Topography and histomorphometry of the cutaneous nerves of the forearm and lower limb; implication for nerve grafting

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Topography and histomorphometry of the cutaneous nerves of the forearm and lower limb; implication for nerve grafting

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이 논문이 완성되기까지 세심한 지적과 지도를 아끼지 않으셨던 정 한성 교수님, 처음 연구회 모임에서 뵙고 무서운 학생주임 같았던 건국대학의 고 기석 교수님, 연구회의 전체적 분위기를 온화하게 만드시는 가톨릭대학의 한 승호 교수님도 바쁘신 중에도 저의 논문에 많은 관심과 지도에 감사의 마음을 전합니다.

항상 같은 교실에서 미우나 고우나 한 식구로 지냈던 허 경석 교수, 부산 치대의 곽 현호 교수, 강 민규 선생 그리고 치과대학 해부학 교실원들에게도 감사드립니다. 또한 조직학 교실원들에게도 감사를 드립니다.

책작업에 바쁜 시간에도 망설임 없이 논문의 그림을 수정해준 윤 관현 선생에게도 감사를 드립니다.

지금은 기억이 나지 않지만 이 시간에 도달하도록 해 주신 저를 아는 모든 분들에게도 한분씩 찾아가서 감사하다는 말을 전하고 싶습니다.

2007년 7월 저자 씀

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ABSTRACT

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The sensory nerve usually is used for nerve grafting. The lateral antebrachial cutaneous nerve (LACN), the medial cutaneous nerve and the superficial branch of the radial nerve of the forearm and the lateral femoral cutaneous nerve (LFCN) of the thigh or the dorsal branch of the ulnar nerve and sural nerve (SN) may be used. I examined the LACN, LFCN, and SN for present study. This study is for providing guideline in the selection of nerve graft by detecting similarities between donor and receptor nerves relative to cross sectional area and fasicle number of the cutaneous nerve from the forearm and lower limb in Koreans.

Eighty fresh and fixed cadavers from Korean males and females were used. Eighty-one upper extremities for LACN, seventy-four lower limbs for LFCN and seventy-one lower limbs for SN were investigated. Topography of these nerves was examined, and nerve segments were harvested to compare with a histomorphometric method. Harvested nerve specimens were fixed immediately in a 10% formalin solution. Specimens were embedded in paraffin blocks and histologic sections of 4μm thickness were prepared in a cross-sectional plane and stained with Luxol fast blue.

The running type of LSCN, LFCN and SN were divided into three, four, and five types. The first division of LACN was located at first distal part (53.1%) from interepicondylar line. The first division of anterior branch from LFCN was located at second distal part (n=31, 41.9%) from ASIS. The MSCN and the communicating branch of the LSCN joined together was to form the SN in 52 cases, and this was found in the lower two-fifths of the calf in 28 (53.8%) of the specimens. The LACN pierced the brachial fascia at an average distance of 12.9 mm upper (n=30, 49.2%) to the interepicondylar line and located an average of 15.5 mm lower (n=28) to the interepicondylar line. The LFCN perforated at third distal part from ASIS (33/44 cases, 75.0%) and the MSCN pierced at third distal part from fibular head (62.0%). The mean number of fascicles from LACN was 5.8 in the first medial part and 2.5 in the fourth distal part from interepicondyle line. The total fascicular area of the nerve fascicles was 0.26 mm^2. The mean fascicle number of LFCN was 3.8 in the first part from ASIS and the fascicular area was 0.37 mm^2. The mean number of fascicles from SN was 8.1 and the fascicular area was 0.55 mm^2.

The results of this study such as topography and the fascicular area and number of fascicles of donor nerves may be provide a guidelines for selection of nerve graft harvest sites according to defects encountered.

Key words: nerve graft, lateral antebrachial cutaneous nerve, lateral femoral cutaneous nerve, sural nerve, surgical anatomy, nerve fascicles

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I. INTRODUCTION

The purpose of a nerve graft is to restore continuity between nerve ends and to provide a physical guide along which axons can regenerate. Excellent safety and efficacy profiles are associated with the application of autogenous nerve transplantation to nerve injuries. The regeneration through an autograft is similar to the regeneration that follows the simple sectioning and suturing of a nerve[1]. Several donor sites are commonly used for harvesting nerve grafts, with many parameters being assessed when selecting a site. The choice of donor nerve is based on anatomic and histologic features, and the length and cross-sectional area of the nerve must match those of the nerve defect and be associated with acceptable donor-site morbidity[2]. The sources of donor nerve for nerve graftinghave been the medial antebrachial cutaneous nerve, lateral antebrachial cutaneous nerve (LACN)[3], terminal posterior interosseous nerve, and the dorsal cutaneous branch of the ulnar nerve in the upper limb[4], and the sural nerve (SN) and lateral femoral cutaneous nerve (LFCN) in the lower limb[3,5].

The lateral antebrachial cutaneous nerve (LACN) was used as a nerve graft to bridge a defect in injured nerve. The LACN is a continuation of the musculocutaneous nerve that extends from the lateral cord and upper trunk of the brachial plexus. The nerve emerges from the anterior surface of the brachialis muscle just beside to the biceps brachii tendon at the level of the interepicondylar line[6]. This nerve runs adjacent to the cephalic vein in the superior forearm and terminates at the base of the thenar eminence[7]. The LACN is the primary sensory nerve to the territory of forearm skin most commonly harvested. The LACN have enough length to be useful in replacing small defects.

