves are important in many interventional procedures. (Folia Morphol 2012; 71, 4: 221–227)

Key words: sural nerve, formation, variations, foetus

INTRODUCTION

The sural nerve (SN) is clinically important, as it is commonly used for nerve conduction studies, nerve biopsies, and as a convenient source for nerve grafting [20]. The SN is a sensory nerve supplying the skin of the lateral and posterior part of the inferior third of the leg and lateral side of the foot [16]. The SN, next to the small saphenous vein, extends downwards following the lateral margin of the tendo calcaneus. Later, it extends forward to the lateral part of the foot and the fifth toe passing behind the lateral malleolus. The SN gives off lateral calcaneal branches out on the outer part of the calcaneus [15]. The SN is usually described as being formed by the direct continuation of the medial sural cutaneous nerve (MSCN), a branch of the tibial nerve (TN), or as union between the MSCN and the peroneal (fibular) communicating branch (PCB) of the

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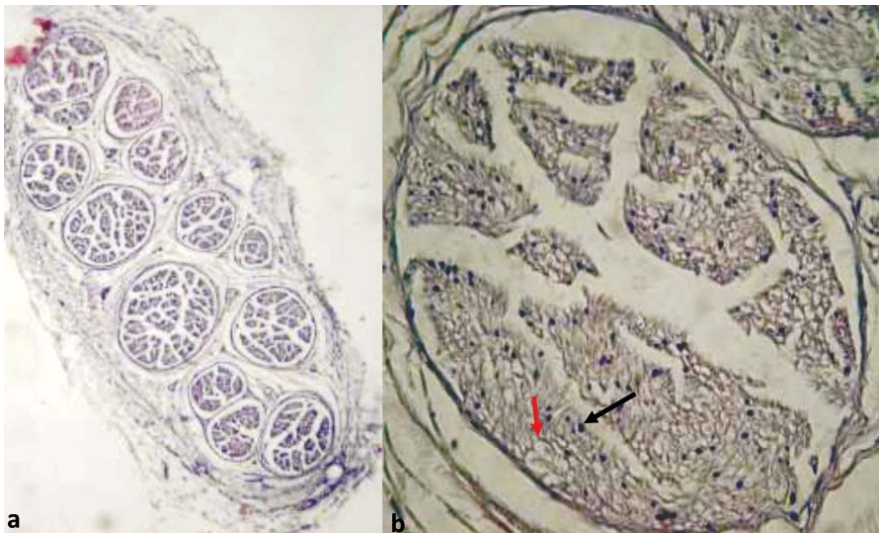

Figure 1. Sections of sural nerve; **A.** Fascicle of sural nerve (×10 magnification); **B.** Axon shown with red arrow and Schwann cell shown with black arrow (×40 magnification).

common peroneal nerve (CPN) [9]. The nomenclature applied to the lateral sural cutaneous nerves (LSCN) contribution is confusing. It is termed the PCB by some authors [2, 3, 6, 11, 13, 16, 17, 19, 21, 25]; Clemente [4] in "Gray's anatomy" named it the communicating ramus of the LSCN. We followed the terminology used by Ortiguela et al. [17] and named it the PCB. The site of union of the MSCN and the PCB to form the SN is highly variable. It may be in the popliteal fossa, the distal third of the leg, or at the ankle [13, 16, 25]. The purpose of this study is to provide a morphologic description and formation level of the SN and its components. Also we aim to reveal the histological features of the SN components.

MATERIAL AND METHODS

In this study 100 limbs from 50 embalmed foetuses (24 male and 26 female) aged between 15 and 40 weeks of gestation were studied in the Department of Anatomy Laboratory in the Faculty of Medicine at Suleyman Demirel University. Foetuses with no external pathology or anomaly were obtained from Isparta Maternity and Children's Hospital. The foetuses were used with written consent from the families and approval from the Ethics Board of the Faculty of Medicine at Suleyman Demirel University.

