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Case-controlled Study

An anatomic study of the perforators from the peroneal artery. A new method to locate the cutaneous perforator

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ABSTRACT

Background: The goal of this study was to investigate the anatomy of the perforators from the peroneal artery in Vietnamese patients.

Methods: 30 cadaver's legs were dissected and investigated for the distribution, course, origin, number and types of perforators of the peroneal artery. The locations of the exit points on the skin of perforators were marked in relation to reference points and segments.

Results: The total number of cutaneous perforating branches of the peroneal artery from 30 specimens was 149, which included 63 (42.2%) musculocutaneous perforators and 86 (57.8%) septocutaneous perforators. In most cases, the perforator branches were located in the range from 4 to 7 of the total fibula length (69.8%). The average number of perforating vessels in a leg was 4.9, ranging from 1 to 8 vessels. All the perforators were positioned behind the posterior border of the peroneal bone. In all the dissected samples presented, there was always one cutaneous perforator within a distance of 18 mm from the F point, which is the junction between the 6/10 and 7/10 segments at the posterior border of the fibular bone.

Conclusion: The abundance of cutaneous perforators in Vietnamese patients can be used to plan various combined skin and bone flaps. A cutaneous perforator was consistently found near the F point, and this factor can be used in the planning of a bone flap with accompanying skin for monitoring survival of the underlying fibular bone flap.

1. Introduction

A vascularized fibula flap has been used to repair bone defects since Taylor's report of its application in 1975 [1]. Initially, the skin was not included in a fibula osseous flap. In 1983, Chen et al. modified this flap by including a skin paddle perfused by the perforating cutaneous branches of the peroneal artery for the reconstruction of bone and soft-tissue defects of the extremities [2]. Yoshimura et al. used a small skin flap based on an underlying perforating vessel (the Buoy Flap) for postoperative monitoring of the viability of the "buried" bone graft [3].

The results from other studies on the anatomy of vessels of the skin paddle showed that a free fibular graft can be combined with a fasciocutaneous flap, both of which are supplied by the peroneal artery. The inclusion of a skin flap allows for treatment of concomitant skin and bone defects [4–6].

As fragmentation of the peroneal bone has been shown not to compromise the viability of the bone segments in a vascularized fibular bone graft, a free fibula flap has become an option for the reconstruction of large mandibular defects. Hidalgo et al. was the first to use a free fibular flap for reconstruction of the mandible in 1989 [7]. The bone segment in the flap is sufficiently long to reconstruct the mandibular defect and restore the contour of the lower border of the jaw. The fibula osteocutaneous flap can be suitably used to reconstruct mandibular defects including the oral mucosa and facial skin [8]. Many authors now consider the fibula flap as the first option for most mandible reconstructions [9–11].

In Vietnam, we have been performing free fibula flap transplantation in our department since 1995. This technique has been applied to mandibular defects after resection of a bone tumor, osteomyelitis or ameloblastoma. A small skin paddle is included in the flap to serve as an indicator for monitoring the viability of the underlying tissues in the reconstruction of large defects that involve the mucosa or skin and bone combined. Therefore, understanding the regional anatomy of perforating branches of the peroneal artery is crucial for a successful surgery. As such, this study aimed to investigate the anatomical features of the perforating branches of the peroneal artery in Vietnamese patients and apply them for the reconstruction of skin and bone defects.

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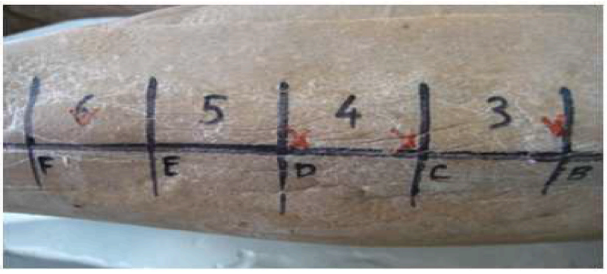
A

B



C

Fig. 1. Method to locate cutaneous perforators. A: Marking and labeling of reference points. B: Dissection on the anterolateral side of the leg to find the perforator branches of the peroneal artery. C: The locations of the perforators in relation to the reference points (marked with X in red color). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 1
The position of the cutaneous perforators at different segments.

