Journal of the Anatomical Society of India 66 (2017) 37–42

Contents lists available at ScienceDirect

Journal of the Anatomical Society of India

journal homepage: www.elsevier.com/locate/jasi

Original Article

Anatomical and histological morphometry of the sural nerve in human fetuses

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ARTICLE INFO

Article history:
Received 24 January 2017
Accepted 11 May 2017
Available online 18 May 2017

Keywords:
Sural nerve
Fetus
Morphometry
Anatomy
Histology

ABSTRACT

Introduction: In our study, the aim was to anatomically and histologically investigate the morphometric structures of the branches involved in the sural nerve and sural nerve formation.
Method: The study was conducted on 46 lower extremities of 23 fetuses which were obtained from Izmir Katip Çelebi University, Atatürk Training and Research Hospital, with ages from 18 and 32 gestational weeks, without any external pathology or anomaly. During the study period, the posterior-side skin dissection of the lower extremity was performed with the aid of a surgical dissection microscope initially, and the structures forming the sural nerve and the sural nerve were exposed and made visible. Afterwards, sections were taken from these structures for morphometric measurements and histological examination.
Results: The mean values and standard deviations of morphometric measurements obtained were determined. Separately, it was determined that there was no statistical difference between right-left sides and genders in morphometric measurements ($p > 0.05$). The sural nerve was determined to be differentiated into 4 types as A, B, C and D according to the way the nerve branches forming sural nerve join. In addition, differing characteristics pertaining to the sural nerve and branches were determined.
Discussion: We are of the opinion that the data obtained in our study will be of use to neurologists, orthopedists and clinicians engaged in this region during interventional procedures.

1. Introduction

The sural nerve (SN) is formed by the juncture of the medial sural cutaneus nerve (MSCN), which is a branch of the tibial nerve (TN), and the lateral sural cutaneus nerve (LSCN), which is a branch of the common peroneal nerve (CPN), in the posterior of the leg.[1] Afterwards, it follows the small saphenous vein as far as the posterior of the malleolus lateralis. On the exterior part of the dorsum of the foot, it extends up to the little toe as the lateral dorsal cutaneous nerve.[1] The SN receives cutaneous sensations from the posterolateral part of the distal region of the leg, malleolus lateralis, lateral part of the feet, and 4th and 5th toes on the feet.[1–4]

The fact that the SN shows variation was reported in former studies.[4,5] In studies conducted on adults, it is reported that the nerve branches forming the SN join at the popliteal fossa in 5.9%, in the middle of the leg in 1.9%, in the distal region of the leg in 67.4%, and at the ankle in 25.5% and, thus, they form the SN.[4,6] It is also stated in studies that the sural nerve originates directly from the sciatic nerve (ScN), CPN or TN.[6–10]

In general, although the SN is a sensory nerve, the fact that it may variationally show motor function and contain motor fibers has been emphasized in studies.[2,4,11] For this reason, the SN is of clinical importance in the diagnostic evaluation of tissue biopsies, in nerve grafts, and in the identification of sensory losses that develop due to distal neuropathies, since mono-neuropathies pertaining to the sural nerve are stated to be quite rarely seen.[4,9,12–14] Separately, in human fetus studies conducted previously, there is some information in regard to the morphometric structure and anatomic variations of the SN.[15,16]

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http://dx.doi.org/10.1016/j.jasi.2017.05.005
0003-2778/

In our study, we aimed to morphometrically investigate the anatomic and histological structures of the SN in human fetuses as well as its neighboring relations with the gastrocnemius muscle and calcaneal tendon.

2. Material and method

Our study was conducted on 46 lower extremities (16 male and 7 female fetuses) of 23 fetuses, the ages of which varied between 18 and 32 gestational weeks, without any external pathology or anomaly. The fetuses were obtained from Izmir Katip Çelebi University, Atatürk Training and Research Hospital with the approval of parents. Separately, permission was received for the study from the ethics committee of Izmir Katip Çelebi University, Atatürk Training and Research Hospital.

