Neural Anatomy of the Anterolateral Thigh Flap

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Abstract The anterolateral thigh (ALT) flap is one of the commonly used sensate flaps for intra-oral, hand, and foot reconstruction. The objective of this study was to describe the anatomic location of the sensory nerves supplying the ALT flap in relation to the surface landmarks and with the vascular pedicles. The dissections were carried out in 28 embalmed specimens. An axial line from the anterior superior iliac spine to the superolateral border of the patella and two circles with radii of 5 and 10 cm centered on the midpoint of the former line were used for the surface landmarks. At the intersection point of the axial line and the 10-cm circle, the main lateral femoral cutaneous nerve (LFCN) and its anterior branch were located within 1 and 2.4 cm, respectively. At the intersection point of the axial line and the 5-cm circle, the anterior branch of the LFCN was located within 2.8 cm. The anterior branch of the LFCN can be detected within 3 cm from the central perforator pedicle in all specimens. The posterior branch of the LFCN, superior perforator nerve, and median perforator nerve were found in more variable locations. The findings from our study provide additional information for clinical use in the planning of sensate ALT flap harvest.

Keywords Anterolateral thigh flap · Sensate flap · Neural anatomy · Lateral femoral cutaneous nerve

Introduction

With the advance in microsurgical technology, a free flap can be used not only to cover soft tissue defects but also to provide the sensation for intra-oral, genital, breast, and foot weight-bearing area reconstruction [1–4]. Sensory nerve co-aptation in free flaps has been shown to be advantageous in terms of quality and speed in functional rehabilitation [5–7].

The anterolateral thigh (ALT) flap has been widely used in clinical practice for a sensate flap [8–11]. The dominant sensory nerve of the ALT flap is the lateral femoral cutaneous nerve (LFCN) arising from the dorsal divisions of the second and third lumbar nerves. It emerges from the lateral border of the psoas major and crosses the iliacus muscle obliquely toward the anterior superior iliac spine. It continues down the thigh dividing into an anterior and a posterior branch [11, 12]. Besides the LFCN, the ALT flap is also innervated with the superior perforator nerve (SPN) and the median perforator nerve (MPN), which are cutaneous sensory branches of the femoral nerve [12].

During the past 20 years, while several studies regarding the vascular and neural anatomy of the ALT flap have been reported, the topographic landmarks of each sensory nerve in the different flap sizes and designs have not been well systematically investigated [11, 13–16]. The goal of this study was to describe the anatomic location of the sensory nerves supplying the ALT flap in relation to the surface landmarks and with the vascular pedicles.

Materials and Methods

The sensory nerves and vascular pedicles were identified in 28 specimens (right 14, left 14) of 14 embalmed cadavers (male 7, female 7).

From the literature review, based on the perforators derived from the descending or transverse branch of the lateral

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circumflex femoral artery, a large ALT flap can be harvested, with some maximum dimensions reported in ranges of 25×18 , 20×26 , and 17×30 cm [14, 17, 18]. When the smaller flap was required, donor site defects for up to 10 cm can be closed directly by undermining the surrounding skin suprafascially [19]. Therefore, a skin territory of 10 and 20 cm in diameter was designed in this study.

First, surface landmarks were established (Fig. 1). A line between the anterior superior iliac spine (ASIS) and the superolateral border of the patella was drawn and used to determine the axis of the flap. A midpoint of this line is broadly accepted for the standard surgical landmark to identify the perforator vascular pedicle [11, 19–21]. Using this point as a center, two circles with radii of 10 (outer circle) and 5 (inner circle) cm were developed. The skin and dermis outside of the outer circle was removed. The LFCN, SPN, and MPN entering the outer circle were identified with the aid of a loupe with $\times 3.5$ magnification (Fig. 2). Adhering to the related literature, small and thin nerves with diameters less than 1 mm could be considered to be clinically insignificant and, therefore, were not included in the present study [12]. The dissection was continued inside the flap territory to determine the distance to correlate the nerves with the surface landmarks and vascular pedicles (Fig. 3). The measurements medially to the axis were recorded as plus and laterally as minus. The dermal innervations of the cutaneous branches arising from the LFCN, SPN, and MPN in the dermis were dissected. The location and length of the cutaneous branches of each nerve were also recorded.

Results

The LFCN was identified in all 28 dissections (100 %), whereas at least one additional nerve (SPN or MPN) was identified in every specimen as well. The MPN was identified in 19 of 28 (67.9 %) and the SPN in 23 of 28 (82.1 %) dissections.

The Anatomic Location of the Sensory Nerves in Relation to the Surface Landmarks

LFCN

The LFCN were bifurcated into anterior and posterior branches before entering the outer circle in 18 specimens

Fig. 1 Surface landmarks were established, and ALT flaps with a skin territory of 10 and 20 cm in diameter were designed

Fig. 2 Anatomical dissection of a left anterolateral thigh flap. LFCN lateral femoral cutaneous nerve, SPN superior perforator nerve, MPN median perforator nerve

(64.29 %), at the circular line in four specimens (14.29 %), and after entering in six specimens (21.43 %). In all specimens, the LFCN were separated into anterior and posterior branches and entered the inner circle. After entering the outer circle, the LFCN were in the deep subcutaneous layer (deep to Scarpa's fascia) and gradually became more superficial while running distally. After exiting the inner circle, the nerves were in the superficial subcutaneous layer (above Scarpa's fascia).