Segments	Number of perforators			Number of Specimens (n, %)
	All (n, %)	Septocutaneous (n,%)	Musculocutaneous (n,%)	
1/10	4 (2.7)	2(2.3)	2(3.2)	4(13.3)
2/10	17 (11.4)	7(8.1)	10(15.9)	15(50) 17(56.7)
3/10	18(12)	4(4.6)	14(22.2)	24(80)
4/10	28 (18.8)	5(5.8)	23(36.5)	18(60) 25(83.3)
5/10	20 (13.4)	11(12.8)	9(14.3)	21(70) 5(16.7)
6/10	32 (21.5)	27(31.4)	5(7.9)	
7/10	24 (16.1)	24(27.9)	0(0)	
8/10	6(4)	6(6.9)	0(0)	
Total	149 (100)	86(100)	63(100)	

Table 2
Distribution of perforators according to the reference points.

Reference points	Number of perforators			Number of Samples (n, %)
	All (n, %)	Septocutaneous (n,%)	Musculocutaneous (n,%)	
A	14 (9.39)	4(4.65)	10(15.85)	12(40.00) 12(40.00)
B	13 (8.72)	7(8.13)	6(9.52)	21(70.00) 23(76.66)
C	23 (15.43)	4(4.65)	19(30.15	16(53.33) 30(100)
D	28 (18.79)	5(5.81)	23(36.50)	8(26.66) 3(13.33)
E	20 (13.42)	16(18.60)	4(6.34)	
F	38 (25.50)	37(43.02)	1(1.58)	
G	10 (6.71)	10(11.62)	0(0)	
H	3(2.01)	3(3.48)	0(0)	
Total	149 (100)	86(100)	63(100)	

Table 3
Distance from perforators to reference points.

Reference points	A	B	C	D	E	F	G	H
Longest distance (mm)	16.5	28.6	23.7	28.7	23.2	18	21.3	17.7
Shortest distance (mm)	4.1	3.2	3.5	1.4	2.0	2.5	8	15.9

2. Materials and methods

This study was carried out on 30 legs of 15 adult Vietnamese cadavers (9 males, 6 females) aged from 28 to 70 years (mean 43 years), who had no history of diabetes or peripheral vascular disease.

The locations of the fibular bone's processes, distal head and the posterior border of the fibula were marked on the skin. The posterior border of the fibula was divided into 10 equal segments numbered from 1 to 10. The junctions between segments were named from A to I (Fig. 1a).

An incision was made at the posterior aspect of the leg parallel to the posterior border of the fibula, which went through the fascia. Dissection was made anteriorly to find the arterial branches supplying the skin on the lateral side of the leg. Further dissection was made along the perforating branches in order to identify their course and origin (Fig. 1b); all branches originating from the peroneal artery were preserved. The arterial branches supplying blood to the skin were categorized into two types: septocutaneous perforators, which ran in between muscular bundles and terminated at the skin, and musculocutaneous perforators, which ran through the soleus and also terminated at the skin.

Locations of the perforator branches involved in each division were also numbered from 1 to 10.