The lateral femoral cutaneous nerve (LFCN) usually emerges from the lateral border of the psoas major muscle and crosses the ilium as it runs toward the anterior superior iliac spine, its course is variable[8]. The LFCN passes under the inguinal ligament and it divides into anterior and posterior branches over the sartorius muscle into the thigh. The anterior branch becomes superficial below the inguinal ligament and distributed to the skin of the anterior and lateral parts of the thigh[9]. The variations of the course of the LFCN have been described by a number of authors about iliac crest bone craft. Recognizing the variability and the relationship of the LFCN and its branches in relation to specific anatomic landmarks is important to gain the nerve during nerve grafting.

The sural nerve (SN) is the generally preferred donor nerve in the leg. 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[10]. The SN is formed by two main nerve branches: the medial sural cutaneous nerve (MSCN), a branch of tibial nerve and a communicating branch (Cb) from the lateral sural cutaneous nerve (LSCN), a branch of the common peroneal (fibular) nerve. The MSCN is normally described as the tibial nerve, forming the SN after joining the ramus communicans of the common peroneal nerve. The site of union of the MSCN and LSCN to form the SN is highly variable. However, there are not enough clinical-anatomical studies about the SN.

The LSCN as an alternative to the SN for grafting because its diameter and length were similar, and the resultant sensory deficit would be less[11]. The LSCN can also be utilized in a sensate composite free flap for various reconstructive procedures[12,13,14]. The SN is accessible to ease for harvest and the high fascicular density and minimal branching and acceptable donor defect. Therefore the nerve has been used as a nerve graft such as median nerve[3,15], ulnar nerve[3],inferior alveolar nerve[5], radial nerve[15], and facial nerve[16].

The purpose of this study was to provide guidelines for nerve graft selection by detecting topographic appearances of donor nerves and similarities between common donor and injured nerves with regard to the cross-sectional area and number of nerve fascicles. Therefore, this study was investigated to provide a morphologic description in the variability of its branching pattern, piercing point from fascia, and location of first division from main branch of the LACN and LFCN. Furthermore, the SN was identified communicating and uniting pattern of the SN is formed by the MSCN and the LSCN. The topographical study investigated the variation of the LFCN course relationship with the reference line and the emerging point. The reference line is between the anterior superior iliac spine (ASIS) and the middle point of superior margin of patella. The number of fascicle and fascicular area of cutaneous nerves were calculated including a microscopic assessment.

A rationale governing the selection of appropriate segments of the cutaneous nerves as donor graft tissue for repair was formulated by using the data obtained and that available for the injured nerve.

The present study is to provide the criteria for the selection of appropriate segments of the cutaneous nerves, particularly as donor graft nerve available for injured nerve by using the data obtained in the topography and histomorphometry.

II. MATERIALS AND METHODS

80 Korean cadavers (46 males, 34 females) were dissected in the present study. The mean age of cadavers was 64.7 years (range 13－101 years). For the topographic study of the cutaneous of the forearm and lower limb, 81 cases was used for the LACN, 74 cases was used for the LFCN, and for the SN was used 71 cases. Each the cutaneous nerves were classified the branching pattern and checked the branching point of first branch. Also the perforating point of the cutaneous nerve was examined the anterior branch of the LACN and LFCN. The SN was formed the MSCN and communicating branch of LSCN. The MSCN was the main nerve of the SN. Therefore the perforating point of the MSCN was identified at this study.

The reference point of the LACN was the interepicondylar line of humerus and wrist crease. The length between the points was divided four equal parts. The reference point of the LFCN was the anterosuperior iliac spine (ASIS) and superior border of the patella. The length between the points was divided five equal parts and the line through the points was used by reference line for running the anterior branch of LFCN. The relationship between the reference line and the course of the anterior branch from LFCN was examined. The SN was classified the communication and uniting pattern between MSCN and communicating branch of LSCN. The location of the MSCN perforates the fascia have been identified. These points were determined with the reference to transverse line the five equal parts dividing between the head of fibula and the lateral malleolus.

The topographic relation of the SN and the small saphenous vein was examined.

Nerve samples for histological examination (about 1 mm lengths) were cut the each level of anterior branch from the LACN and the LFCN. The MSCN, the CbLSCN, and the SN were harvested at the point where they emerged from the fascia. These specimens were post-fixed for 72 hours with 4% paraformaldehyde and then embedded in paraffin wax. Transverse 4-μm-thick sections were cut along the nerve branches, mounted on glass slides, and then stain with haematoxylin-eosin and Luxol fast blue. Histological observations were performed with the aid of a light microscope, and photographs were taken with a Spot RT digital camera (Leica, DFC300FX, Germany). The images of the sections were measured using an image analyzing system (Image-Pro® Plus, ver. 4.0, Media Cybernetics, USA) after standard calibration. The measurement items are mean of fascicular number, average fascicular diameter and area, and total fascicular area. The number of fascicles was counted in each nerve section with light microscopy at 40 magnification. Each fascicle appeared to be compartmentalized by perineurium. Images were digitally captured at 100 magnification, and the area of the nerves was measured using an image analyzing system. The data were analyzed with Microsoft Excel software to obtain the mean areas and the mean numbers of fascicles.

No distinction was made between male and female cadavers. And all photographs and diagrams in this article were of structures viewed from the right side.