Fig. 3 The distance correlation of the nerves with the surface landmarks and vascular pedicles was measured

Table 1 LFCN

Structure	Distance from the axis (mm)	Diameter (mm)
The entering point at the outer circle (a radius of 10 cm)		
The main branch of LFCN	0.21 ± 0.77 (−1.0 to 1.0)	3.12 ± 0.31 (2.5 to 3.5)
The anterior branch of LFCN	0.71 ± 1.04 (−1.0 to 2.4)	3.01 ± 0.15 (2.0 to 3.2)
The posterior branch of LFCN	-0.38 ± 1.98 (−5.2 to 0.5)	2.20 ± 0.72 (1.5 to 3.5)
The entering point at the inner circle (a radius of 5 cm)		
The anterior branch of LFCN	0.26 ± 0.73 (−2.2 to 2.8)	2.76 ± 0.30 (2.5 to 3.2)
The posterior branch of LFCN	-2.11 ± 2.03 (−5.6 to 1.7)	2.04 ± 0.43 (1.5 to 2.5)
Location at the center of the circle		
The anterior branch of LFCN	-1.16 ± 0.89 (−3.0 to 2.5)	1.67 ± 0.35 (1.2 to 2.3)
The posterior branch of LFCN	-5.10 ± 2.04 (−7.2 to 1.5)	1.42 ± 0.31 (1.0 to 1.8)

Data are presented as means±standard deviations (ranges). The measurements medially to the axis were recorded as plus and laterally as minus.

The distances from each reference point and the nerve diameters are shown in Table 1 and Fig. 4. While exiting the inner and outer circles, all nerves have diameters less than 1 mm and were not included in the measurements.

SPN and MPN

The SPN and the MPN emerged through the sartorius muscle or at its lateral margin and entered in the upper-medial quadrant between the outer and inner circles. The distances from the axis to the points where these nerves enter the flap are shown in Table 2 and Fig. 4. In the superficial subcutaneous layer, the nerves run medially distally.

The Cutaneous Branches

The measurements are presented in Table 3. The amount of dermal innervations of the LFCN was higher in the lower half of the circle (6.07 ± 1.90 (4 to 9)) than in the upper half (18.79 ± 5.38 (12 to 31)) (Fig. 5). A small number of SPN branches (0.60 ± 0.30 (0 to 3)) and none of the MPN branches penetrated into the dermis inside the inner circle.

The Anatomic Location of the Sensory Nerves in Relation to the Vascular Pedicles

The perforators were identified. In the area of dissection, two perforators were found in six specimens (21.43 %), three perforators in 15 specimens (53.57 %), and four perforators in seven specimens (25 %). Based on its pathway in relation to the muscle, the perforator is classified as septocutaneous or musculocutaneous type [22, 23]; 34 perforators were of septocutaneous type (38.8 %) and 51 perforators were of musculocutaneous type (61.2 %). The location of the nearest perforator to the center and the distances between the sensory nerves in relation to these perforators are shown in Table 4.

Discussion

The ALT flap is one of the most popularized microvascular free flaps in reconstructive surgery because of its versatility and relatively minimal donor morbidity [9, 10, 19, 21]. It has been commonly used as a sensory innervated flap for hand,

Fig. 4 The locations of the LFCN, SPN, and MPN

Table 2 SPN and MPN

Structure	Distance from the axis ^a (mm)	Distance from the equator ^b (mm)	Diameter (mm)
The entering point of SPN	6.01±1.59 (4.0 to 7.9)	6.58±1.17 (5.1 to 8.5)	1.72±0.39 (1.1 to 1.9)
The entering point of MPN	.95±1.34 (5.6 to 9.8)	4.43±1.54 (1.1 to 6.7)	1.06±0.23 (0.9 to 1.7)

Data are presented as means±standard deviations (ranges)

^a The measurements medially to the axis were recorded as plus and laterally as minus

^b The measurements superiorly to the equator were recorded as plus and inferiorly as minus

intra-oral, and foot reconstruction. Although free flaps can be re-innervated without carefully considering the areas supplied by each specific nerve [24], many studies have demonstrated that the degree of sensory recovery of innervated flaps is significantly earlier and greater than that of noninnervated ones [1, 5–7]. To our knowledge, only limited topographic studies of the neural anatomy have been previously reported [11, 12].