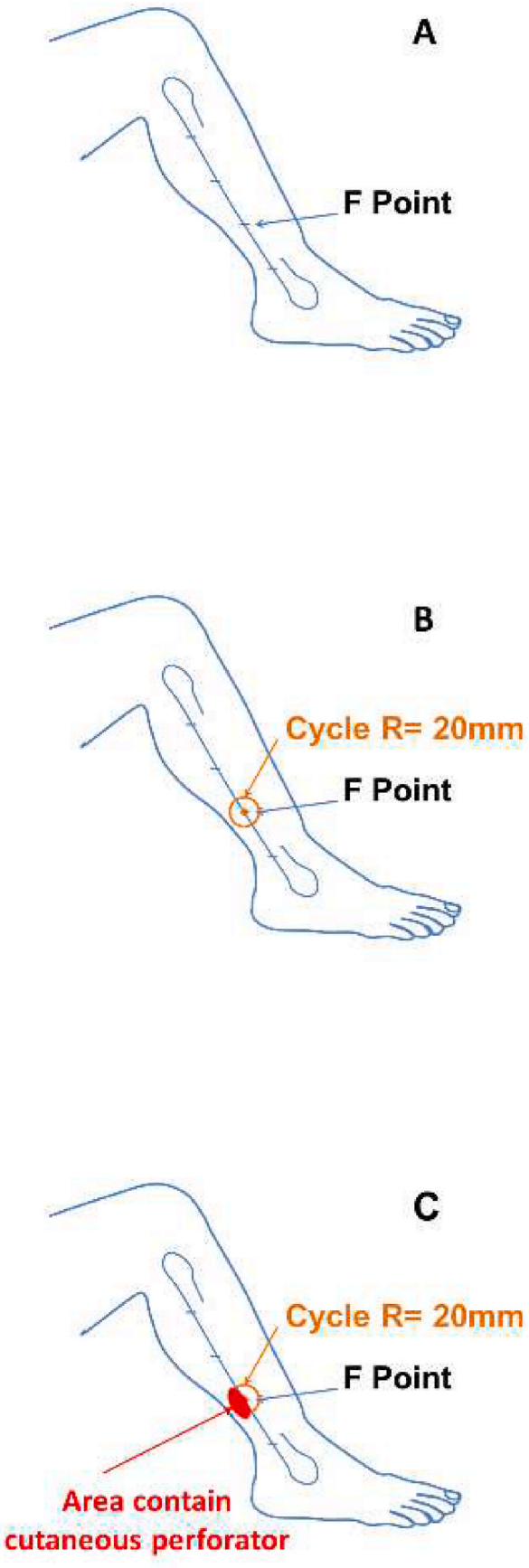
The exit points of the perforators on the skin (where they perforate the leg's fascia) were marked, and the distance from exit points to the nearest reference points were noted (Fig. 1c).

This study has been reported in line with the STROCSS criteria [12].

3. Results

3.1. Anatomy study

The total number of cutaneous perforating branches of the peroneal artery found in 30 specimens was 149, including 63 (42.2%) musculocutaneous perforators and 86 (57.8%) septocutaneous perforators.



(caption on next column)

Fig. 2. The location of the constant cutaneous perforator. A: A line of marking on the skin along the posterior margin of the fibular bone, connecting the two heads of the bone is created, and divided into five equal segments, in which the F point is the junction between segment 3/5 and 4/5. B: a circle with a radius of 20 mm taking F as the center is drawn. C: the area that includesthe posterior half of the circle (the area in red) contains at least one cutaneous perforator. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

The average number of perforators in a leg was 4.9, ranging from 1 to 8 vessels per leg (Table 1). All the perforators were located behind the posterior border of the peroneal bone.

In most cases, perforator branches were located between segments 4 and 7 of the whole fibula length (69.8%). The musculocutaneous branches of the peroneal artery were located in between segments 2 and 5 (88.9%), and the septocutaneous branches were located in between segments 5 and 7 (72.2%) (Table 1).

A perforator was consistently seen near Point F (between the segments 6/10 and 7/10) in all samples (100%). The highest number of perforators was also detected near Point F (25.5%), followed by Point D (18.8%) (Table 2).

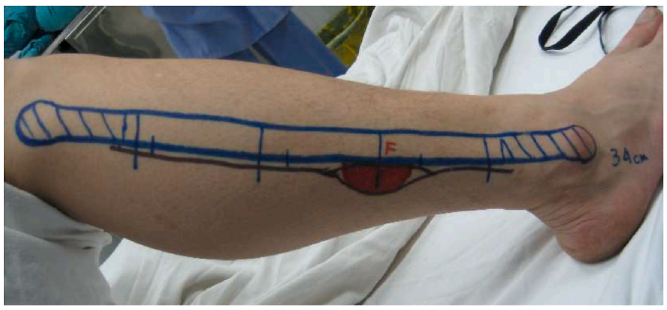
The distance between the exit point of a perforator to the nearest reference point was measured. As shown in Table 3, the distance varied from 1.4 to 28.7 mm. For the reference point F, the shortest and longest distances were 2.5 and 18 mm, respectively. As such, if we draw a circle taking point F as the center with the radius of 20 mm, all exits of the perforators can be found within this circle.