III. RESULTS

1. The lateral antebrachial cutaneous nerve

The LACN was demonstrated to emerge from the anterior surface of the brachialis muscle to the lateral aspect of the brachii tendon at the around interepicondylar line. The running pattern of the LACN divided into three types (Fig. 1). The one nerve divides into two was in 90.1% (n=73). In 3 cases (3.7%) were branched into three from one trunk. And the other 5 cases were running parallel with two nerve branches (6.2%). The branching point of first branch from the LACN was signified in 53.1% (n=43) at the first distal part from interepicondylar line and 4.9% (n=4) was branched at the third part (Fig. 2). The LACN was branched 4 cases (4.9%) upper from interepicondylar line. The emerging point of the LACN was measured from interepicondylar line. The nerve pierced the brachial fascia an average of 12.9 mm (49.2%, n=30) upper from the interepicondylar line and 28 cases was located an average of 15.5 mm lower from the interepicondylar line. Also 3 cases (4.9%) were emerged on the interepicondylar line (Fig. 2).

The mean number of fascicles was 5.8 in the first part and 2.5 in the fourth part from interepicondylar line (Fig. 3). There was a significant decrease in fascicular number as the distal portion of the nerve was approached. But the third part from interepicondylar line was measured 5.7. A fascicular area was 0.05 mm^2 in the first part and a fascicular area was gradually smaller until third part but at the forth part (0.05 mm^2) was measured similar with first part from interepicondylar line. The total fascicular area in the cross section of the nerve was 0.26 mm^2 in the first part and toward a distal part (0.12 mm^2) from interepicondylar line was became small area. There were differences in fascicular area between the first part and the fourth part interepicondylar line.

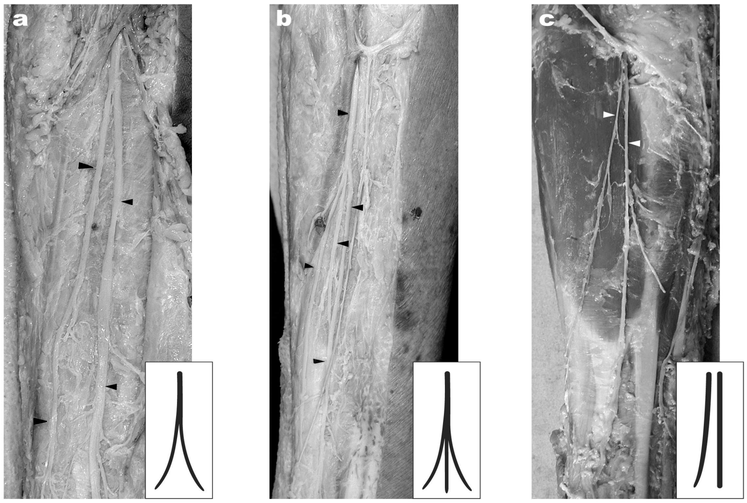
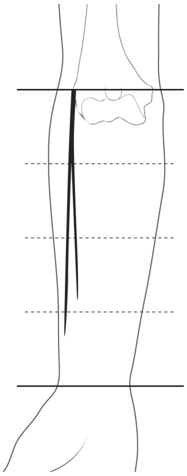
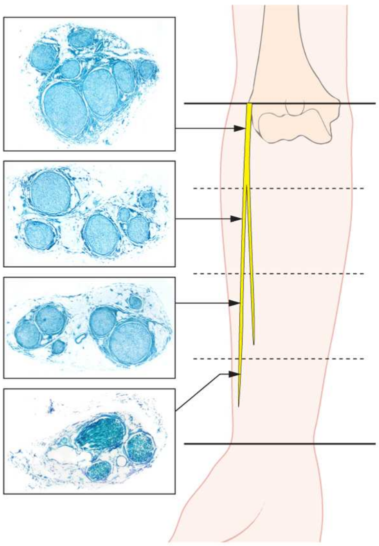


Fig. 1. Running patterns of the lateral antebrachial cutaneous nerve (LACN). a, Type I (90.1%, n=73); b, Type II (6.2%, n=5); c, Type III (3.7%, n=3).



Branching point	Distance of fascial perforation
4.9% (n=4)	49.2% (12.9mm)
	4.9% (on line)
53.1% (n=43)	45.9% (15.5mm)
37.0% (n=30)	
4.9% (n=4)	

Fig. 2. Percentages along the levels of branching and piercing point of the LACN and the distance of the fascia piercing point from the interepicondyle.



Mean of fascicle number (ea)	Mean of fascicle area (mm^2)	Mean of nerve area (mm^2)
5.8	0.05	0.26
4.7	0.04	0.18
5.7	0.03	0.17
2.5	0.05	0.12

Fig. 3. Histomorphometry of the LACN. The values indicate the number and their mean area of fascicle and mean of nerve area excepting connective tissue.

2. The lateral femoral cutaneous nerve

The topographic data about the LFCN was ordered after which the cutaneous nerve comes out in inguinal ligament. The branching pattern was classified four types (Fig. 4). Type I was bifurcated from the common trunk with a lateral branch and an anterior branch in 48.7% (n=36). In type II (20.3%, n=15), a lateral branch from the common trunk existed and an anterior branch was branched the other branch. In the case of type III, a lateral and an anterior branch was separated from inguinal ligament (22.9%, n=17). Type IV was separated three branches; a lateral branch and separated anterior branch (8.1%, n=6). The first branching point of the anterior branch was investigated after inguinal ligament (Fig. 5). Branching at the second part from the ASIS was observed the most cases (41.9%, n=31). At the first part was observed 33.8% (n=25). At the third and fourth part were identified 14.9% (n=11) and 1.3% (n=1) respectively. The case of no branch observed 6 cases (8.1%). The anterior branch of the LFCN examined piercing point from fascia lata (Fig. 5). In this case was invested only the cases remaining a fascia (n=44). At the third part from the ASIS was observed 75% (n=33) and the second part was 13.6% (n=6). At the fourth and first parts were 9.1% (n=4) and 2.3% (n=1) respectively.