A longitudinal skin incision was made from the gluteal fold to the prominence of the heel along the midline of the limb, as described by Ugrenovic et al. [22]. Horizontal incisions were made, and then the skin and superficial fascia were removed so that the SN could be easily seen on the surface of the distal third of the leg. It was then traced upwards through the deep fascia to its origin and distally to the level of the lateral malleolus. All contributions to the SN were noted and their diameters measured using digital Vernier callipers. Also, distances of the formation level of the SN to the intercondylar line and the lateral malleolus were measured. After calculating relevant percentages, the findings were tabulated. Statistical analyses were carried out using SPSS 15.0. Statistical significance was $p < 0.05$.

The contributions of the MSCN, PCB, PFCN, and sciatic nerve were analysed via histological techniques (Fig. 1). Formalin-fixed and paraffin-embedded nerve sections were cut at 5 μm and stained with haematoxylin-eosin for histological examination. Analysis was performed on 16 randomly chosen fields in each slide under standard conditions at ×10 and ×40 magnification. Then axons were counted.

Any intramuscular course of the above nerves through the gastrocnemius muscle was noted.

Furthermore, the origin of the SN was classified into Type A, B, C, or D. Type A was the anastomotic type, in which both the MSCN and the PCB contributed to the formation of the SN. Then Type A was classified into two subgroups. The first of these PCBs originates in the CPN, and the second PCB originates in the LSCN then joining the MSCN. When the SN was formed only by the MSCN, it was designated as Type B. Type C was divided into four subgroups: first, the PCB and fibres of the posterior femoral cutaneous nerve (PFCN) joined the MSCN; second, the

Table 1. Mean distances of origin of the sural nerve (SN) to the intercondylar line (IL) and the lateral malleolus (LM) and mean length of the medial sural cutaneous nerve (MSCN) and the peroneal communicating branch (PCB) according to trimesters (N — number of foetuses)

Trimester	N	SN-IL		SN-LM		Length of the MSCN		Length of the PCB	
		Right	Left	Right	Left	Right	Left	Right	Left
2	15	23.60± 9.68	23.26± 7.65	18.23 ± 6.40	17.89 ± 6.04	27.15 ± 9.72	26.05 ± 8.15	26.75 ± 10.53	25.58 ± 7.87
3	16	29.58 ± 11.60	30.31 ± 14.67	33.07 ± 14.57	33.04 ± 16.64	34.66 ± 12.44	34.49 ± 15.88	32.81 ± 12.92	33.14 ± 14.08
4	4	80.25 ± 6.05	80.25 ± 6.05	43.44 ± 20.53	45.39 ± 20.63	40.85 ± 29.28	38.18 ± 23.16	35.85 ± 26.24	34.85 ± 25.05
Total	35	28.10 ± 13.31	27.93 ± 14.45	28.18 ± 15.35	28.28 ± 16.54	32.96 ± 14.88	31.99 ± 15.01	31.22 ± 14.32	30.73 ± 14.02

Table 2. Mean length of the leg, mean distances from origin of the sural nerve (SN) to the intercondylar line (IL) and mean ratio of the distances from origin of the SN to the IL, to length of the leg according to trimesters

Trimester	N	Length of leg		SN-IL		SN-IL/length of the leg	
		Right	Left	Right	Left	Right	Left
2	15	43.82 ± 8.99	41.76 ± 9.17	23.60 ± 9.68	23.26 ± 7.65	0.52	0.55
3	16	62.72 ± 6.85	62.37 ± 7.23	29.58 ± 11.60	30.31 ± 14.67	0.46	0.47
4	4	84.43 ± 2.42	84.79 ± 3.80	33.16 ± 24.97	31.60 ± 26.14	0.38	0.36

MSCN, PCB, and sciatic nerve did not unite and coursed separately; third, the SN arose directly from the sciatic nerve alone and the MSCN made little contribution; and fourth, the PCB, fibres of the sciatic nerve and the MSCN formed the SN. When the SN was formed only by the PCB it was defined as Type D.

RESULTS

The mean distance between the origin of the SN and the intercondylar line and lateral malleolus were measured, as shown in Table 1. Also, the length of the leg, the length of the MSCN, which arises from the TN to the origin of the SN, and the length of the PCB, which arises from the CPN to the origin of the SN, were measured, as shown in Table 1.

It was found that all parameters were increased with age during the foetal period (Table 1). No significant differences were observed between the sexes and right or left sides for any of the parameters ($p > 0.05$). In addition, the ratio of the distance of the origin of the SN to the intercondylar line to the length of the leg, according to trimesters, was also calculated (Table 2).