During the study, firstly a longitudinal skin incision was made via a surgical dissection microscope (Leica M320F12) on the posterior side of the lower extremity, from the gluteal fold up to the protrusion of the heel so it was mid-line. Later, the superficial and deep fascia were removed, and the SN structures and the structures involved in the formation of the SN were exposed. Afterwards, morphometric measurements were taken from the anatomic structures that were exposed by using a digital compass. The lengths of the SN, MCSN and LSCN were taken as morphometric measurements. The length of the SN was taken as the distance remaining between the starting point of the nerve and malleolus lateralis; whereas the length of MSCN was taken as the distance remaining between the starting point of the nerve and the point at which it participated in sural nerve formation. The length of LSCN was taken as the distance remaining between the starting point of the nerve and the point at which it was involved in SN formation. Separately, the typology of the SN and the variations related to the sural nerve were determined. The SN, as in the former fetal studies, was typologized as Type A–D.[8] If the SN was formed by the juncture of MSCN and the peroneal communicating branch (PCB) parting from CPN or by the juncture of MSCN and PCB parting from

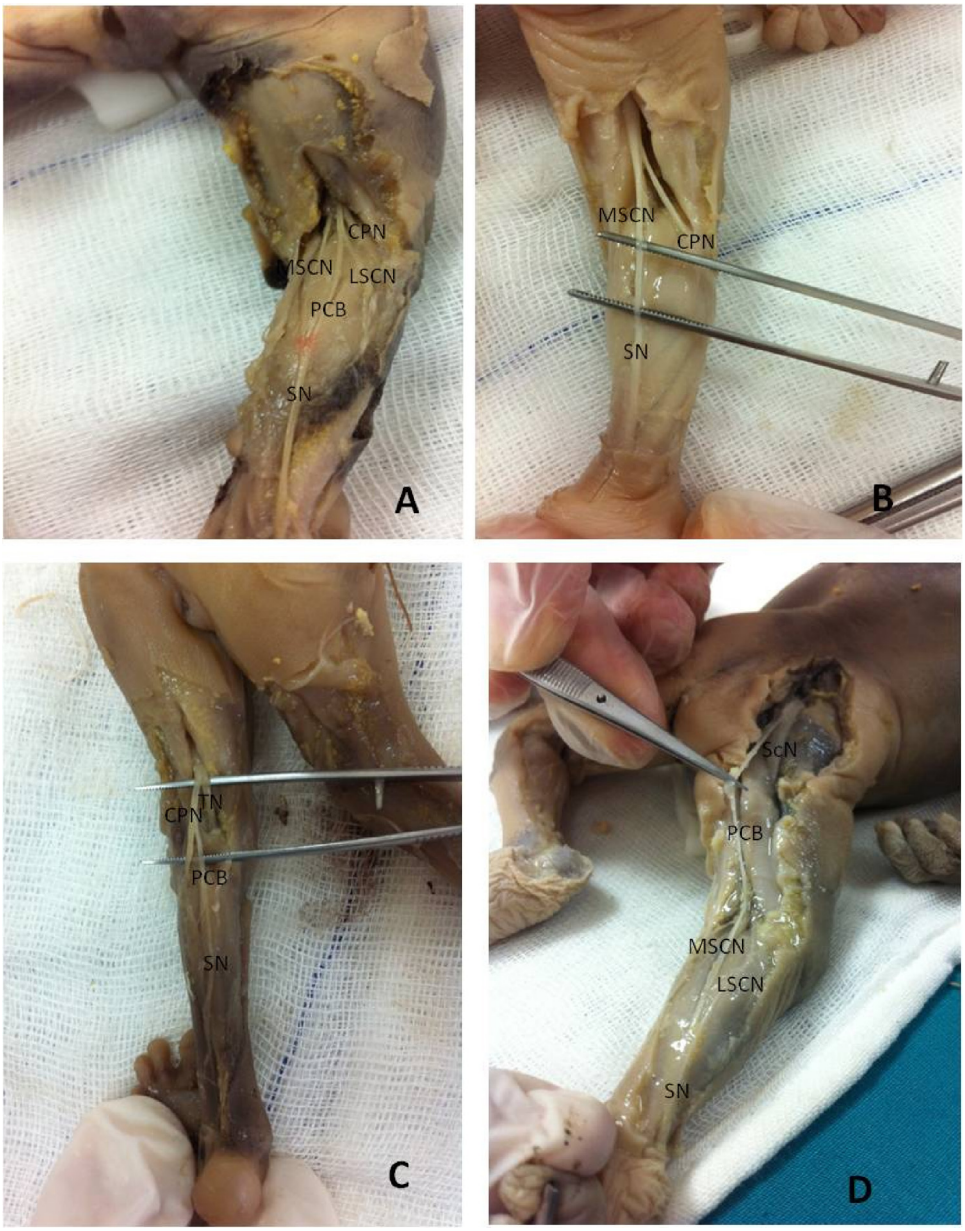

Fig. 1. Types of sural nerves. A: Formed by the juncture of MSCN and PCB parting from LSCN (Type A); B: Formed only by MSCN (Type B); C: Formed only by PCB (Type C); D: Formed by the juncture of MSCN, LSCN and (ScN) (Type D).

LSCN, then it was referred to as Type A; if it originated only from MSCN, then it was called Type B; if it was formed of only PCB or LSCN, then it was called Type C; and if was formed of the juncture of several nerves, such as MSCN, LSCN, posterior femoral cutaneous nerve (PFCN) and ScN, it was referred to as Type D (Fig. 1A–D).[8] Afterwards, histological sections were taken from these structures for histological examination.

Each tissue was vertically embedded in paraffin blocks in the wake of routine histological tissue follow-up methods. Later, transverse sections were obtained for tissue samples of 5 μm thickness in a vertical position. As for the obtained sections; 7–10 section samples were taken from each case through the systematic random sampling method. The sections taken were stained with Hematoxylin-Eosin (H&E) and were evaluated under a light microscope (Olympus CX41RF). Under the light microscope, the total diameters of section samples from each tissue were measured with an ocular micrometer in both transverse and vertical directions, and the averages were taken. Separately, the total capsule thickness from four sides (upper-lower-right-left) was measured, and the mean value of these measurements was obtained, after which the total capsule thickness was specified (Fig. 2A, B). The measurements were evaluated on horizontal and vertical axes via an ocular micrometer by using methods applied in similar studies conducted previously.[15]