4. Discussion

The fibular flap is currently used as a free or pedicle flap in the treatment of trauma patients with long bone defects, nonunion or necrosis of the femoral head. It can also be used for defects of the maxillary and mandible bones [5,9,13,14]. However, the conditions of the flap, including the patency of the anastomosis and flap survival, are difficult to monitor, as it is covered by the local skin. Therefore, the peroneal cutaneous flap is preferred due to the attached skin paddle that can be used to monitor the survival of the bone flap, therefore also called a monitor flap. Peroneal artery perforator flap can be used for soft tissue reconstruction [3,15–17]. It should be noted that “through and through” defects or complex injuries in the head and neck area that involve multiple tissues such as bone, skin, mucosa require simple or chimeric cutaneous peroneal flaps, or even two more free flaps for their complete reconstruction [8]. The reconstruction of those complex defects with a combined skin and fibular bone flap in Vietnamese patients may be more manageable due to the availability of cutaneous perforators of the peroneal artery.

Our data showed that there were 1–8 (4.97 ± 0.35) perforator branches of the peroneal artery that supply blood to the lateral aspect of the lower leg; 93.4% of the samples had 3 perforators or more, in which 33.3% of samples had 4 perforators, and only 3.3% of the samples had 1–2 perforators. Wei et al. (1986) reported the presence of 4–7 perforator branches of the peroneal artery [6]. Similarly, Carr et al. (1988) and Schusterman et al. (1992) confirmed the presence of 3–8 perforator branches with diameters between 0.4 and 1.5 mm, including both septoperforators and musculoperforators [4,18]. Since the perforators occurred more frequently in segments 4, 6 and 7 (83.3%, 80%, and 70%, respectively), a combined skin and fibular bone flap based on these segments may have the highest chance of having cutaneous perforator branches.

Yoshimura et al. (1980) classified perforator branches into three types: A, B and C [19]. Type A branches are usually located in the proximal third of the lateral side of the leg, where they generally penetrate the peroneus longus muscle but rarely go through the soleus muscle. Type B branches are found along the whole lateral side of the leg, from its proximal to distal end, passing between the soleus and



A

B

C

Fig. 3. A fibular flap with a monitoring skin paddle for the reconstruction of defects of the mandibular bone. A: Design a flap on a patient. B and C: Raising and osteotomy of the fibular flap.

peroneal muscles and branching out to the adjacent muscles. Type C branches are found primarily in the middle and distal thirds of the lateral side of the leg. Type C branches, like Type B branches, pass between the soleus and peroneal muscles on their way to the subcutaneous and cutaneous layers but do not branch out to the muscles. Beppu et al. (1992) categorized the cutaneous branches into musculocutaneous (type A), septocutaneous with side branches (type B), and septocutaneous (type C) [20]. In their study on 23 legs, 110 perforating branches were identified, including 39 type A (38%), 64 type B (58%) and 8 type C (7%) branches. However, Heitman et al. (2003) denies this system of classification because he believed that it causes more confusion and is of little clinical relevance [21]. Moreover, type B and type C perforators run in the intermuscular septum, where they can easily be identified. Instead, Heitman classified these vessels into musculocutaneous (type A, 34%) and septocutaneous (type B, 66%) perforators. We applied the Heitman's classification system for perforators in our study - musculocutaneous and septocutaneous perforators. 149 cutaneous perforators were presented in 30 samples, in which perforators at segments 1/10 to 6/10 included both septocutaneous and musculocutaneous types. 55/60 (91.6%) perforators identified in segments 6/10 to 10/10 were septocutaneous, while all perforators located in segments 7/10 and 8/10 were septocutaneous. As such, a flap based on segments 6–8 may have very high chance of containing septocutaneous perforators, which are easier to dissect as compared to musculocutaneous ones, make the surgery shorter and lower risks of injury to the soleus muscle.