Histological analyses were performed on 16 randomly chosen fields in each slide and showed that the MSCN was thicker than the PCB in most of cases in this study. In only one case, the PCB was thicker than the MSCN (6.25%). The mean axon number of MSCN and PCB were 1127 and 546, respectively, and the axon number of the MSCN was 1.5 times more than the axon number of PCB. The mean axon number of SN was 1682, and in this respect, avowable that the SN was formed substantially by the MSCN (Fig. 1). When the MSCN was replaced by the SN, at the origin and at the termination level of the MSCN the thickness of the nerve was equal subjectively. This situation supported the theory that the SN was formed only by the MSCN. Similarly, when the PCB was replaced by the SN, at the origin and at the termination level of the PCB the thickness of the nerve was equal subjectively. This situation supported the theory that the SN was formed only by the PCB.

The origin of the SN was highly variable. When male and female foetuses were considered together, the SN was most commonly of Type A (71 of 100 limbs; 71%). The first subgroup of Type A (the PCB originating in the CPN) was observed in 68 of 100 limbs; 68% (Fig. 2A); and the second subgroup of Type A (the PCB originating in the LSCN) was observed in 3 of 100 limbs; 3% (Fig. 2B). The origin of

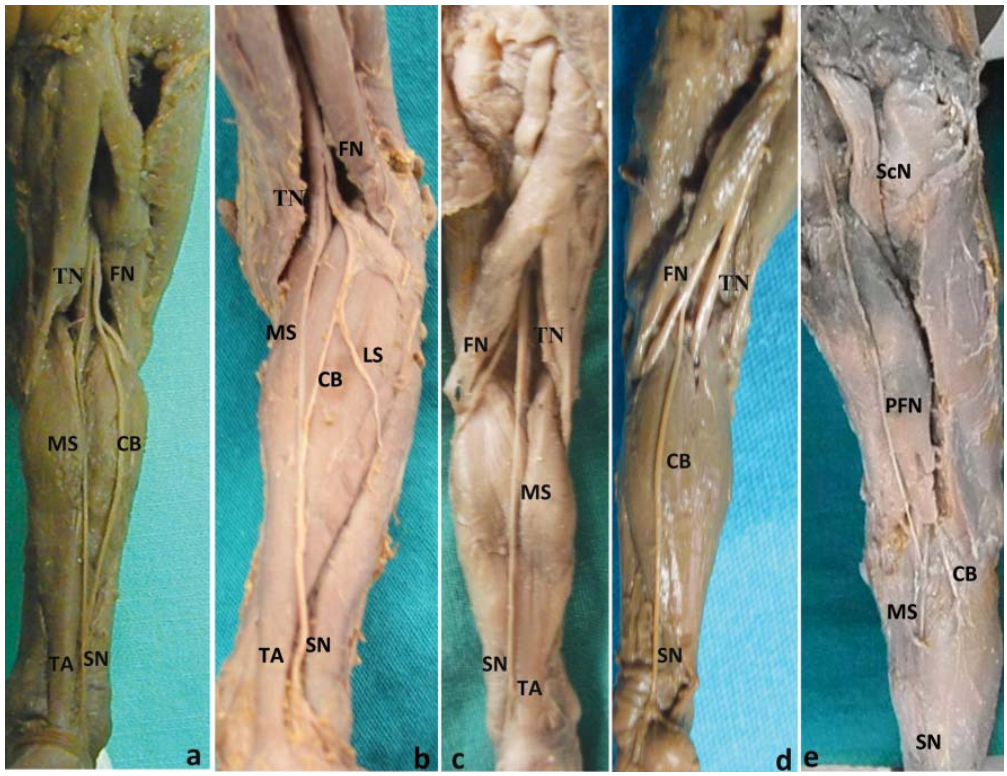

Figure 2. Origin of the sural nerve (SN); **A.** SN consists of medial sural cutaneous nerve (MS) and communicating branch (CB), which arise from common fibular nerve; **B.** SN consists of MS and CB, which arise from lateral sural cutaneous nerve (LS); **C.** SN consists of only MS; **D.** SN consists of only CB, which arises from common fibular nerve; **E.** SN consists of MS, CB, and fibres of the posterior femoral cutaneous nerve (PFN); TN — tibial nerve; FN — common fibular nerve; TA — tendo Achilles; ScN — sciatic nerve.

the SN was unusual in the remaining 29 cases. Type B (the SN was formed only by the MSCN) was observed in 20 of 100 limbs; 20% (Fig. 2C).