The anterior branch of the LFCN was identified the relationship with the reference line (Fig. 5). The anterior branch was running at the lateral side of reference line in 45.9% (n=34), the course on the line in 39.2% (n=29) and the medial side was 14.9% (n=11).

The nerve specimen for histomorpometry after the third part from the ASIS no prepared because the cutaneous nerve was too thin. The mean number of fascicles was 3.8 in the first part and 3.5 in the second part from the ASIS (Fig. 6). A fascicular area was 0.1 mm^2 in the first part and the second part was 0.07 mm^2. The total fascicular area in the cross section of the nerve was 0.37 mm^2 in the first part and the second part was 0.2 mm^2. It compared at the first and second part in a fascicle and total fascicular area of the LFCN that the decrease range of fascicular area was larger than the other cutaneous nerves.

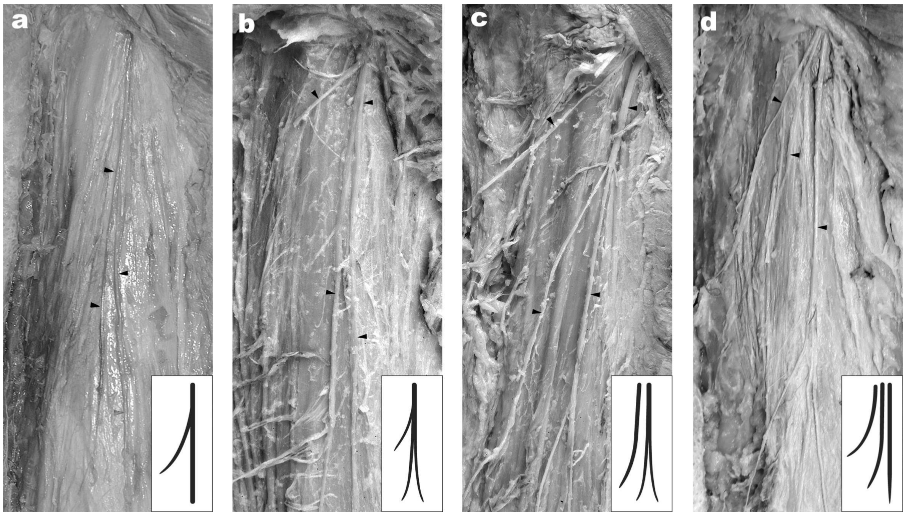
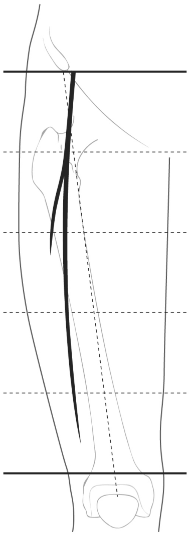
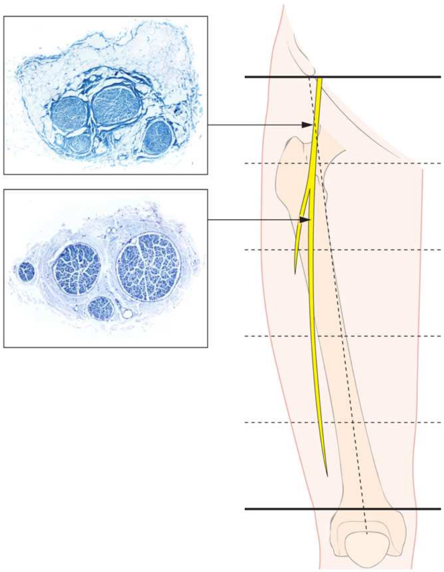


Fig. 4. Branching types of the lateral femoral cutaneous nerve (LFCN). a, Type I (48.7%, n=36); b, Type II (20.3%, n=15); c, Type III (22.9%, n=17); d, Type IV (8.1%, n=6).



First division of anterior branch	Perforation fascia of anterior branch
33.8%(n=25)	2.3%(1/44)
41.9%(n=31)	13.6%(6/44)
14.9%(n=11)	75.0%(33/44)
1.3%(n=1)	9.1%(4/44)
One branch: 8.1%(n=6)	

Fig. 5. Percentages along the branching and perforating point of anterior branch from the LFCN.



Mean of fascicle number (ea)	Mean of fascicle area (mm^2)	Mean of nerve area (mm^2)
3.8	0.10	0.37
3.5	0.07	0.20

Fig. 6. Histomorphometry of the LFCN. The values indicate the number and their mean area of fascicle and mean of nerve area excepting connective tissue.

