

Map of perforators of the posterior tibial artery and peroneal artery using handheld doppler ultrasound evaluating clinical outcome of perforator flaps which cover soft tissue defects of the lower leg and foot

Le Hong Phuc^{1*}, Le Nghi Thanh Nhan¹

(1) University of Medicine and Pharmacy, Hue University

Abstract

Background: Soft tissue defects of the lower leg and foot are complicated injuries with numerous causes including trauma, ulcers, and Gout. Widespread treatment of these defects has been effectively applied with perforator flaps of the peroneal artery and posterior tibial artery. **Objectives:** 1. To construct a map of the perforators of the peroneal artery and posterior tibial artery using a handheld Doppler ultrasound. 2. To evaluate the clinical outcome of perforator flaps to cover soft tissue defects in the lower leg and foot. **Materials and method:** Cross-sectional study of 34 volunteers with no previous history of vascular diseases and the prospective study of 31 patients with soft tissue defects treated with peroneal artery perforator flap and posterior tibial artery perforator flap. **Results:** There are, on average, 4.7 peroneal perforating arteries. From the lateral malleolus to the fibula's head, the percentage of perforating arteries in the 2/10 and 6/10 segments is 85.3% and 97%, respectively. In the 2-3/10 segment, 94.1% have perforator arteries. There are, on average, 3.3 posterior tibial artery perforators. From the medial malleolus to the medial tibial plateau, it was found that 100% of volunteers had perforating arteries in the 3-4/10 segments and 61.7% in the 5/10 segment. Evaluation of postoperative results in 31 patients: 77.49% showed the right flap. The most common complications were edge necrosis (12.9%), partial necrosis (6.44%), and infection (3.23%). The donor sites showed good survival in 96.4% of patients, while partial necrosis resulted in 3.6%. A follow-up examination revealed that 90.32% of flaps had a good result, 9.68% had an average result, and no poor results were shown. 100% of donor sites had good results. **Conclusion:** An average of 4.7 perforators of the peroneal artery is detected by handheld Doppler ultrasound. Also, there are 1-2 relatively constant perforators in segments 2/10 and 5-6/10 from the lateral malleolus. On average, there are 3.3 perforators of the posterior tibial artery, primarily in the 3-4/10 and 5/10 segments proximally from the medial malleolus. 90.32% of the flap had good results.

Keywords: perforator flap, soft tissue defect, lower leg, foot, reconstruction.

1. INTRODUCTION

Soft tissue defects of the lower limb are common injuries, frequently associated with bone injuries, osteomyelitis, or bone necrosis, often leading to limb amputation. The risk of flap failure in the lower limb appears to be greater than in other locations due to the lack of elastic material and limited perfusion in this region.

Reconstruction of defects in the lower leg with either peroneal artery perforator (PAP) flap or posterior tibial artery perforator (PTAP) flap is a flexible and efficient therapy. A handheld Doppler to identify the perforator arteries and design the flap is a simple and accurate solution, up to 91.9%, according to Blondeel research [1]. A map of perforators being developed by a Doppler ultrasound is helpful. Furthermore, complications and treatment outcomes of PAP flaps and PTAP flaps in the lower limb have not been extensively studied.

Therefore, we conducted the research: "Constructing a map of the perforators of the posterior tibial artery and peroneal artery using handheld Doppler ultrasound and evaluating the clinical outcome of perforator flaps to cover soft tissue defects in the lower leg and foot" with two objectives:

1. Construct of the perforators of the peroneal and posterior tibial arteries using a handheld Doppler.
2. Evaluating the treatment outcome of PAP and PTAP flaps.

2. MATERIALS AND METHOD

2.1. Materials: 34 volunteers (18-50 years old) with no previously confirmed vascular disease and 31 patients with soft tissue defects in lower limbs treated with PAP and PTAP flaps were selected. All of the patients were treated in the Orthopedics -

Thoracic Surgery Department, Hue University of Medicine and Pharmacy Hospital, from 7/2019 to 4/2011.

2.2. Method:

* Objective 1:

A cross-sectional study was developed to investigate the number and location of perforators using handheld Doppler. Steps on how to perform this are discussed below:

Step 1: Draw the baseline from the fibula's head to the lateral malleolus, and divide into ten equal segments. The segments are marked distally to proximally.

Step 2: Identify the peroneal perforating arteries

with handheld Doppler (Hadeco Bidop Es100v3 Bi-Directional Doppler)

Step 3: Find the correlation between the Location of detected perforating arteries and the previously divided segments.

Step 4: Draw the baseline from the medial tibial plateau to the medial malleolus, and divide into ten equal segments. The segments are marked distally to proximally.

Step 5: Identify the peroneal perforating arteries with a handheld Doppler.

