

Original Paper

PERFORATORS OF THE CALF ARTERIES - ANATOMICAL STUDY

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REZUMAT

Perforantele arterelor gambei - studiu anatomic

Scop: Acest studiu anatomic este menit să demonstreze existența vaselor perforante din cele trei mari artere ale gambei care pot susține un lambou. Bazate pe aceste perforante pot fi create lambouri cutanate, fascio-cutanate sau complexe pentru acoperirea diferitelor tipuri de defecte la nivelul membrului inferior sau la alt nivel al corpului.

Material și metodă: Studiul anatomic a fost efectuat pe 15 cadavre proaspete după injectarea substanței de contrast, Biodur S 14 roșu, în artera poplitee. Perforantele fiecărei artere mari au fost numărate, notându-se calibrul, distanța între originea din artera și tegument ca și tipul perforantei (musculocutanată sau septo-cutanată).

Rezultate: Au fost găsite perforante suficient de mari și numeroase, atât septocutanate (în diferite septuri intermusculare), cât și musculocutanate, cu o localizare și calibru previzibile ce pot fi folosite pentru a crea lambouri tisulare.

Concluzii: Studiile anatomice asupra perforantelor arterelor gambei reprezintă un instrument puternic pentru chirurgul plastician în încercarea sa de a rezolva cazurile dificile. Cunoscând cu exactitate localizarea și calibrul lor, putem crea lambouri bazate pe perforante care sunt versatile pentru reconstrucții complexe.

Cuvinte cheie: lambouri perforante, studiu anatomic, artere perforante, artera tibială posterioară, artera tibială anterioară, artera peronieră

ABSTRACT

The purpose of this anatomical study is to prove the existence of reliable perforator vessels arising from the three main arteries of the calf. Based on these perforators, cutaneous, fasciocutaneous or complex flaps can be

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raised to cover different types of defects of the leg or other parts of the body.

Material and method: An anatomical study was performed on 15 fresh cadavers, after injecting the contrast substance, Biodur S14 red, in the popliteal artery. The perforators of the main arteries were counted, their caliber noted, the distance from the artery origin to the skin and also the type of perforator (musculocutaneous or septocutaneous) determined.

Results: Reliable perforators were found for each main arteries of the calf, both septocutaneous (in different intermuscular septa) and musculocutaneous, with a predictable location and caliber that can be used successfully in creating perforator flaps.

Conclusions: Anatomical studies of the perforator vessels in the calf region represent a powerful tool for any plastic surgeon in the attempt to solve difficult cases. Knowing their exact location and caliber, we can design reliable perforator flaps that enable us to perform complex reconstructions.

Key words: perforator flaps, anatomical study, perforator arteries, posterior tibial artery, anterior tibial artery, peroneal artery

BACKGROUND

In reconstructive surgery, perforator flaps have a short history. Not more than 27 years ago, Nakajima et al. described the six types of perforator vessels known at present: direct cutaneous, direct septocutaneous, direct cutaneous branch of muscular vessel, perforating cutaneous branch of muscular vessel, septocutaneous perforator and musculocutaneous perforator [1]. (Fig. 1)

The knowledge about these perforator vessels continuously grew, by identifying the vascular networks of the entire body, formed by the perforator vessels. Therefore, it became possible to create a lot of perforator flaps based on these perforator vessels [2]. Thus, perforator flaps can be considered the latest milestone in the evolution of reconstructive flap surgery. Many methods are used for investigating the exact location of the perforators, such as imaging methods: computed tomography, magnetic resonance angiography and lately thermal imaging that became also reliable [3]. The exact knowledge of the location and caliber of perforators became a real help for plastic surgeons, especially in the calf area, where the reconstructive method has to

accomplish the functional and aesthetic needs for both reconstructed and donor areas.

MATERIALS AND METHOD

This study began in 2009. 15 dissections on fresh cadavers within “Mina Minovici” Institute for Legal Medicine were performed with the approval of the Institute Board, the bodies being unknown persons.

From the 15 bodies, 7 were females and 8 were males, aged from 38 to 82 years.

The inclusion criteria were: age less than 85 years, no visible signs of recent trauma, no scars or deformities at the calf level.

The exclusion criteria were: age over 85 years, the presence of toes or foot amputation, which would suggest the presence of peripheral arterial disease, physical signs of severe associated diseases.