3. The sural nerve

The communicating and joining patterns of the SN formed by the MSCN and the CbLSCN were classified into the following five types in 67 cases (Fig. 7). Type I, II, III and IV were joined the MSCN and the CbLSCN (79.1%, n=53), and type V was not joined (20.9%, n=14). Type I, II and III were formed the SN that the MSCN joined with communicating branch from the LSCN (61.2%, n=41), but in the case of type IV, the SN was formed with communicating branch arising from the MSCN (17.9%, n=12). In the case type I, the MSCN was thicker than the CbLSCN (14.9%, n=10), type II, the thicknesses of the MSCN and the CbLSCN were similar (16.4%, n=11), type III, the CbLSCN was thicker than the MSCN (29.9%, n=20), type IV, the existence of a communicating branch arising from the MSCN and the LSCN was thicker than the CbLSCN, and type V, the CbLSCN was not exist and the MSCN was thicker than the LSCN.

The region where the MSCN and the CbLSCN joined was observed in 52 cases. In 28 cases of the specimens (53.8%), the joining point with the MSCN and the CbLSCN was found in the lower two-fifths of the calf. In the other cases, the joining point was located at the middle (34.6%, n=18), lower one-fifth (7.7%, n=4), and upper two-fifths (3.8%, n=2) of the calf (Fig. 8). However, there was no case in which the joining point was located at the upper one-fifth of the calf in the present study.

The point where the MSCN pierced the deep fascia was observed in 66 cases, with this frequently located at the middle of the calf in 41 cases (62%).

In the other cases this point was at the lower two-fifths (23%, n=15), upper one-fifth (6%, n=4), upper two-fifths (6%, n=4), and lower one-fifth (3%, n=2) of the calf (Fig. 8). In no cases did the CbLSCN pierce the deep fascia below the distal two-fifths of the calf. In every case the SN ran with the small saphenous vein at the lower calf, and was located anterior to the small saphenous vein in 56 cases (78.8%) (Fig. 7). In cases where the MSCN and the CbLSCN joined, the mean length of the SN from the joining point to the lateral malleolus was 113 mm (range 40~200 mm). The mean length from the point where the MSCN pierced the deep fascia to the lateral malleolus was 152 mm (range 118~210 mm).

A histomorphometric investigation of the SN revealed that the mean number of fascicles was 8.1 (range 2－12) at the lower calf and 5.8 (range 1－11) at the middle before where the MSCN and the CbLSCN joined. The mean total areas of the fascicles were 0.55 mm^2 and 0.43 mm^2 at the SN and the MSCN, respectively. In the case, the CbLSCN had 0.42 mm^2. The mean diameters of the MSCN and SN were 4.9 mm^2 and 5.4 mm^2 and the CbLSCN was a small diameter (3.7 mm^2) (Fig. 9).

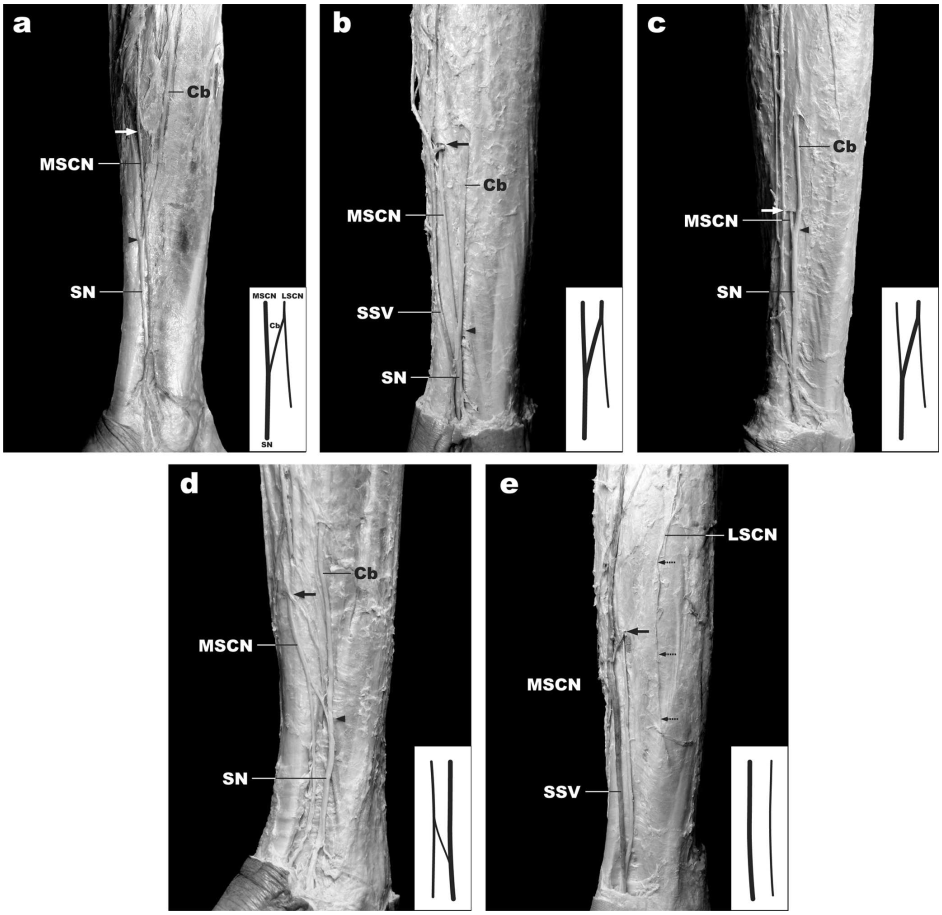
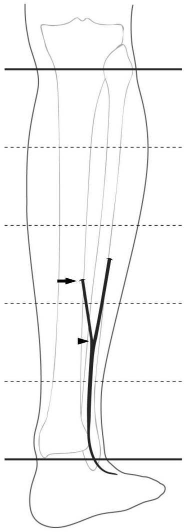
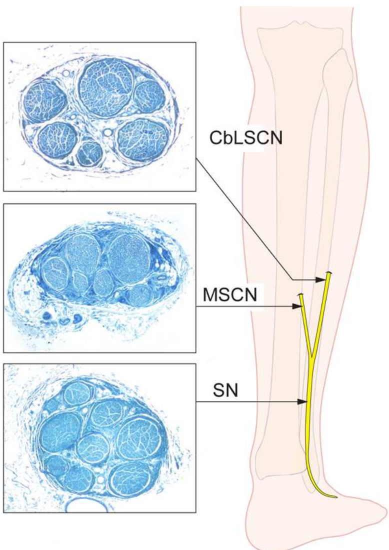