Step 6: Find the correlation between the Location of detected perforating arteries and the previously divided segments.



Picture 1. Location of the peroneal artery perforators by handheld Doppler.

* **Objective 2:** A prospective study was conducted on 31 patients. The treatment result and postoperative complications were monitored. The results were evaluated after 1-3 months based on Touam C and Vo Tien Huy's research, which classifies flaps as good, average, and poor. [2] [3]

* Flap: - Good: Good flap survive, primary heal.

- Average: Malnutritious flap, bluster or partial

necrosis of flap edge (< 1/3 site of flap), skin graft required or not, hematoma or infection,

- Bad: Flap necrosis from 1/3 to total flap, required another reconstructive treatment

* Donor site: - Good: Good primary heal, not infected, grafted skin survive

- Complications: Infection, fistula formation, necrosis of skin graft.

3. RESULTS

3.1. The map of perforating arteries detected by handheld Doppler:

3.1.1. The number of peroneal perforating arteries

Table 1. Number of peroneal artery perforators:

Number of perforator arteries	3	4	5	6	7	8
Number of calves (patients)	7 (20.6%)	9 (26.5%)	10 (29.4%)	5 (14.7%)	2 (5.9%)	1 (2.9%)

3-5 perforators per leg were found in the majority of volunteers (26/34 cases). On average, we found 4.7 ± 1.3 perforator arteries per leg.

3.1.2. Location of peroneal artery perforators:

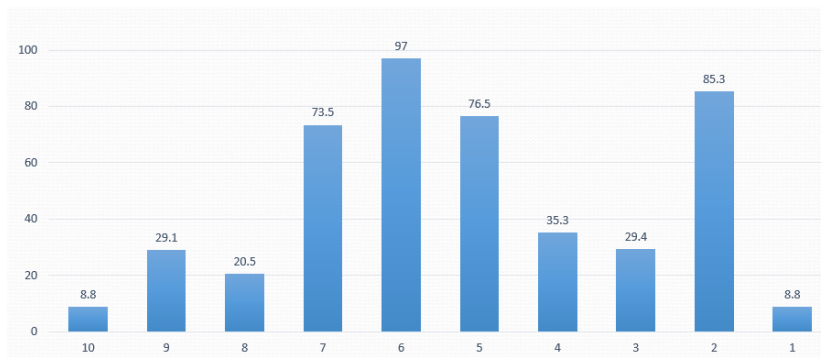


Chart 1. Proportion of the peroneal artery perforators by location.

The perforating arteries mainly concentrated on segments 2 and 6 from the lateral malleolus, 85.3%, and 97.0%, respectively, followed by segment 5 with 76.5%. The average distance between the lateral malleolus and the fibula's head was 33.4 ± 1.81 cm. A higher density of perforating arteries was found between 3.3 and 6.7 cm (segment 2), 13.4 and 16.7 cm (segment 5), 16.7 and 20.1 cm (segment 6).

3.1.3. The number of posterior tibial artery perforators:

Table 2. Number of posterior tibial artery perforators:

Number of perforator arteries (n=34)	2	3	4	5	6
Number of calves (patients)	8 (23.5%)	14 (41.2%)	7 (20.6%)	4 (11.75)	1 (2.9%)

2-4 perforator arteries were found per leg in the majority of volunteers (29/34 cases). On average, each leg had 3.3 ± 1.06 perforator arteries.

3.1.4. Location of posterior tibial artery perforators:

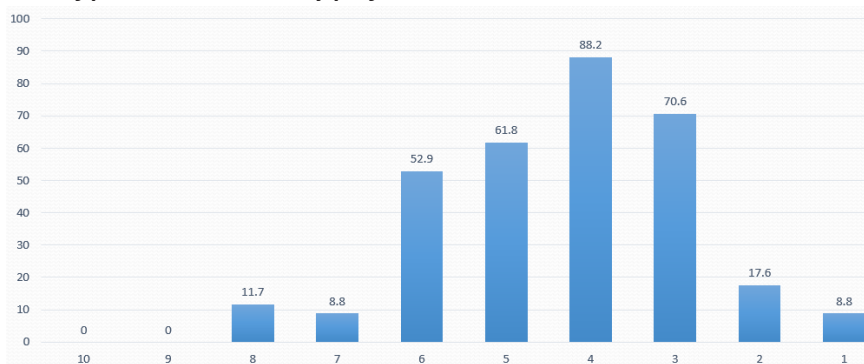


Chart 2. The proportion of the posterior tibial artery perforators by location.

Perforators of the posterior tibial artery mainly concentrate on segments 4,3 and 5, from the medial malleolus, with 88.2%, 70.6%, and 61.8%, respectively. If segments 3 and 4 were considered as a whole, perforating arteries can be found in 100% of volunteers.

