SKIN FLAP OF MEDIAL GASTROCNEMIUS MUSCLE'S PERFORATING ARTERIES: AN ANATOMICAL STUDY

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SUMMARY

Objective: *study of the anatomical parameters of a skin flap irrigation based on perforating arteries of the medial gastrocnemius muscle through medial sural artery.* ***Materials and Methods:*** *dissection of twelve legs and analysis of parameters such as medial gastrocnemius muscle's length and width, amount of perforating vessels for a skin flap, length and width of medial sural artery's pedicle, and medial sural artery origin relatively to popliteal cavus, in addition to perforating arteries localization data.* ***Results:*** *100% of legs presented with at least 2 perforating arteries with minimum diameter of 1 mm, and in 80% at least 3 perforating arteries were seen. The total amount of perforating arteries ranges from 2 to 4, in an average of 2.9. The average length of medial sural artery's pedicle was 37.6 mm, ranging from 20 to 50 mm, and the average diameter was 3 mm, ranging from 2 to 4 mm. Regarding the origin of the pedicle, nine cases showed a distal origin to intercondylar line, with average distance of 24.8 mm, ranging from -10 mm to 40 mm.* ***Conclusion:*** *data reported in this study corroborate data found in literature, enabling us to conclude that this flap shows a vascular pedicle with length and width allowing its use both in local and free flaps.*

Keywords: *Surgical Flaps; Muscle, Skeletal; Dissection.*

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INTRODUCTION

There is a great emphasis today on pursuing reconstructive solutions for skin or muscular loss areas requiring cover or stable cavitary filling, generating studies addressing flaps area.

Authors such as Buncke et al. and Lister[1,2] tried to establish the characteristics of an optimal flap, mentioning aspects such as:

- Minimal morbidity;
- Presence of little anatomical variation;
- Be located at the same body segment as the injured area;
- Variable use – bones-fascia-skin-nerve;
- Be technically feasible, meaning having a pedicle with a diameter that is compatible to microsurgical techniques;
- Have an appropriately long pedicle.

Skin flaps of which irrigation is based on the concept of perforating vessels are currently an increasingly employed alternative in reconstructive techniques [3,4].

Taylor[5], with a study on angiossomes of the skin vascular territory, started a revolution on reconstructive surgery grounds with the introduction of perforating pedicles flaps. The first flap of descending circumflex femoral artery system's perforating vessels irrigating the vastus lateralis muscle, also known as thigh anterolateral flap, was described by Song[6]. Also, in 2001, Wei et al.[7] defined that flaps based on perforating arteries are those nourished by perforating arteries of the adjacent deep fascia and can be dissected through the muscle up to its original vessel, not requiring the muscle to be inserted into the flap.

Hallock[8] was one of the first authors who demonstrated clinical cases using skin flaps based on perforating vessels of the medial sural artery. Cavadas et al.[9], reported the transposition of a free flap.

Currently, the gastrocnemius muscle has been the target of studies investigating the anatomical basis of dermal irrigation of flaps located at the posterior portion of the leg [10,11]. Flaps once regarded as musculocutaneous may have their irrigation not depending uniquely on the considered muscular territory.

It is known that all the posterior skin on the leg may be supplied, in a peninsular way, from popliteal caves up to malleoli height, with no vascular damage. This is seen in open-type amputations, in severe open fractures, in which major leg vessels are bonded above bone level (anterior tibial a., posterior tibial a., and fibular a.) without causing damages to the free posterior skin.

There are questions about whether skin maintenance happens similarly as in a fasciocutaneous flap, once the pedicled base is, many times, lower than free height, or irrigation comes from musculocutaneous perforating arteries of the medial gastrocnemius muscle, whose key pedicle is originated from popliteal artery. Maybe both concepts superpose, as stated by Hallock[10].

The objective of this study is to assess the anatomical parameters of skin flap irrigation based on the perforating arteries of the medial gastrocnemius muscle. This flap is comprised between the popliteal cavus region and the ankle malleolus, at the posterior portion of the leg.

MATERIALS AND METHODS

This study was conducted by dissecting twelve legs of six male cadavers.

We used the following exclusion criteria for cadavers' selection: presence of peripheral vascular disease as causa mortis, and the presence of scars on lower limbs.

Anthropomorphometric data for each individual were recorded:

- Gender; Ethnicity; Height; Weight.

During dissections, the following parameters were recorded:

- maximum length of medial gastrocnemius muscle;
- maximum width of medial gastrocnemius muscle ;
- number of perforating vessels at least 1-mm wide ;
- length of medial sural artery's pedicle ;
- width of medial sural artery's pedicle ;

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• Origin of the medial sural artery to knee intercondylar line (KIL);
• data for locating perforating vessels from medial gastrocnemius muscle as Cartesian coordinates.

DISSECTION

Dissection started by drawing a rectangle on leg's posterior portion, representing the area of a fasciocutaneous flap. The proximal base corresponds to the protuberance of fibular head at popliteal cavus[12], the biggest sides are parallel to lateral and medial edges of the posterior surface of the leg, and the distal edge at ankle malleolus height.