Fig. 7. Communicating and joining patterns of the medial sural cutaneous nerve (MSCN) and the lateral sural cutaneous nerve (LSCN, dotted arrows) at the posterolateral side of the right calf. Cb, communicating branch; SN, sural nerve; SSV, small saphenous vein; joining point (arrowhead); piercing point (arrow). a, Type I (14.9%, n=10); b, Type II (16.4%, n=11); c, Type III (29.9%, n=20); d, Type IV (17.9%, n=12); e, Type V (20.9%, n=14).



Joining level	*Piercing point of the MSCN*
–	6.0%
3.8%	6.0%
34.6%	62.0%
53.9%	23.0%
7.7%	3.0%

Fig. 8. Percentages along the levels of joining and piercing point of the MSCN. Fascia piercing point of the MSCN (arrow); joining point (arrowhead)



Mean of fascicle number (ea)	*Mean of fascicle area (mm^2)*	*Mean of nerve area (mm^2)*
5.8	0.42	3.7
5.8	0.43	4.9
8.1	0.55	5.4

Fig. 9. Histomorphometry of the MSCN, the Cb of the LSCN (CbLSCN), and the SN. The values indicate the number and their mean area of fascicle and mean of nerve area excepting connective tissue.

Table 1. The comparison between the results of the present and the previous studies of the SN.

Study	Number of cases	Ethnicity	Contributing nerves (% of cases)	
			MSCN and CbLSCN	MSCN alone
Ortigüela et al. (1987)[11]	20	Caucasian	80	20
Mahakkanukrauh and Chomsung (2002)[20]	152	Thailander	67.1	32.2
Present study (2007)	71	Korean	79.1	20.9

IV. DISCUSSION

The piercing point and location of the branching determines the maximum length of the nerve segment as well as the histologic features of the nerve. Most of the nerve fibers of the fascicles contain motor and sensory components. At the proximal part nerve fibers are not yet arranged to function, but at the peripheral part the motor and sensory components of the nerve fibers are already arranged according to branching and division[17]. The fascicular pattern changed along the entire length of a nerve. The fasciculi repeatedly divide and unite to form fascicular plexuses that are a feature of nerve cross-section. Fascicular plexuses are responsible for producing repeated changed in the size, number, arrangement and branch fiber content of the fasciculi at levels along the nerve[18]. In peripheral division of the nerve is very important to unite the corresponding fascicle parts of the cross section. However the branching pattern of the nerve is important factor for nerve graft.

The most components of sural cutaneous innervation are the SN, the MSCN and the LSCN, and the peroneal communicating branch of the LSCN[11]. de Moura and Gilbert[19] pointed out that communication exist between the medial division of the LSCN and the MSCN. Hill et al.[3] and Ortigüela et al.[11] reported that the SN was formed by the union of the MSCN and the peroneal communicating branch of LSCN in 80% of cases and was a direct continuation of the MSCN in 20%. The study of Mahakkanukrauh and Chomsung[20] showed that the SN was formed by the union of the MSCN and the LSCN in 67.1% of cases and the continuation of the MSCN alone in 32.2%. In this study, It is suggested that the SN is consistently present and most commonly formed by the union of the MSCN and the peroneal communicating branch of LSCN (79.1%) and not joining the MSCN (type V, 20.9%), which is similar to that found in other studies (Table 1). Hill et al.[3] reported that the MSCN was always larger than any contribution from the peroneal nerve. In this study, the MSCN was similer and larger (type I and II) than the medial division from the peroneal nerve (31.3%) except the cases that the MSCN separated with the LSCN. The CbLSCN was larger than the MSCN in 29.9% of the cases (type III). The CbLSCN seems to be an ideal site for nerve graft, as the loss of sensation in donor site would be minimized. However, these cases (type I, II, III and IV) were observed in 79.1% of the cases. Anastomotic localization of the MSCN and the CbLSCN is important in the context of a surgical approach to the nerve. In other study, the SN was formed by the union of the MSCN and the LSCN in the popliteal fossa in 12% of cases, and in 84% of cases, the union occurred in the lower third of the leg[21]. Mahakkanukrauh and Chomsung[21] found that the site of convergence of the MSCN and the LSCN forming the SN often occurred in the lower third of the leg (67.4%) and showed additional sites of union from the popliteal fossa to the ankle, with two SNs formed in the middle third of the leg (1.9%) and just below the ankle (25.5%). In this study, the region where the MSCN and the CbLSCN joined was mostly observed at the lower 2/5 of the calf in 52% of the specimens. The others were the cases that the joining points were located at the middle (38%) and the lower 1/5 of the calf (10%). However, the case that the joining point located at the upper 2/5 of the calf was not observed in this study.