The data obtained were statistically analyzed using T Test (Student). The correlations between variables were obtained using Spearman’s Rank.

The position of the body was in ventral decubitus and an incision was performed in the popliteal fossa. The popliteal artery was identified and cannulated with ligation of all leaking points. Then the artery

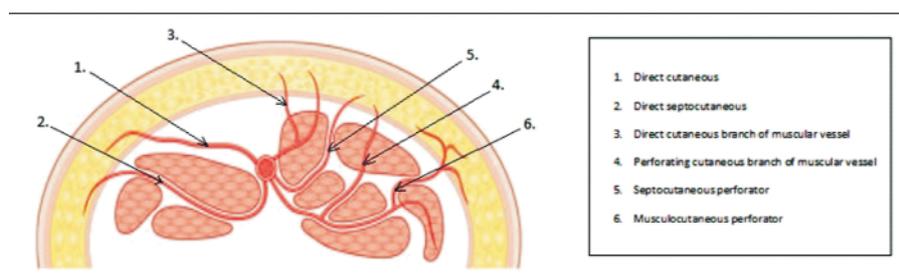


Figure 1. Types of perforators

was irrigated with heparinized saline solution (10 UI/ml) at 37 degrees Celsius until a clear effluent was obtained. The contrast substance was injected in the popliteal artery, Biodur S14, and the body was left at room temperature for 24 hours, to allow the substance to pervade in the perforator arteries. After this, dissections of the posterior tibial artery, anterior tibial artery and peroneal artery were performed. The number, caliber and distance between the origin of the perforator vessel and the area where it pierces the deep fascia to reach the skin territory were taken into account. With the foot in neutral position, medial and lateral incisions were performed from the medial and lateral malleoli to the knee region. First dissection was performed in the suprafascial layer in order to identify each perforator and locate the points where they pierce the fascia. After sectioning the fascia, dissection was performed following the course of the perforators to the main artery. The caliber of the perforator vessel and distance to the origin from the main artery were considered, also counting the number of each type of perforators: septocutaneous and musculocutaneous.

RESULTS

For the 15 dissected bodies, the mean age was 63.96 with a minimum of 38 and a maximum of 82. The mean leg length for men was 37.38 ± 1.4 cm and for women 34 ± 1 cm.

For the posterior tibial artery, a number of perforators with a range between 4 and 7, with a caliber between 0.2 and 0.8 mm were found, the middle lower leg perforator being the constant one, meaning that it was present in all cases. The distance between the origin and the point where they pierce the deep fascia was between 1.5 and 4 cm. The mean

number of septocutaneous perforators was 2.93 ± 0.96 and of musculocutaneous perforators was 2.20 ± 0.94 .

A statistically significant difference ($p < 0.002$) between the number of perforators in men (5.88 ± 0.99) and women (4.29 ± 0.48) was noted.

A strong positive statistically significant correlation between leg length and the number of perforators ($R=0.626$; p value = 0.013) was also identified.

The septocutaneous perforators were found predominantly in the septum between soleus and flexor digitorum longus muscles. The musculocutaneous perforators were found on the medial, lateral and posterior aspects of the soleus muscle.

The perforators with the largest caliber were found in the middle third of the calf. (Fig. 2)

For anterior tibial artery we found a number of perforators between 6 and 9, with a caliber of 0.2-0.6 mm, and the distance to the piercing point in the deep fascia, between 1 and 3 cm. The mean number of septocutaneous perforators was 6.07 ± 1.03 and of musculocutaneous perforators was 2.13 ± 0.99 . Both types of perforators were found emerging in the intermuscular septum between tibialis anterior and extensor hallucis longus, from the tibialis anterior muscle and anteromedial septum. The frequency of perforators was higher in the upper and middle thirds of the calf. Constantly a large perforator was found accompanying the superficial peroneal nerve. (Fig. 3)

For the peroneal artery, a number of perforators between 3 and 6, with a caliber of 0.2-0.7 mm, and the distance to the deep fascia between 1 and 2 cm were found.