The incision was performed at a previously bounded area through skin, subdermal and fascial tissues. This isolation as islands separated this skin flap irrigation from the subjacent muscle.

The popliteal cavus region was then addressed by means of a median longitudinal incision, at adductor tuberculum height, proximally, until the proximal distal portion of the fasciocutaneous flap. The popliteal artery and its branches, medial and lateral sural artery were dissected and isolated. The extension of medial sural pedicle and its outer diameter were measured by using a rule with millimeter increments.

Popliteal artery was bonded in its proximal and distal portions from medial sural artery output, as well as lateral sural artery and the other wide arterial branches originated from popliteal artery on the isolated segment.

The popliteal artery was catheterized through cross-sectional incision and by passing a plastic cannula nr. 23, which was fixated with a 2.0 cotton suture. A vinyl/resin/acetone-based staining solution (10 ml) was injected as previously made by Rezende et al.[13], watching the skin area on the posterior portion of the leg to become stained, as well as the flap areas presenting dye leakage.

The skin flap was built from lateral to medial, taking care to locate the sural nerve and the small saphenous vein as lateral boundaries of the medial portion of gastrocnemius muscle. From this boundary, the dissection of medial gastrocnemius muscle's perforating vessels wider than 1.0 mm was performed.

The number of dissected perforating vessels was recorded, as well as their location compared to the emergence position on gastrocnemius muscle's venter, similarly to the technique employed by Hallock[10]. We must highlight that, at this point, the distance was recorded from the beginning of the muscular portion of gastrocnemius' venter (Figure 1).

RESULTS

Table 1 shows anthropomorphometric data for the subjects of the study.

From the 12 dissected legs, ten could be properly studied, two (subject 3) presented with a strong gastrocnemius degeneration, making impossible to determine the size of the muscle or the presence of perforating vessels. It was only possible to check the presence of the medial sural artery on both legs.

Amount of perforating vessels

In all legs studied, at least two perforating vessels with minimum diameter of 1.0 mm were found, which originated from the medial venter of medial gastrocnemius muscle, going towards the studies skin territory.

Eighty per cent of the legs had three perforating vessels or more. The total number of perforating vessels ranged from two to four, in an average of 2.9 (Figure 2).

Length of the medial sural artery's pedicle

The average length of the medial sural artery pedicle found was 37.6 mm, ranging from 20 to 50 mm, and its average diameter was 3 mm, ranging from 2 to 4 mm (Figure 3).

Origin of medial sural artery compared to intercondylar line

The pedicle origin was proximal to knee intercondylar line (- 10 mm) in only one flap. In the others, these were distal to the intercondylar line. The average for this distance was 24.80 mm, ranging from -10 mm to 40 mm (Table 2).

Medial gastrocnemius muscle dimensions and perforating vessels location

Medial gastrocnemius muscles assessed in this study presented with an average length of 20.55 cm, ranging from 19 to 23 cm, and its average width was 6.46 cm, ranging from 4.5 cm to 9.5 cm. (Table 3) The average emergence distance of the perforating vessels regarding medial gastrocnemius muscle length was 10.7 cm for the first perforating vessel, and 16.38 cm for the third perforating vessel. The only piece where a fourth perforating vessel was found, the emergence distance was 14 cm (Table 4).

Dye injection

By applying the dye through medial sural artery catheterization, it was possible to watch the pathway through which the major arterial pedicle of the flap reached the perforating vessels and ultimately stained the skin, as seen on Figure 4.

Nevertheless, skin staining was poor in four legs; in two of them, the dye progressed through sural artery, but it was blocked at the level of the perforating vessels.

DISCUSSION

As described by Cavadas et al; Hallock and Thione et al [9-11,14], we know that vascular anatomy of the skin area of leg's posterior portion is related to medial and lateral sural arteries and its perforating musculocutaneous branches through the gastrocnemius. However, skin and intramuscular distribution of these perforating branches, as well as the anatomical relationship between its pedicle and the gastrocnemius muscle are not yet totally clear [9].

The medial gastrocnemius muscle is characterized for being biarticular, constituting part of the sural triceps muscle's structure, together with the soleus muscle and the lateral head of the gastrocnemius muscle. Its role is to perform ankle's plantar flexion, as well as to contribute to the irrigation of leg's posterior skin territory.

Authors such as McCraw and Dibbel [15] noticed that the skin centralized over the muscle received perforating vessels coming straight from it. Should the skin segment of the flap extended beyond muscular territory, the peripheral portion became poorly vascularized, being only nourished by perifascial vessels and subdermal plexus.