The mean values and standard deviations of the parameters were determined by using SPSS statistical program. The significance level during the statistical analysis was taken as $p < 0.05$. For comparison of parametric data between genders, the Student-t test was used. The p values obtained are given in the results section.

3. Results

A longitudinal skin incision was performed via a surgical dissection microscope on the posterior region of 46 lower extremities from 23 fetuses, from the gluteal fold up to the protrusion of the heel along the mid-line. Later, the superficial and deep fascia were removed, and the sural nerve structures and the structures taking part in the formation of the SN were exposed. Anatomical and histological morphometric measurements were taken from these structures. In the measurements taken, it was determined that there was no statistical difference between right-left sides and genders ($p > 0.05$). In the measurements with a digital compass on 23 fetuses (46 lower extremities), it was determined that the mean length of SN was 24.11 mm, while the mean length of LSCN was 19.18 mm, and the mean length of MSCN was 20.17 mm (Table 1). Separately, the SN was determined to have been formed in the proximal part of the legs in 30% of the cases (14 cases), in the middle region of the legs in 22% of the cases (10 cases) and in the distal parts of the legs in 48% of the cases (22 cases). Afterwards, the localization of the SN with reference to the gastrocnemius muscle and the relationship of the SN with calcaneal tendon were examined. The SN was determined to have been formed in the proximal part of gastrocnemius muscle in 17% of the cases (8 cases), in the middle region of gastrocnemius muscle in 14% of the cases (6 cases), and in the distal part of gastrocnemius muscle in 69% of the cases (32 cases). As for the relationship between the SN and calcaneal tendon; the SN was determined to have decussated the calcaneal tendon in its proximal part at a rate of 30% (14 cases), while it decussated the calcaneal tendon in its middle region in 22% (10 cases) and it also decussated the calcaneal tendon in its distal part in 48% (22 cases). The SN was evaluated by being differentiated into 4 types based on the status of the integration of the nerve branches it is composed of. As a result of the evaluation, it was determined that 69.56% of the cases (32 cases) belonged to Type A (Fig. 1A), 19.56% (9 cases) belonged to Type B (Fig. 1B), while 6.52% (3 cases) belonged to Type C (Fig. 1C), and 4.36% (2 cases) belonged to Type D (Fig. 1D) (Table 1). Separately, as a result of our study, it was observed that the SN was asymmetric in 15.21% (7 cases), that the SN progressed intramuscularly within the gastrocnemius muscle in 4.34% (2 cases) while MSCN progressed in the same way in 13.04% (6 cases), and that SN followed the lateral part of the small saphenous vein in all cases (Fig. 3A, B). Moreover, as a result of histological examination, the mean diameters pertaining to the SN, LSCN and MSCN were ascertained as 163.4 μm, 95.3 μm and 112.8 μm, respectively (Fig. 2A) (Table 1). The mean total capsule thicknesses pertaining to each of the three nerves were measured as 13.3 μm, 8.63 μm and 8.65 μm, respectively (Fig. 2B) (Table 1).