The mean number of septocutaneous perforators was 2.60 ± 1.12 and of musculocutaneous perforators was 1.53 ± 0.51 . They were found predominantly in the middle third of the fibula, mostly in the posterior

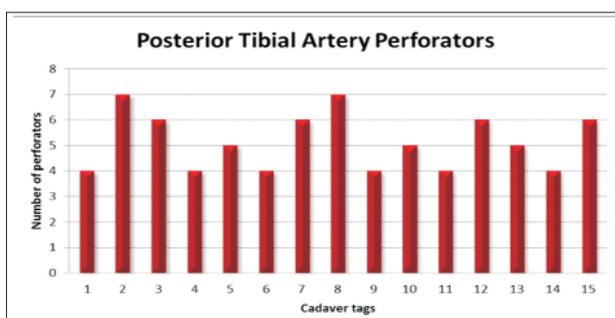


Figure 2. Graphic with the number of perforators for each dissected cadaver

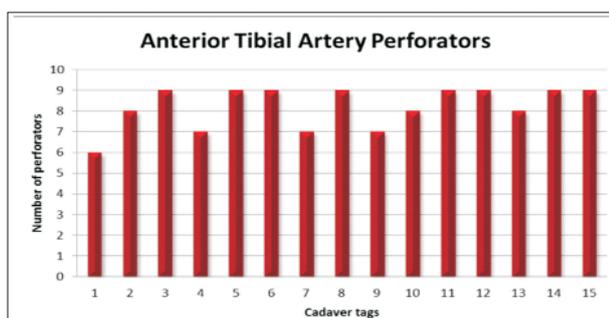


Figure 3. Graphic with the number of perforators for each dissected cadaver

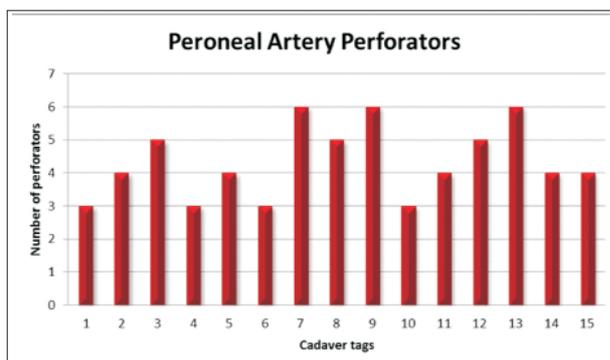


Figure 4. Graphic with the number of perforators for each dissected cadaver

peroneal septum. A constant perforator situated approximately 5 cm above the lateral malleolus was found. (Fig. 4)

DISCUSSION

The present study confirms that reliable perforators with predictable location and caliber can be found in the calf region, and based on these perforators, useful perforator flaps can be created to cover defects in any part of the body.

According to the data we gathered until now from anatomical studies, the lower extremity represents the largest donor site in the body for perforator flap harvest. The knee, calf and leg areas represent about 34% of the integument of the lower extremity, the integument being supplied by 30 ± 13 perforators with a diameter of 0.2-0.7 mm. Musculocutaneous and septocutaneous perforators are equal in number, and each perforator can supply an area about 40 cm [4].

From previous studies the number and location of the perforator vessels are predictable but certain variability exists if the recent data are analyzed. The perforators of the posterior tibial artery were found in this study to be mostly septocutaneous and also

with the largest caliber and approximately constant location. Their dissection was easier than for the perforators of the peroneal or anterior tibial artery due to their large caliber and also location in the intermuscular septa as previous studies of Boriani (2010), Schaverien(2008), Whetzel(1997), Koshima (1992) have proved. (Table 1)

From previous anatomical studies, it is known that posterior tibial artery supplies 10% of the integument of the lower extremity: $- 337 \pm 111 \text{ cm}^2$. It supplies the tibia in addition to the soleus, flexor digitorum longus and tibialis posterior muscles and throughout its course it supplies an average of 10 ± 4 perforators to the skin. Usually there is a row of four to five septocutaneous perforators that emerge from the intermuscular septum between the soleus and flexor digitorum longus that supply the overlying integument. These perforators anastomose superiorly with the descending genicular artery and form a long vascular chain that accompanies the greater saphenous vein. These perforators send medial branches to supply the periosteum of the tibia and anastomose over the tibial crest with perforators from anterior tibial artery. Three or four musculo-cutaneous perforators arise from the medial aspect of the soleus muscle. Other musculocutaneous perforators arise from the posterior and lateral aspects of the soleus muscle and supply the skin around the region of the calcaneal tendon.