When Type C was analysed, the first subgroup (the PCB and fibres of the PFCN join the MSCN) was observed in 4 of 100 limbs; 4% (Fig. 2E). The second subgroup (the PCB and fibres of the sciatic nerve join the MSCN) was observed in 4 of 100 limbs; 4%. In one of these limbs, the MSCN, PCB, and sciatic nerve did not unite and coursed separately (1 of 100 limbs; 1%) (Fig. 3A). Two of these SNs arose directly from the sciatic nerve alone and the MSCN made little contribution (2%) (Fig. 3B). One of these PCBs and fibres of the sciatic nerve joined the MSCN and all nerves to the SN (1 of 100 limbs; 1%). In one case, the SN was formed only by the PCB (1 of 100 limbs; 1%) (Fig. 2D) and was defined as Type D. An intramuscular course of three branches of the SN through the gastrocnemius muscle was noted.

DISCUSSION

This study was carried out to provide a morphologic description and level formation of the SN and its components and to reveal the histological features of the SN components in 50 embalmed foetuses. Because of its great importance in neurosurgery and in plastic surgery, the SN was and has remained a focus of interest for a long time.

The mean distance between the origin of the SN and the lateral malleolus was measured and found to be 28.18 mm in the right side and 28.28 mm in the left side. The mean distances found by Aktan Ikiz et al. [1] between the most prominent part of the lateral malleolus and the tip of the lateral malleolus to the SN were 12.76 cm and 13.15 cm, respectively, in 30 lower limbs of 15 cadavers. Kim et al. [10] indicated that the mean length of the SN after anastomosis with the MSCN and the PCB was 16 cm from the site of the union to the lateral malleolus. Mahakkanukrauh and Chomsung [12] reported that the mean length was 14.4 cm. The mean distance between the origin of the SN and the intercondylar line was measured and found to be 28.10 mm in the right side and 27.93 mm in the left side in this study. But the mean distance between the origin of the SN and the intercondylar line has not been measured in any other study.

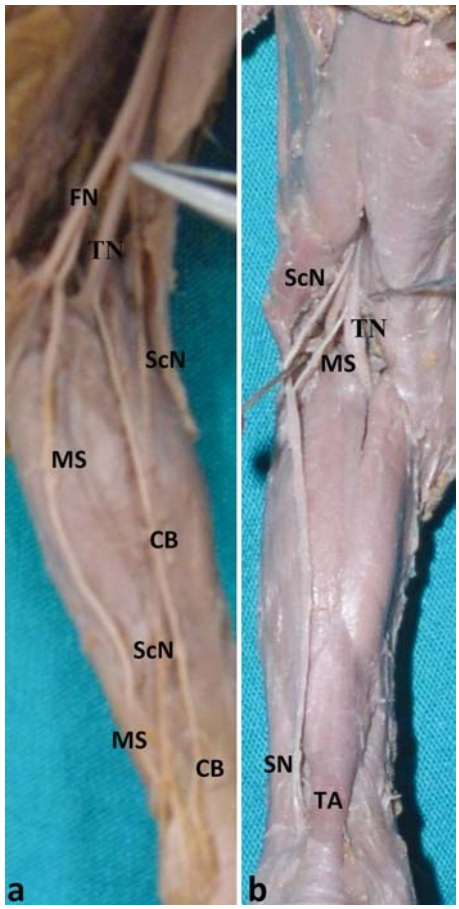

Figure 3. Contribution of the sciatic nerve to sural nerve (SN); **A.** Medial sural cutaneous nerve (MS), communicating branch (CB), and sciatic nerve do not unite and course separately; **B.** SN arises directly from the sciatic nerve alone and the MS makes little contribution; TN — tibial nerve; FN — common fibular nerve; TA — tendo Achilles; ScN — sciatic nerve.