4. Discussion

As mentioned in previous studies, SN is stated to be a variational nerve.[4,5] In general, it is highlighted in studies that SN, despite being a sensory nerve, may also have a variable motor function and may contain motor fibers as well.[2,4,11] Therefore, SN is of clinical importance in the diagnostic evaluation of tissue biopsies, in nerve grafts, and in the identification of sensory losses that develop due to distal neuropathies, since mono-neuropathies pertaining to the SN are stated to be quite rarely seen.[4,9,12–14]

In our study, we identified the morphometric measurements and histological characteristics of the SN and its branches in 46 legs

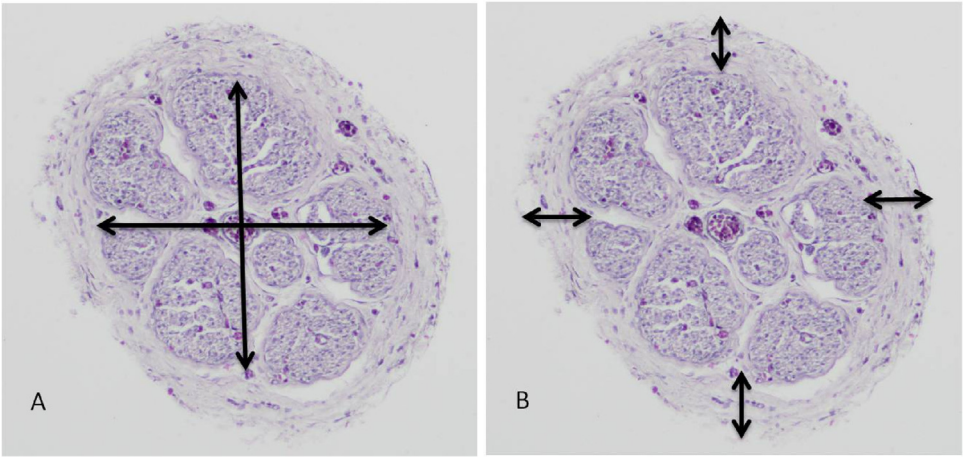

Fig. 2. Histological image of the nerves (H&EX120). A: Vertical and transverse diametric measurement points of the nerves. B: Measurement points for capsule thicknesses of nerves.

Table 1
Morphometric data of the nerves.

N	Mean length of nerves (mm)			Sural nerve type				Mean diameters of nerves (μm)			Mean total capsule thicknesses of nerves (μm)		
	NS	LSCN	MSCN	Type A	Type B	Type C	Type D	NS	LSCN	MSCN	NS	LSCN	MSCN
46	24.11	19.18	20.17	69.56% (32 cases)	19.56% (9 cases)	6.52% (3 cases)	4.36% (2 cases)	163.4	95.3	112.8	13.3	8.63	8.65

NS: sural nerve, LSCN: lateral sural cutaneus nerve, MSCN: medial sural cutaneus nerve.