The average distance between the medial malleolus to the medial plateau of the tibia was 33.9 ± 1.78 cm. A high density of perforators was found between 6.8 and 10.2 cm (segment 3), 10.2 and 13.6 cm (segment 4), 13.6 and 16.9 cm (segment 5).

3.2. Preoperative characteristics:

3.2.1. Etiology of the Defect:

The two most frequently reported causes of defects in the lower extremity were tophaceous ulcers (35.5%) and trauma (32.3%), which were mostly due to traffic accidents. Several other causes included infected ulcers (22.6%), burn injuries (6.5%), and carcinoma (one case, 3.2%).

3.2.2. Location of the Defect:

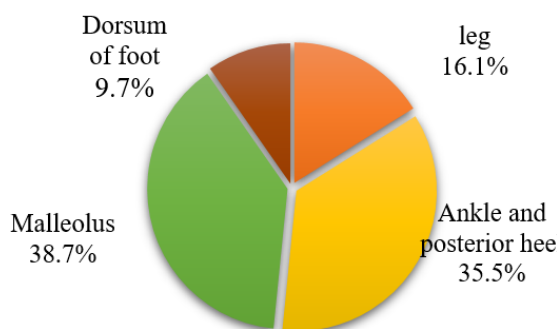


Chart 3. Location of soft tissue defects (n=31)

Most of the defects were found in the heel and malleolus (35.5% and 38.7%). The leg and dorsal foot had a lower rate of soft tissue defects.

3.2.3. The base of the defects:

Underlying tissue was exposed in 48.4% of cases. The most common issues were tendon (19.4%) and bone (16.1%).

3.3. Evaluation of treatment results:

3.3.1. Types of flaps and methods of transfer:

The PAP flaps were commonly used (67.8%), while posterior tibial artery perforators flaps were in 32.2%. The most common method was V-Y advancement (58.1%). The rotation flap in 9 cases (29.0%), and the rest were transposition flaps (12.9%).

3.3.2. Closure of the donor site

The primary closure was performed in 80.6%. A skin graft was in 6 cases (19.4%).

3.3.3. Flap and donor site status in the postoperative period:

3.3.3.1. Status of flap:

22.6% of patients had complications (n=7). The most frequent complications were edge necrosis in 12.9% (n=4), partial necrosis in 6.44% (n=2) and infection in 3.23% (n=1). The four flaps with distal necrosis were further corrected with either a skin graft or dissection, which all led to successful healing. The 2 cases with partial necrosis were treated with a full-thickness skin graft.

Table 3. Flaps in postoperative period (n =31)

Flap	Flaps in postoperative period					Total (n=31)
	Good survival	Edge necrosis	Infected	Partial necrosis	Complete necrosis	
PAP	16	4	1	0	0	21
PTAP	8	0	0	2	0	10
Total	24 (77.41%)	4 (12.90%)	1 (3.23%)	2 (6.44%)	0 (0%)	31 (100.0%)

3.3.3.2. Donor site result:

Table 4. Donor site survival

Donor site	Number of case (n=31)
Survival	30 (96.77%)
Partial necrosis	1 (3.23%)

In most of the cases, the donor site showed a good result in the postoperative period. Only one patient (3.23%) with partial necrosis was further treated with a skin graft.

3.3.4. Flap status after 1-3 month of monitoring:**Table 5.** 1-3 months monitoring

Evaluation		Number (n=31)
Flap	Good	28 (90.32%)
	Average	3 (9.68%)
	Poor	0
Donor site	Good	31 (100%)
	Bad	0

The rate of complete flap survival was 90.32% (n=28). There were 2 cases with partial necrosis and 1 case with edge necrosis, which was then classified as average result (9.68%). There was no case of complete necrosis.

The donor site showed promising results, with 100% of skin graft survival.

4. DISCUSSION

The handheld Doppler had excellent reliability in many researches. In Khan and G.Miller's study, handheld Doppler could identify the perforator artery with a sensibility of 87%, and Blondeel had an 80.6% right positive rate and a positive predictive value of 91.9% in discovering perforators [4][5]

An average of 4.7 ± 1.3 peroneal artery perforators was found in each lower limb. This is similar to the result found by Lykoudis (4.54 perforators in 52 cadavers), and Yooseok Ha (4.8 perforators) [6], [7]

Perforator vessels are consistently found in segment 2 (3.3 - 6.7 cm); segment 5 (13.4 - 16.7 cm) and 6 (16.7 - 20.1 cm) from the lateral malleolus. According to Fu-Chan Wei, there are 1-2 constant perforators on the posterior side of the fibula at the intersection of the middle third and the lower third of the leg [8].