The reference points of perforators on the skin are all on or behind the posterior border of the fibular bone. This feature agrees with the anatomic characteristics of the peroneal artery, which is in the posterior compartment of the leg and separated from the anterior compartment by the intercostal membrane and lateral intermuscular septum. As this septum attaches to the posterior border of the fibular bone, the perforator's exit points are on or behind the posterior border of the fibular bone.

The distribution of cutaneous perforators in the posterior aspect of the leg has been mentioned in previous studies. Wei et al. (1986) concluded that one or two septocutaneous branches can provide an adequate blood supply to a skin area of about 22–25 cm in length and 10–14 cm in width centered at the posterior fibular margin and the junction of the middle and lower thirds of the fibula [6].

These findings from the Wei's study suggest that the exit points of the perforators on the skin on the lateral side of the leg can be accurately located. As shown in our data, similar findings were also observed in Vietnamese patients. All the dissected samples presented with a cutaneous perforator located near the F point, which is the junction between segments 6/10 and 7/10. This vessel was also observed in sample 12, which had only one cutaneous perforator at 7 mm away from the F point. The distances from perforators to the F point of all samples varied from 2.5 mm to 18 mm (Table 3). Our data showed that all cutaneous perforators were behind the posterior margin of the fibular bone, with at least one vessel consistently presented within 18 mm from the F point. The consistently present cutaneous perforators mentioned in Wei's study correspond to the cutaneous perforators located near the F point in our study. Therefore, we proposed a method to locate the cutaneous perforator as in the following: (1) mark on the skin the two heads and posterior margin of the fibular bone, (2) divide the line marking the posterior margin of the fibular bone into five equal segments and mark the F point that is the junction between segment 3/5 and 4/5 (Same the junction between segment 6/10 and 7/10) (Fig. 2a), (3) draw a circle with a radius of 20 mm taking F as the center (Fig. 2c), (4) a combined skin and bone flap will include the posterior half of the circle, which should contain at least one cutaneous perforator of the peroneal artery (Fig. 2c). This simple, fast and accurate method to locate the exit points of perforators has been applied in more than 100 patients (Fig. 3).

The territory of distribution of these cutaneous perforators was not investigated in this study due to the samples taken from cadavers. Therefore, these perforators were only used for planning of small flaps in order to monitor their survival. Further study would be required to evaluate the territory of distribution of these perforators.

5. Conclusion

The abundance of cutaneous perforator branches of the peroneal artery in Vietnamese patients can be used to plan various combined skin and bone flaps. A cutaneous perforator was consistently present near the F point (the junction between segments 6/10 and 7/10 at the posterior border of the fibular bone). This perforator can be applied in planning a bone flap with accompanying skin paddle for monitoring the survival of the underlying fibular bone flap.

Ethical approval

Ethical approval was obtained from institutional review board of local faculty and the participating hospital.

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Author contribution

Nguyen Quang Duc: Study concept, data collection, data analysis and writing the paper. Vu Ngoc Lam: Study concept, data collection, data analysis and writing the paper. Nguyen Phuong Tien: Study concept and writing the paper.

Declaration of competing interest

All authors declare no conflicts of interest.

Provenance and peer-review

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Consent

None.

Guarantor

Nguyen Quang Duc, Ph.D, MD.
Vu Ngoc Lam, Ph.D, MD, Associated Professor.

Registration of research studies

- Name of the registry: http://www.researchregistry.com
- Unique Identifying number or registration ID: researchregistry7848
- Hyperlink to your specific registration (must be publicly accessible and will be checked): https://www.researchregistry.com/browse-the-registry#home/registrationdetails/626a16e43f57d1001fa627cf/

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2022.103735.

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