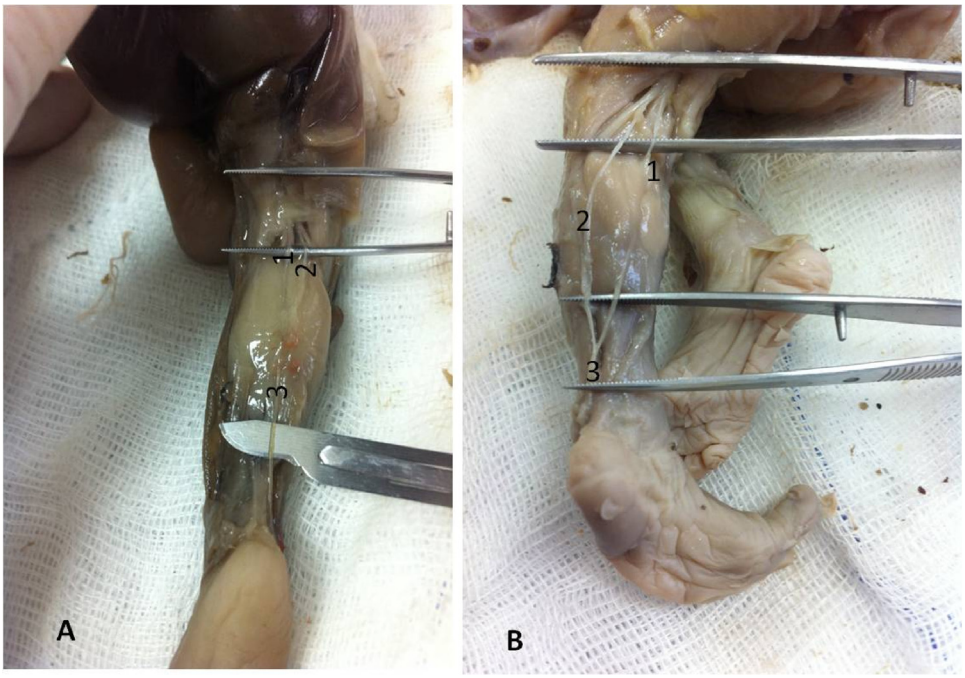

Fig. 3. Intramuscular path of the nerves. A: SN on intramuscular path. B: MSCN on intramuscular path (1: MSCN, 2: PCB, 3: SN).

of human fetuses through the anatomic dissection method and under the guidance of a surgical dissection microscope. During the study, firstly a longitudinal skin incision was made via a surgical dissection microscope on the posterior sides of 46 lower extremities from 23 fetuses, from the gluteal fold up to the protrusion of the heel along the mid-line. Later, the superficial and deep fascia were removed, and the SN structures and the structures involved in the formation of the SN were exposed. Morphometric measurements were taken from these structures. It was determined that there was no statistical difference between right-left sides and genders in the morphometric measurements ($p > 0.05$).

In our study, the lengths of SN, LSCN and MSCN were measured initially. Albay et al.[15] in the study they conducted previously on fetuses, measured the mean lengths of SN, LSCN and MSCN according to the trimester groups as 28.18 mm, 31.22 mm, and 32.96 mm in the right leg, and as 28.28 mm, 30.73 mm and 31.99 mm in the left leg, respectively. Separately, in the studies conducted on adult cadavers, the mean length of the SN was measured as 14.4 cm and 16 cm[5,16] As a result of our study, the mean length of SN was determined as 24.11 mm, the mean length of LSCN was identified as 19.18 mm, and the mean length of MSCN was determined as 20.17 mm in measurements performed with a digital compass on 23 fetuses (46 lower extremities). The results of our study do not show compliance with the results of these previous studies. We explain this outcome as due to the development of the nerves during the fetal period and the difference in the number of fetuses used in the study. Separately, we interpreted this noncompliance as due to the fact that the development of nerves does not end during the fetal period but continues during adulthood.