Furthermore, we calculated the ratio of distances from origin of the SN to the intercondylar line, to the length of the leg according to trimesters to find the localisation of the SN (Table 2). This ratio decreased according to trimesters, which indicates that the formation level of the SN was at the lower third of the leg in the second trimester (43%), at the middle third of the leg in the third trimester (46%), and at the upper third of the leg in full-term cases (11%). The site of union was observed to be in the lower half of the leg in 75% of cases by Huelke [9], and in the foot to the lateral side of the fifth toe (60%) by Aktan Ikiz et al. [1]. Mahakkanukrauh and Chomsung [12] found the site of union in 5.9% of cases to be the popliteal fossa, 1.9% in the middle third of the leg, 25.5% just below the ankle, and 66.7% in the lower third of the leg. Pyun and Kwon [18] indicated that the anastomoses were located in the middle (45%) and distal (55%) third of 20 legs. Ugrenovic et al. [22] found that the most frequent location of the origin of the SN was in the second quarter of the distance between the lateral malleolus and the lateral femoral condyle. Other authors reported that the origin of the SN was most frequently in the middle third of the calf, which mainly corresponds with our results [5, 14, 22, 23]. In summary, the communication between the MSCN and the PCB at the calf is highly variable, and the sites of anastomoses were located in the mid and lower thirds in similar proportions. Also, the length of the MSCN and the length of the PCB were measured in this study. The mean length of the MSCN was found to be 32.96 mm, and the mean length of the PCB was found to be 31.22 mm, in 35 foetuses. In only one study, the mean length of the MSCN was found to be 20.42 cm and the mean length of the PCB was 22.48 cm, in cadavers [12].

Histological analyses showed that the MSCN was thicker than the PCB in most cases in our study. Hill et al. [7] had reported that the main contributor to the SN is the MSCN. The thicknesses of the components of the SN, MSCN, and PCB were compared to each other by Uluutku et al. [23]. They determined that the PCB was thicker than the MSCN in only six of 33 legs (18.2%) and both had the same thickness or the MSCN is thicker in the others [23]. But these authors did not compare the diameter or contribution rate. They concluded this result based only on observation; however, our results are based on a histological procedure. Therefore, it can be assumed that these results are more dependable in terms of the method of data collection.

There are a large number of variations of the origin of the SN [22]. The term SN complex was first used by Ortiguela et al. [17] to refer to the MSCN, LSCN, PCB, and SN. We classified the SN into four morphologic types based on the origin of the SN. Type A was the anastomotic type, in which both the MSCN and the PCB contributed to the formation of the SN (71%). Then Type A was classified into two groups. The first of these PCBs originates in the CPN (68%) and the second PCB originates in the LSCN then joins the MSCN (3%).

A similar study was done by Ugrenovic et al. [22] on 200 lower extremities of 100 human foetuses, and they designated Type A as Type 1, and this quantity was found in 58% of lower extremities. In another study, Mahakkanukrauh and Chomsung [12] investigated anatomical variations of the SN on 76 Thai cadavers. Their results revealed that 67.1%

of the SN was formed by the union of the MSCN and LSCN [12]. Huelke [8] also researched the origin of the SN on 352 lower extremities, and he found Type A in 80.7% of cases. Aktan Ikiz et al. [1] found this frequency to be 60% in 30 lower limbs of cadavers. Mestdagh et al. [14] investigated the origin of the human SN on 37 limbs of cadavers; 67.5% of the cases SN originated in communication between the MSCN and the PCB of the LSCN. Pyun and Kwon [18] investigated types of SN formation on 26 legs of cadavers. They found this ratio in 76.9% of cases, but they did not classify Type 1. The location and formation of the SN was examined in 40 legs of newborn cadavers by Uluutku et al. [23]. They described four groups for the formation of the SN. The first group (the PCB from the CPN joining the MSCN) was found in 67.5% of the cases. The second (the PCB from the LSCN joining the MSCN) was found in 10% of the cases (4 legs) [23]. Furthermore, Huelke [9] investigated the origin of the PCB on 99 adult cadavers. In this study, the union between the PCB and the MSCN was seen in 80.3% of the cases. The PCB arose directly from the PCN in 54.7% of cases and arose from the LSCN in 13.2% of sides.