In a limited survey of the SN, Sunderland and Ray[2] reported that the average of the maximum length prior to branching was 26 cm, but it was unclear whether the first branch was a communicating branch or a calcanean branch[5]. Brammer and Epker[5] reported that the average length of an unbranched segment was 24 cm but the length from localization of the anatomosis of the MSCN and the CbLSCN to the malleolus was 15 cm. In this study, the average length of the SN (113 mm) and the length from the point that MSCN pierced the deep fascia to the lateral malleolus (152 mm) were in agreement with the observations of Hill et al.[3] and Brammer and Epker[5]. The important factor influencing the results of nerve repair is tension at the suture site[22]. Therefore, the length of a donor nerve get over 10% of the length of a graft to avoid tension[23].

A peripheral nerve is composed of many fascicles. Each fascicle is associated with supporting Schwann cells and is wrapped in thin collagen tissue, termed the endoneurium. This cylindrical structure becomes important in nerve degeneration and regeneration after injury. Each fascicle is bounded by perineurium, a connective tissue layer of multiple concentric lamellae. A fascicle is a group of nerve fibers packed within its endoneurium and wrapped within perineurium. Fascicles can also be found clustered in groups of some, surrounded by loose connective tissue, the inner (internal) epineurium. These groups of fascicles are encased by the outer (external) epineurium, a dense layer of connective tissue surrounding the entire nerve[24].

The similar cross-sectional area and number of fascicles in the criteria for nerve graft make a basis to provide guidance for selection by examining similarities between donor nerve and recipient nerve[25]. Knowledge of fascicular number and area may be essential for achieving optimal results in nerve graft. In nerve grafting procedures the selection of a donor nerve with similar fascicular area and number would enhance the results.

The study about the LACN was examined by Higgins et al.[25] and Tank et al.[26]. A number of fascicles was observed in 4－6 and 4－9, respectively. A cross-sectional area of nerve was examined 1~1.5 mm^2 by Higgins et al.[25] and the mean fascicular area of the LACN was obtained in 34.68 mm sq^{-2} by Tank et al.[26]. The present study examined a number of fascicles in 5.8 and the mean area of fasciculi was 0.26 mm^2. The cross-sectional area of a nerve occupied the fascicular tissue varies that range from 25 to 70%[18] and Tank et al.[26] was calculated the mean percent of the LACN fascicles occupying the entire LACN bundle in 26.7%. When this data was used to compare other data, a number of fascicles was not significantly different from each data.

Hagan[16] described the nerve as being 2 mm in diameter and composed of about two large fascicles in the calf. In the histomorphometric study, the average number of fascicles was 8.1 (2－12) at the lower of SN and 5.8 (1－11) at the middle calf before where the MSCN and the CbLSCN joined. The average of total area of the fascicles was 0.55 mm^2 and 0.43 mm^2 at the lower and the middle calf. The cases of the CbLSCN was 0.42 mm^2. The average diameter of the LSCN, CbLSCN, and SN was 3.7mm^2, 4.9mm^2 and 5.4mm^2, respectively.

This study demonstrates that the surgeon must view the sural nerve at the ankle level as a common sural nerve. The SN almost appears with the small saphenous vein[27] between the achilles tendon and the lateral malleolus[28]. In the LFCN, the ralatonship between the reference line and the course of anterior branch from the LFCN was located at lateral side (45.9%). When rate from Zhao et al.[29] was compared, there was no statistical difference (43%). This anatomic situation affects the harvesting of the donor nerve for grafting. When the donor nerve is harvested for nerve grafting purposes, these results will provide a useful reference for graft procedures. And then it may be beneficial in developing more effective clinical procedures.

Interfascicular nerve grafting is a useful method to repair a injure nerve. There are many donor nerves such as the lateral femoral[9,29], sural[16], and lateral antebrachial[30] cutaneous nerves for autogenous nerve grafting. The intraneural topographical similarity between the recipient and donor nerve is thought to be important in nerve repair.

The ideal graft would have a larger than the nerve to be repaired would have the advantage of being better able to collect the sprouting axons of the proximal stump, but when the smaller distal stump is reached many of the sprouting axons would be lost. Small donor grafts would lead to reduce numbers of axons at the proximal junction[31].

A functional recovery can be expected after nerve grafting. Pollard and Fitzpatrick[1] have confirmed that regeneration through an autograft is similar to the regeneration that follows simple section and suture of a nerve. The factors of regenerating axons into fascicles regenerate within the fascicle are significant for functional recovery[26].

The significance of the full features about the donor and recipient nerve is provided with satisfactory regeneration in grafting. So, The topographic and histological information of the cutaneous nerve make better to choice a suitable donor nerve for injury nerve.