In our study, the region of the leg the SN was formed in was also identified. When we looked at previous studies, we encountered fetal studies about the formation region of the SN within the leg.[8,15] There were also similar studies conducted on adult cadavers.[4,6] Albay et al.[15] state that the SN is formed in the distal region of the leg at a rate of 43% during the second trimester, in the middle of the leg at 46% during the third trimester, and in the proximal part of the leg at 11% during all trimesters. Shankar et al.[8] reported that the SN is formed in the distal part of the leg for 45.9%, in the middle part of the leg for 32.4% and in the proximal part of the leg for 5.4%. In the studies conducted on adults, it is stated that the SN is formed at a rate of 5.9% in popliteal fossa, at a rate of 1.9% in the middle of the leg, at a rate of 67.4% in the distal part of the leg, and at a rate of 25.5% in the ankle.[4,6] In our study, however, we ascertained that the SN formed in the proximal part of the legs in 30% of the cases (14 cases), in the middle region of the legs in 22% of the cases (10 cases), and in the distal part of the legs in 48% of the cases (22 cases). Our study result is concordant with the study results from the fetal period and adults. The result of this study is interpreted to indicate the SN develops mainly in the distal part of the leg from the fetal period onward, and continues to develop in the same way during adulthood. Furthermore, we are of the opinion that the result of our study will be of use to clinicians involved in operations to be performed on this region of the leg. In our study, the

localization of the SN with reference to the gastrocnemius muscle was specified. We did not encounter any study on this parameter as regards the sural nerve during the fetal period. As a result of our study, the SN was observed to have formed in the proximal part of gastrocnemius muscle in 17% of the cases (8 cases), in the middle region of gastrocnemius muscle in 14% of the cases (6 cases), and in the distal part of gastrocnemius muscle in 69% of the cases (32 cases). Separately, the relationship between the SN and calcaneal tendon was examined in our study. We did not encounter any study on the relationship between the SN and calcaneal tendon during the fetal period. Only studies conducted by Apaydın et al.[17] on adult cadavers investigated the neighborhood relations between the SN and calcaneal tendon. Apaydın et al.[17], as the result of their study on adult cadavers, stated that the SN exists on the lateral side of the tendon in 95%, so that it is on the proximal part of the calcaneal tendon. As a result of our study, it was determined that the SN decussated the calcaneal tendon in its proximal part at a rate of 30% (14 cases), it decussated the calcaneal tendon in its middle region in 22% (10 cases), and it also decussated the calcaneal tendon in its distal part in 48% (22 cases). Our study result does not comply with the result of the study conducted by Apaydın et al.[17] We interpret this outcome as being associated with the development of SN and due to the fact that the SN could show different variations depending on its development. Separately, we are of the opinion that both of the results in our study will be of use in terms of avoiding any injury to the nerve during surgical interventions to be performed on the gastrocnemius muscle and calcaneal tendon.