Type B (the SN was formed only by the MSCN) was observed in 20% of the cases in this study. The abovementioned investigators found this ratio to be 26% by Ugrenovic et al. [22], 32.2% by Mahakkanukrauh and Chomsung [12], 19% by Huelke [9], 16.7% by Aktan Ikiz et al. [1], 18.91% by Mestdagh et al. [14], 15.4% by Pyun and Kwon [18], 12.5% by Uluutku et al. [23], and 19.7% by Huelke [9]. Shankar et al. [20] found this ratio to be 26.5% of 102 lower limbs. Type B was reported in 20% of cases by Ortiguela et al. [17].

In rare situations, the PFCN joins the formation of the SN [24]. Our findings showed that the first subgroup of Type C (the PCB and fibres of the PFCN join the MSCN) was observed 4 of 100 limbs; 4%. Uluutku et al. [23] reported that the SN was formed by the PCB, MSCN, and PFCN in 2 of 40 limbs (5%). Ugrenovic et al. [22] detected the presence of the PFCN in 4.5% of cases (200 lower extremities). Shankar et al. [20] found this ratio in 3 of 38 limbs (7.9%). However, they indicated that this ratio was slightly higher in comparison with earlier studies.

The earlier studies did not take any notice of the contribution of the sciatic nerve. However, we made a skin incision from the gluteal sulcus down to the ankle, as described by Ugrenovic et al. [22], and thus had a better approach to the sciatic nerve and its terminal part. Our findings showed that in 2 of 100 limbs the SN arose directly from the sciatic nerve alone, the MSCN makes little contribution (2%), and in one of 100 limbs the PCB and fibres of the sciatic nerve join the SN (1%). The contribution of the sciatic nerve was described only in two studies. In the first of them, the origin of the SN as a single branch from the sciatic nerve near its termination was described in 14 of 102 limbs (13.7%) by Shankar et al. [20]. They indicated that the explanation for finding a greater frequency of the origin of the SN or one of its contributors from the sciatic nerve may be related to age, race, and method of dissection. A second study was carried out by Ugrenovic et al. [22]. They found in 4.04% of cases that the MSCN originated from the terminal part of the sciatic nerve, and in 3.2% of cases the PCB originated from the terminal part of the sciatic nerve.

In one of 100 limbs (1%) in this study the MSCN, PCB, and sciatic nerve did not unite and coursed separately. This ratio was different from that seen in other studies, such as 7.84% by Shankar et al. [20], 8% by Mestdagh et al. [14], 5% by Ugrenovic et al. [22]. They found that the MSCN and PCB were present but that they did not unite and coursed separately. However, in our study the MSCN, PCB, and the fibres of the sciatic nerve were present and coursed separately to the lateral malleolus. Aktan Ikiz et al. [1] found in two specimens (6.7%) that the nerves had separate courses in 30 lower limbs.

In one case the SN was formed only by the PCB (1%) and was defined as Type D in our study. This type is rare and it was rarely presented in the literature. Ugrenovic et al. [22] described as Type IV, in which the PCB took over the SN function, in 1.5% of cases. Mestdagh et al. [14] found this ratio in 2.7% of cases. Mahakkanukrauh and Chomsung [12] studied in 76 Thai cadavers and they found that one SN (0.7%) was formed by the union of the MSCN and a different branch of the common fibular nerve, running parallel and medial to but not connecting with the PCB. Huelke [8] found the MSCN to be completely absent in one case of 352 extremities. Aktan Ikiz et al. [1] found that the MSCN was absent in two (6.7%) specimens in 30 lower limbs.

The SN has important diagnostic value in tissue biopsy, nerve grafting, and for the neurophysiologic evaluation of diverse causes of peripheral neuropathies [10]. Knowledge of the anatomical features of the SN throughout its course along the leg is important for the protection of the nerve during SN graft

harvesting, local and regional anaesthetic techniques, and nerve conduction studies [18]. The loss of sensation is less serious and the chance of success increased when components forming this nerve are used instead of SN grafting [23]. These described variations should be helpful for planning operative approaches that minimize the risk of sural nerve injury.

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