Anatomical studies of the septocutaneous vessels of the leg showed a perforator that is consistently the lowest one, proximal to the medial malleolus. The largest perforators are those located in the middle two quarters of the lower leg, therefore free posterior tibial perforator-based flaps are reliable, relatively large, thin, making them useful without sacrificing the posterior tibial artery [4].

For the anterior tibial artery a number of

Table 1. Posterior tibial artery perforators

Study	Number of perforators	Caliber	Distance between the origin and deep fascia
Present study	5.1 ± 1.12	0.2 - 0.8 mm	1.5-4 cm
Wu et al. [5]	2-5	1.0-1.5	
Liu et al. [6]	3.3 ± 1.13		
Carrquiry et al. [7]	8 (6-10)	0.3-0.8 mm	
Whetzel et al. [8]	5.4(3-8)	0.5 - 1 mm	
Koshima et al. [9]	3.1 ± 0.8	0.8 ± 0.2	
Hung et al. [10]	5-8	$1.5 \pm 0.2 \text{ mm}$	
Schaverien et al. [11]	4.9 ± 1.7	1.0 - 1.5	3.2 ± 1.8

perforators between 6 and 9 were found, with a lesser caliber than for posterior tibial artery perforators, with a greater number of septocutaneous perforators than musculocutaneous.

Also known from previous anatomical studies, the anterior tibial artery gives an average of 6 ± 3 perforators to supply the skin over the anterior compartment of the leg. They are both musculocutaneous and septocutaneous; however the musculocutaneous perforators have a short course within the muscle before reaching the overlying integument. (Table 2)

The perforators emerge as two prominent rows: one row is from the tibialis anterior muscle or from between the tibialis anterior and extensor hallucis longus muscles; the other row is from the anteromedial septum. An especially large cutaneous perforator from the anterior tibial artery accompanies the superficial peroneal nerve into the integument. The most proximal branches of the anterior tibial artery are approximately 7 to 8 cm distal to the fibular head, descending longitudinally through the anterior intermuscular septum between extensor digitorum longus and peroneus muscles and penetrate the deep fascia in the middle third of the lower leg. The middle perforators arise from the anterior tibial artery about 12 to 14 cm distal to the tibial condyle, they course downward through the

intermuscular space between the anterior tibial muscle and the extensor digitorum longus muscle to penetrate the deep fascia at the junction of the upper and middle thirds of the lower leg. The most distal septocutaneous perforator arises at approximately 17 to 22 cm distal to the tibial condyle and runs caudally beneath the extensor digitorum longus muscle, and finally pierces the deep fascia to enter the skin in the lower two thirds of the lower leg. [4]

For the peroneal artery, in the present study a number of perforators between 3 and 6 were found, with a caliber of 0.2-0.7 mm, and the distance to the deep fascia between 1 and 2 cm.

Many anatomical studies were performed to assess the number and caliber of the perforators from the peroneal artery, for example Schusterman et al. made 80 cadaver dissections and found an average 3.74 cutaneous perforators from the peroneal artery; Yoshimura et al. first described the peroneal flap, they found 4.8 cutaneous branches. (Table 3)

These vessels tended to be musculocutaneous in the proximal one third of the lower leg and septocutaneous in the distal one third of the lower leg [16]. The perforators predominate in the 13 to 18 cm interval, so they are most frequently found in the middle third of the fibula, and there is a constant perforator at 5 cm proximally to external malleolus. [11].

Table 2. Anterior tibial artery perforators

Study	Number of perforators	Caliber	Distance between the origin and deep fascia
Present study	8.2 ± 1.01	0.2 - 0.6 mm	1-3 cm
Schaverien et al.[11]	9.9 ± 4.4	0.5-1 mm	2.8 ± 1.5 cm
Taylor and Pan[17]	6.2	0.81 mm	
Carrquiry et al.[7]	8 (6-10)	0.3-0.8 mm	
Whetzel et al.[8]	9.8(6-14)		