Nevertheless, the new concept of perforating vessels enabled the

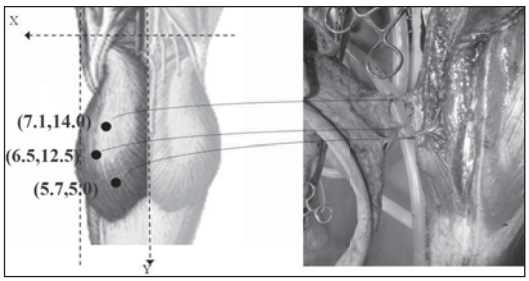

Figure 1 - *Method for locating medial gastrocnemius muscle's perforating vessels as coordinates vs. muscular venter dimensions – Leg 03.*

Cadaver	Age (years)	Weight (Kg)	Height (cm)	Gender	Ethnicity
1	41	70	175	M	mulatto
2	60	65	180	M	white
3	35	68	180	M	white
4	50	56	180	M	white
5	50	70	170	M	mulatto
6	46	70	180	M	mulatto
Average	47.00	65.50	177.50		
Standard Deviation	8.58	5.50	4.18		

Table 1 - *Anthromorphometric data.*

Figure 2 – *Perforating vessels output on medial gastrocnemius muscle - leg 4.*

Leg	Pedicle length (mm)	Pedicle width (mm)	Total perforating vessels	KIL* (mm)
1	48	3	2	-10
2	20	4	4	10
3	30	3	3	35
4	30	3	3	33
5	40	2	3	35
6	50	2	3	35
7	40	3	3	20
8	35	2	2	20
9	45	4	3	40
10	38	4	3	30
Average	37.60	3.00	2.90	24.80
Standard Deviation	9.19	0.82	0.57	15.32

*KIL: pedicle origin vs. knee intercondylar line measured as mm (negative if medial sural artery's pedicle is proximal to knee intercondylar line; positive if distal to the intercondylar line)

Table 2 *Values for medial sural artery's pedicle width and length (mm) and amount of perforating vessels found.*

Leg	Length (cm)	Width (cm)
1	19.0	9.0
2	19.5	7.0
3	19.0	4.5
4	19.0	5.0
5	23.0	7.0
6	23.0	7.0
7	20.5	6.0
8	20.0	5.5
9	21.5	6.6
10	21.0	7.0
Average	20.55	6.46
Standard Deviation	1.55	1.28

Table 3 – *Values for maximum length and width of medial gastrocnemius muscle.*

Leg	First Perforating Vessel	Second Perforating Vessel	Third Perforating Vessel	Fourth Perforating Vessel
1	8.0	17.0	-	-
2	8.5	10.5	13.0	14.00
3	12.5	14.0	15.0	-
4	12.0	13.0	16.0	-
5	13.0	16.5	19.0	-
6	16.0	18.5	21.0	-
7	10.5	12.5	13.0	-
8	7.5	16.0	-	-
9	10	13.5	19	
10	9	14.5	15	
Average	10.70	14.60	16.38	14.00
Standard Deviation	2.67	2.40	2.97	---

Table 4 – *Values for perforating vessels emergence distance vs. medial gastrocnemius muscle length in centimeters.*

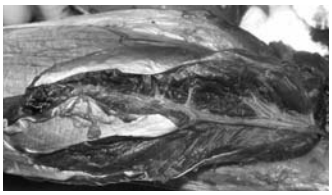

Figure 3 – *Intramuscular appearance of the medial sural artery and its perforating branches – leg 4.*

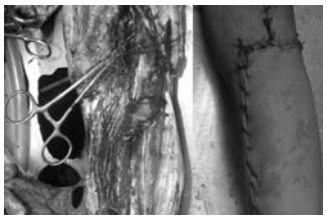

Figure 4 *- Dissection of the skin flap and its perforating vessels and its staining after catheterization of the medial sural artery.*

possibility of larger skin flaps than adjacent muscles, provided the presence of perforating vessels communication with skin territory is feasible.

The anatomical data of this study, similarly to studies described in literature by authors such as Cavadas et al.;Thione et al. and Hallock[8,9,11,14], allow us to state that the medial sural artery and the perforating arteries originated from the medial portion of the gastrocnemius muscle are found in 100% of the cases.

Our study showed that 100% of the legs had at least two perforating vessels with at least 1 mm in diameter, warranting irrigation to the skin flap of leg's posterior surface.

The average width of medial sural artery's pedicle was 3 mm, a value that enables the use of this flap both in a pedicled and in a microsurgical manner [15] .

Another parameter that matches data on literature, as described by Hallock[10], is medial sural artery's pedicle positioning, which, in 90.0% of the flaps, had its output located distal to knee intercondylar line (KIL), at 24.8 mm distal do KIL, in average.

A quite relevant factor was the finding that the emergence of perforating vessels occurs from the distal half of medial gastrocnemius muscle in 50% of the studied legs. Such fact is similar to reports by authors such as Hallock and Potparic et al.[10,17]. By this finding, it's possible to infer that this skin flap pedicle may be long enough to enable a rotation range for free flaps. By observing dissections and reported data, we believe that a skin flap based on medial gastrocnemius muscle's perforating vessels enables to obtain a flap with a long and reliable pedicle, wide dimensions, as well as the advantage of allowing the preservation of the muscular function of the gastrocnemius, causing less morbidity.

CONCLUSIONS

The regular presence of medial sural artery's perforating vessels in 100% of the legs corroborates the reliability of the flap. The length of the sural artery's pedicle combined to the emergence of perforating vessels from the distal half of the gastrocnemius muscle in 50.0% of the cases, suggests an appropriate rotation range for local or free flaps. It presents lower morbidity because it preserves the muscular function of the gastrocnemius.

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