In our study, the SN and the ways in which the nerve branches it is composed of integrate were typologized. When we reviewed the previous studies regarding the fetal period, it was determined that if the SN was formed by the juncture of MSCN and the peroneal communicating branch (PCB) parting from CPN or by the juncture of MSCN and PCB parting from LSCN, then it was typologized as Type A; if it originated only from the MSCN, then it was called Type B; if it was formed of the juncture of several nerves, such as MSCN, LSCN, PFCN and sciatic nerve, it was referred to as type C; and if it was formed of only PCB, then it was called Type D.[15] According to the typology in the studies conducted previously on adults; it was observed that if the SN was formed by the juncture of MSCN and the peroneal communicating branch (PCB) parting from LSCN, then it was called Type Ia; if it was formed of the juncture of MSCN and PCB parting from FPCN, it was Type Ib; if it was formed only of MSCN and if there was LSCN along with it, then it was Type II; if it was formed only of MSCN and if there was no LSCN along with it, then it was Type III; if it was formed only of LSCN and if there was MSCN along with it, then it was called Type IV; and if it was formed only of LSCN and if there was no MSCN along with it, then it was referred to as Type V.[18] In our study, however, as Shankar et al.[8] typologized, the SN was referred to as Type A if it was formed of the juncture of MSCN and the peroneal communicating branch (PCB) parting from CPN or of the juncture of MSCN and PCB parting from LSCN; if it originated only from MSCN, then it was called Type B; if it was formed of only PCB or LSCN, then it was Type C; and if it was formed of the juncture of several nerves, such as MSCN, LSCN, PFCN and ScN, it was referred to as Type D. Albay et al.[15] in their typology, state in their study that Type A is seen at a rate of 71%, Type B in 20%, whereas Type C is seen in 4% and Type D is seen in 1% of cases. Shankar et al.[8] reported that they found Type 1A at the rate of 37.2%, Type B at 26.5%, Type C at 22.5% and Type D at 13.7%. According to the results of a study performed on adults, the researchers noted that they found Type I in 63%, Type II in 27%, Type III in 7% and Type IV in 3%.[18] However, as the result of our study it was determined that there was Type A (Fig. 1A) in 69.56% of the cases (32 cases), Type B (Fig. 1B) in 19.56% of the cases (9 cases), Type C (Fig. 1C) in 4.36% of the cases (2 cases), and Type D (Fig. 1D) in 6.52% of the cases (3 cases). When our study results are compared with those performed previously during the fetal period, both seem to be in accord with each other in terms of Type A and Type B, whereas they do not match in terms of Type C and Type D.[8,15] In the same way, when our study result is compared with the one performed on adults, Type I and Type II are accordant, whereas Type III and Type IV do not show compliance.[18] We think this non-compliance is associated with the development of the sural nerve during the fetal period and with the fact that SN is a variational nerve. Separately, we are of the opinion that the results regarding the types of SN will be of use to clinicians involved in this region in their procedural interventions in terms of avoiding any damage likely to occur to the nerve.

As a result of this study, it was observed that the SN showed asymmetry in 15.21% of cases (7 cases), that the sural nerve followed an intramuscular course at the rate of 4.34% (2 cases) and MSCN followed an intramuscular course at the rate of 13.04% (6 cases) within the gastrocnemius muscle, and that SN followed the lateral side of small saphenous vein in all cases (Fig. 3A, B).

In our study, we also performed a histological examination on the SN, MSCN and LSCN (Fig. 2A, B). During the histological examination, we measured the mean vertical and transverse diameters of the nerve as well as the capsule thicknesses taken from four regions, in addition to which we calculated the averages. We did not come across any similar study conducted during the fetal period. Albay et al.[15], as a result of their study conducted on fetal cadavers, reported that MSCN is thicker in diameter than PCB and that only in one case was PCB thicker in diameter than MSCN. Uluutku et al.[19], as the result of their fetal study, pointed out that PCB was thicker in diameter than MSCN in 6 out of 33 cases, while in the remaining cases, MSCN was thicker in diameter than PCB, or equal to PCB. As a result of our study, the mean diameters pertaining to SN, LSCN and MSCN were determined as 163.4 μm, 95.3 μm and 112.8 μm, respectively. Our study results show compliance with those performed previously. We also measured the capsule thicknesses of SN, LSCN and MSCN in our study. We did not come across such a study performed for the fetal and adulthood periods before. According to the result of our study, the mean capsule thicknesses of SN, LSCN and MSCN were measured as 13.3 μm, 8.63 μm and 8.65 μm, respectively. We interpreted both of our study results indicating that MSCN played a greater part in the formation of SN, as was also seen in the results of the study conducted by Albay et al.[15]

As mentioned in former studies, SN is a variational nerve.[4,5] In general, it is emphasized in studies that despite being a sensory nerve, SN may have a motor function in a variational manner and it may contain motor fibers.[2,4,11] For this reason, SN is of clinical importance in the diagnostic evaluation of tissue biopsies, in nerve grafts, and in the identification of sensory losses that develop due to distal neuropathies, because the SN has important diagnostic value in tissue biopsies and nerve grafts for the neurophysiological evaluation of various causes of peripheral neuropathies.[4,9,12–14]

5. Conclusion

In conclusion, we are of the opinion that the data we obtained in our study will be of use to clinicians involved in determining the localization of the SN, in the path of the SN and its relations with neighboring structures, and also in minimizing nerve injuries likely to occur during surgical procedures to be performed on these regions.

Conflicts of interest

All authors have none to declare.

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