Table 3. Peroneal artery perforators

Study	Number of perforators	Caliber	Distance between the origin and deep fascia
Present study	4.3 ± 1.3	0.2 - 0.7	1 - 2 cm
Schusterman et al.[12]	3.74 ± 1.12		
Carrquiry et al. [7]	3 - 5	0.4 - 1.3	
Heitman et al.[13]	4.8 (3 - 7)	0.6 (0.3 - 1.5)	
Ozalp et al. [14]	4 - 7	0.8 - 1.1	
Beppu et al. [15]	4.8 (3.7)		
Yoshimura et al.[16]	4.8 ± 1.4	0.6 ± 0.2	5.4 ± 1.5
Taylor and Pan[17]	4.83	1.03	
Wolff[18]	4.2		
Whetzel et al.[8]	4.8 (1 - 7)	0.5 - 1.5	
Schaverien et al[11]	4.4 ± 2.3	0.5 - 1.5	3.7 ± 1.3

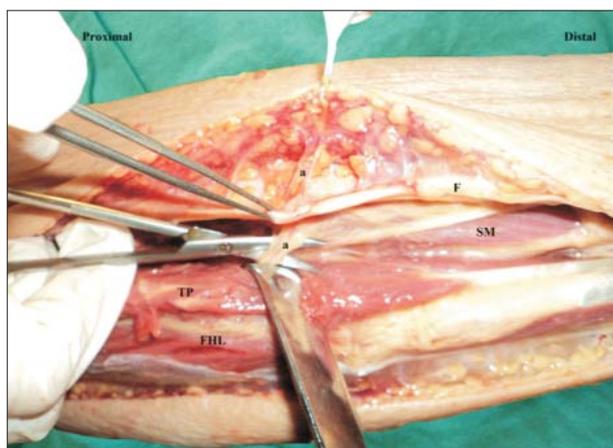


Figure 5. Cadaver dissection of the posterior tibial artery perforators: a - musculocutaneous perforator ; F – fascia; SM – soleus muscle; TP – tibialis posterior muscle; FHL – flexor hallucis longus muscle

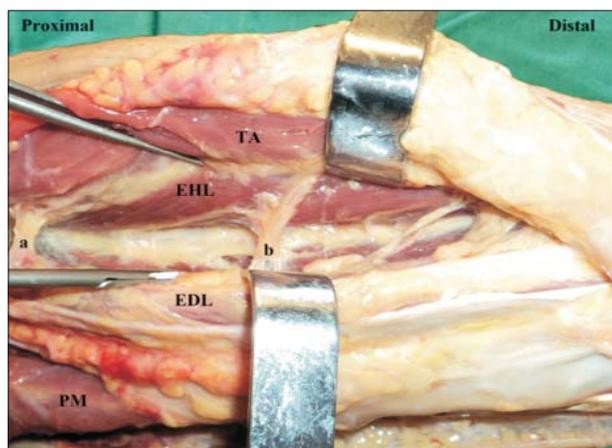


Figure 6. Cadaver dissection of the anterior artery perforators: a, b – musculocutaneous perforators; TA – tibialis anterior muscle; EHL – extensor hallucis longus muscle; EDL – extensor digitorum longus; PM – peroneal muscles

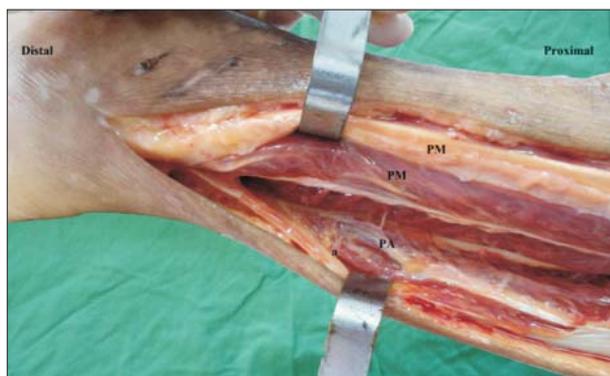


Figure 7. Cadaver dissection of the peroneal arteries perforators: a – septocutaneous perforator; PM – peroneal muscles; PA – peroneal artery

CONCLUSIONS

Anatomical studies of the perforator vessels in the calf region represent a powerful tool for any plastic surgeon in the attempt to solve difficult defects at this level and at any level of the body. Knowing their exact location and caliber, we can design reliable perforator flaps that enable us to perform complex reconstructions.

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