The LFCN, SPN, and MPN were reported to be used for the nerves supplying the ALT flap [12]. Information regarding the correlated surface anatomy will assist the surgeon to locate and find these sensory nerves. In our study, we established the surface landmarks using an axial line from ASIS to the superolateral border of the patella and two circles with 5- and 10-cm radii centered over a midpoint of the line. The main LFCN or its anterior branch was persistently found close to the intersection point of the axial line and outer circle in all specimens. For 10 of 24 specimens (35.71 %), in which the LFCN did not bifurcate, the nerves were identified within 1 cm of this reference point. For the rest of the specimens (64.29 %), in which the LFCN bifurcated, the anterior branches were found within 2.4 cm. After bifurcation, the anterior branch of the LFCN proceeded downward within 2.8 cm of the intersection point of the axial line and inner circle in all specimens (Fig. 6). On the contrary, the posterior branch of the LFCN, SPN, and MPN were found in more variable locations.

To ensure that sensory nerve co-aptation would actually cause the re-innervation of the flap, performing a nerve block preoperatively is advocated to outline the area that becomes

Table 3 The cutaneous branches

Structure	The amount of dermal innervations (branches)	The length of cutaneous nerves (cm)
LFCN	24.86±5.45 (17 to 35)	2.72±2.32 (0.4 to 5.8)
SPN	8.74±2.43 (6 to 11)	1.80±1.29 (0.5 to 3.2)
MPN	4.21±1.75 (3 to 7)	1.40±0.88 (0.5 to 2.2)

Data are presented as means±standard deviations (ranges)

Fig. 5 The number of dermal innervations of the LFCN was higher in the lower half of the flap

numb [12, 24, 25]. Ribuffo et al. suggested injection of 4 ml of 2 % lidocaine at the groove between the ASIS and anterior inferior iliac spine (AIIS) for LFCN block. The SPN and MPN are blocked at 16±1 and 20±1.5 cm, respectively, from the ASIS, 1 cm medial to the lateral margin of the sartorius muscle [12]. With reference to the site of LFCN injection, the block is located proximally close to the inguinal area. It may not represent the actual innervation when the upper edge of the flap is designed further distally in the thigh and only one of either the anterior or the posterior branch is included in the flap. Drawing of the surface landmarks, as described in Fig. 4 of the present study, will guide the surgeon to the proper site of selective nerve block in the vicinity of the flap. The sartorius

Table 4 Relationship measurement

Relation	Distance (cm)
The central vascular pedicles to the center of the circle	-1.99±1.25 (0.3 to -3.6) from the axis ^a
	-0.34±2.21 (4.9 to -3.1) from the equator ^b
The anterior branch of LFCN to the central vascular pedicle	0.80±0.88 (-0.3 to 2.9) ^a
The posterior branch of LFCN to the central vascular pedicle	-3.88±1.99 (0 to -6.6) ^a
The SPN to the central vascular pedicle	6.82±1.39 (5.4 to 8.3) ^a
The MPN to the central vascular pedicle	8.22±1.24 (7.3 to 9.8) ^a

Data are presented as means±standard deviations (ranges)

^a The measurements medially to the axis were recorded as plus and laterally as minus

^b The measurements superiorly to the equator were recorded as plus and inferiorly as minus

Fig. 6 Illustration of the surface landmarks and nerve locations. *CL* common LFCN, *AL* anterior branch of LFCN, *P* vascular pedicle

muscle was proposed as a landmark for the SPN and MPN blockage. However, its superficial outline may be difficult to define in a patient with thick subcutaneous tissue. The anatomic variation and absence of this muscle have also been reported [26, 27]. Alternatively, the surface landmarks set up from the bony prominent structures including the ASIS and superolateral border of the patella in our study can be used. The comparison of the accuracy between both references in blockage should be further investigated.

According to our finding, as the anterior branch of the LFCN can be detected within 3 cm of the perforator pedicle in all specimens (Fig. 6), the ALT flap would be a reliable alternative even when a small size of sensory flap is required. The density of dermal innervations from the LFCN is higher in the distal half of the circle. We hypothesized that a flap design including more of this area may provide a better sensation following LFCN co-aptation. In the dissection, we found that the SPN and MPN mainly supplied the medial aspect of the thigh, corresponding to a previous report [12]. A small number of dermal innervations of these nerves were made within 5 cm from the center. Co-aptation of these perforator nerves may not provide the benefit for sensory innervation of the skin paddle around or lateral to the center.

The advantage of the ALT flap over other flaps is its minimal donor site morbidity. However, a recent systematic review reported that lateral thigh paresthesia is the most common complication, which is found in up to 24 % of patients [28]. When an ALT flap is designed, not including the sensory nerves, a dissection based on the surface landmarks as shown in this study may be useful to reduce the sensational loss of the donor area. In the area proximal to the distal edge of the inner circle, dissection superficial to or at the level of Scarpa's fascia is likely to preserve most of the major branches of the LFCN.

In conclusion, the anatomy of the main and anterior LFCN is consistent with the established surface landmarks proximal to the midpoint of the thigh, whereas the posterior LFCN, SPN, and MPN are more variable. This study provides information for clinical use in planning sensate ALT flap harvest and performing preoperative anesthetic blockage.

Conflict of Interest All named authors hereby declare that they have no conflicts of interest to disclose.

Ethical Standards This article does not contain any studies with human participants performed by any of the authors.

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