The constant perforators in segments 5 and 6 discovered in our study were also found in the study of Matthew L.Iorio [9], and Nguyen Quang Duc [10] (the study of Vietnamese cadavers)

Table 6. Comparison of study on the peroneal artery perforators.

Study	10	9	8	7	6	5	4	3	2	1
Current study	8.8	29.4	20.5	73.5	97.0	76.5	35.3	29.4	85.3	8.8
Nguyen Quang Duc	12.5	53.1	56.3	87.5	68.75	96.8	71.9	18.75		
Matthew L. Iorio	3.6	8.2	36.7	68.9	62.5	79.1	73.5	55.6	21.2	5.6

3.3 ± 1.06 posterior tibial artery perforators were found. This was not similar to the conclusion of Drimouras [11] (5 perforating arteries). The reason for this may be due to the lower sensitivity of handheld Doppler compared with the study of cadavers.

In our study, segments 3-4 were quite similar when compared with the study by Liu and Koshima. Segment 5 was also similar to another study by Boriani and Schaverien. Even though these studies used cadavers, some similarity was found in the results of both methods.

Table 9. Comparison of study on the posterior tibial artery perforators:

Study (year of study)	10	9	8	7	6	5	4	3	2	1
Current study						x	x	x		
Boriani(2010) [12]				x	x	x		x	x	
Schaverien (2008) [13]				x	x	x		x	x	
Liu (1990) [14]							x	x	x	
Koshima (1992) [15]							x	x	x	

Our study showed that the two most common causes were ulcers and trauma, which is comparable to Vo Tien Huy [2] (the most common cause was trauma, 84.4%) and Nguyen Anh Tuan [16] (ulcers

occupied the highest percentage of 41.2%).

Complications of the flap in the postoperative period were 22.57%, which was lower than several other studies: Bekara (25.2%) and Innocenti (42.4%).

The donor site had a high percentage of survival, which was identical to the study of Yasir (96.4%) [17], [18].

Our study demonstrated good results in 90.32% of flaps during the short-term follow-up, higher than other studies conducted in Vietnam and other countries. For example, the study conducted by Vo Tien Huy and Yasir had a complete flap survival rate of 84.4% and 82.6% [18]. Furthermore, knowledge of anatomy, dissection skills, and better postoperative care may increase flap survival and decrease complications.

5. CONCLUSION

- There was an average of 4.7 peroneal artery perforators per leg. Several constant arteries were

concentrated in segments 2, 5, and 6, corresponding to 3.3 - 6.7 cm; 13.4 - 16.7 cm and 16.7 - 20.1 cm from the lateral malleolus.

- There was an average of 3.3 posterior tibial artery perforators per leg. Constant perforators were found in the segments 4-5/10 and 5/10, corresponding to 6.8-13.6 cm and 13.6-16.9 cm from the medial malleolus.

- The PAP flap and PTAP flap showed good results in 90.32%, average in 9.68%, and no case had bad result. Donor sites were good in 100% of patients.

- Perforator flaps have shown significant advantages, leading to satisfying results. Some of these include the practical preservation of the donor site and ensuring a satisfactory cosmetic outcome.

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Volunteer: H.D. 22 years old



Map of the peroneal artery perforators.



Map of the posterior tibial artery perforators.

Case 1: Patient V.N.B.L. 6 years old. Post-trauma ulcer; defect size 4x4 cm. Reconstruction by PAP flap, result after 3 months:

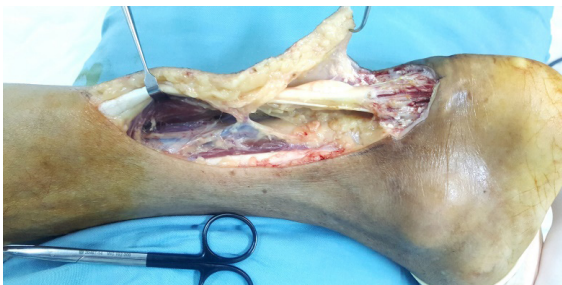


Case 2: Patient N.A.M. 8 years old. Motorbike accident; soft-tissue defect 5x4 cm; tendon exposed; Achilles tendon rupture. He was treated by suturing the tendon and PTAP flap. The excellent result is shown after two months.





Case 3: male 53 yrs patient, chronic Gout ulcer, Achille's tendon exposed 4x5cm, PTAP(4) island advancement flap. Good result after one week.



Case 4: male 43 yrs patient, distal third tibia bone exposed 3x5x10cm on external fixation device, cement spacer antibiotic, PTAP propeller flap coverage and FTSG for the partial donor site. Good result after three months.