V. CONCLUSION

The following conclusions were obtained from a careful and precise dissection and the histomorphometrical observation at upper arms and lower limbs of eighty Korean cadavers:

1. The LACN and LFCN classified three and four types of branching pattern. The SN was formated five joining types by the MSCN, LSCN and CbLSCN.
2. Division point of first branch from the LACN was examined the first distal area (53.1%) from interepicondylar line and the first division of anterior branch from the LFCN was observed the second distal area (41.9%) from ASIS. The joining point of the LSCN and MSCN to form the SN was noted the fourth distal area (53.9%) from the calf.
3. The facial piercing point of anterior branch from the LACN was examined at the medial (49.2%, 12.9 mm) and distal (45.9%, 15.5 mm) of interepicondylar line and on the interepicondylar line was observed 4.9%. The anterior branch of LFCN pierced from the fascia at third distal area (75.0%) from ASIS. The perforation of the MSCN was noted at third distal area (62.0%) from the fibular head.
4. The greatest number of fascicle from the LACN was mean 5.8 at first distal division. The LFCN was mean 3.8 at the first distal area. The number of fascicle of the MSCN and CbLSCN was 5.8 and the SN was examined 8.1.
5. The mean area of fascicle of the LACN and LFCN was measured 0.05 mm^2 and 0.1 mm^2. The mean of fascicular area of the SN, MSCN and CbLSCN was examined 0.55 mm^2, 0.43 mm^2 and 0.42 mm^2 respectively.

6. The fascicular area of the cross-section of the LACN and LFCN was calculated 0.26 mm^2 and 0.4 mm^2. The SN was measured 5.4 mm^2 and the MSCN and CbLSCN were 4.9 mm^2 and 3.7 mm^2 respectively.
7. The anterior branch from LFCN run along the lateral side (45.9%) of reference line that is between the ASIS and middle point of basis patella. The location of the SN was anterior side (78.8%) to the small saphenous vein.

Knowledge of the aforementioned branching types in the cutaneous nerve and the histological analysis should help to choice the donor nerve for the injury nerve.

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국문요약

자가신경이식술을 위한 팔과 다리 피부신경의 국소해부와 조직학적 계측

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박 현 도

피부감각신경은 신경이식에 주로 사용된다. 위팔의 가쪽아래팔피부신경(LACN), 안쪽피부신경 및 노신경의 얕은가지와 넙다리의 가쪽넙다리피부신경(LFCN) 또는 자신경의 등쪽가지나 장딴지신경(SN)이 이용된다. 이 연구는 LACN, LFCN과 SN을 사용하여 한국인의 위팔과 다리의 피부신경에서 신경의 단면적과 다발의 수를 조사하여 신경이식을 할 경우 받는신경(recipient nerve)과 유사한 주는신경(donor nerve)을 찾기 위한 자료를 제공하고자 본 연구를 실시하였다.

한국인 남녀 80구를 사용하였다. LACN을 위해 81쪽, LFCN은 74쪽 그리고 SN은 71쪽을 사용하였다. 해부하여 국소해부학적 양상을 관찰하였고 조직학적 계측을 위하여 신경조직을 떼어내었다. 떼어낸 조직은 10%포르말린 용액에 넣어 고정시켰다. 각 조직은 파라핀블럭을 만들고 4μm 두께로 잘라 H-E염색과 Luxol fast blue염색을 한 후 현미경에서 계측하였다.

LSCN, LFCN과 SN의 주행양상은 세가지, 네가지 및 다섯가지유형으로 분류하였다. LACN의 첫 번째 가지가 나뉘는 지점은 융기사이를 연결한는 선에서 먼쪽 첫째에서 가장 많았다 (53.1%). LFCN에서 나오는 앞가지의 첫째 가지는 위앞엉덩뼈가시(ASIS)에서 먼쪽 둘째에서 많았다 (31예, 41.9%). 가

쪽장딴지신경(LSCN)의 교통가지(CbLSCN)과 안쪽장딴지신경(MSCN)이 만나 SN을 형성하는 경우가 52예였으며, 만나는 곳은 먼쪽 2/5지점에서 28예 (53.8%)가 관찰되었다. 팔의 근막을 뚫고 나오는 LACN은 융기사이선에서 위쪽으로 평균 12.9 mm 떨어진 곳에서 30예(49.2%), 아래쪽으로 평균 15.5 mm 위치에서 28예가 관찰되었다. LFCN은 ASIS에서 먼쪽 셋째부위에서 근막을 뚫고 나오는 경우가 많았으며(33/44예, 75.0%), SN은 종아리뼈머리에서 먼쪽 셋째에서 나오는 경우가 많았다(62.0%). LACN의 평균 신경다발의 수는 융기사이선의 몸쪽 첫째에서 5.8개였고 먼쪽 넷째에서 2.5개였다. 신경다발의 전체 면적은 0.26 mm^2이었다. LFCN은 ASIS에서 첫째에서 3.8개였으며, 신경다발의 평균 면적은 0.37 mm^2이었다. SN의 평균 신경다발의 수는 8.1개 였으며, MSCN과 CbLSCN은 5.8개이었다. SN의 신경다발의 평균 면적은 0.55 mm^2이었고 MSCN은 0.43 mm^2, CbLSCN은 0.42 mm^2이었다.

이 연구의 결과는 신경이식에서 주는신경(donor nerve)으로 이용되는 가쪽아래팔피부신경(LACN), 가쪽넙다리피부신경(LFCN)과 장딴지신경(SN)의 선택기준을 마련해 줄 것으로 기대한다. 각 신경의 신경다발의 면적과 다발의 수는 한국인에서 신경이식의 좋은 결과를 얻기 위한 안내자역할을 할 것으로 기대한다.

핵심되는 말: 신경이식, 가쪽아래팔피부신경, 가쪽넙다리피부신경, 장딴지신경, 신경다발