COVERING THE DISTAL THIRD OF THE LEG WITH PEDICLED PERFORATING VESSELS PATCHES

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SUMMARY

Perforating vessels patches represent an advancement in terms of skin failures treatment. On the distal third of the leg, the alternatives for skin covering are scarce, often requiring microsurgery. In this study, we aimed to make a prospective assessment of 20 patients submitted to treatment of bloody areas of leg's distal third by means of pedicled patches in perforating arteries. The location of the perforating arteries was preoperatively found using the echodoppler test. The patches were planned to allow up to 180-degree rotation in the bloody area. In 6 cases, perforating vessels had the fibular artery as source; in 10, the posterior tibial artery, and; in 4, the anterior tibial artery. The accuracy rate of the echo-doppler was 88.2%. For young patients presenting injuries caused by trauma, procedure failures were found in 15.4%, and for those with associated comorbidities, 33.3%. Based on our studies, we conclude that perforating vessels patches are a good alternative for skin failures on the distal segment of the leg.

Keywords: *Surgical patches; Lower end; Reconstructive surgical procedures; Microsurgery*

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INTRODUCTION

Restoring skin layer is a crucial step when treating trauma, tumors and infections evolving with tegmentum continuity solution. The decision about the best technique depends on several factors such as: location, injury extension, critical structures exposure, and on surgeon experience with reconstruction techniques.

Deep skin injuries of the leg's distal third will certainly leave tendons, vasculonervous bundles, and bones exposed, which must be protected with good quality and good vascularization tissues so as to prevent deep infections and deterioration of such structures. Skin grafts are contraindicated in these circumstances. Muscle parches, such as soleus and gastrocnemius, are restricted for use to two proximal thirds of the leg[(1)]. At this level, the well known alternatives are the islands of reverse-flow pedicled patches[(2,3)], and microsurgical patches[(4)].

Currently, free perforating patches obtained from the thigh, abdominal and thoracic regions have been widespread and well used. Skin flaps based on pedicled perforating vessels, especially for covering the distal third of the leg, have been little explored so far, with few literature reports.

Our objective was to prospectively assess the results achieved on 20 patients operated for restoring the skin layer of the distal third of the leg using pedicled perforating vessel patches.

CASE SERIES AND METHODS

The inclusion criteria in this study included cases of deep injuries of the distal 1/3 of the leg with critical structures and/ or synthesis material exposure.

We prospectively assessed 20 patients submitted to coverage procedures on the distal 1/3 of the leg with the local patches technique based on perforating vessels. The sample included fifteen male patients and five female patients. Patients ages ranged from 19 to 80 years, in an average of 40.3 (Table 1).

The etiologies of treated injuries were the following: 13 young patients with traumatic injuries, 4 aged patients with chronic ulcers related to type-II diabetes mellitus, 2 patients using corticoids for rheumatoid arthritis, and one patient submitted to lipossarcoma resection with a large safety margin (Table 1).

Injuries sizing was based on their longest longitudinal and cross-sectional axis in centimeters, from which an ellipse was projected, considering its area in square centimeters as the approximated area of the injuries - Figure 1 (A and B). Patches sizes were similarly calculated.

Surgical planning

Injury location was the primary factor determining which artery stem the pedicled perforating vessel would be withdrawn from: for medial perimalleolar injuries, Achilles and/ or calcaneus tendon exposures, vessels from the posterior tibial artery were used. Injuries with anterior compartment tendon exposures, perforating vessels of the anterior tibial artery. Lateral perimalleolar injuries, anterior tibial artery or fibular.

The patients were submitted to a preoperative mapping study with echodoppler to identify the closest perforating vessels to the injury margin. Once perforating vessels topography was identified, these were outlined with a dermographic pen. Based on this previous mapping, patches were designed on donor areas considering the longitudinal axis of the main vessel, as well as the length and width required for covering the skin defect without tension.

Study conducted at the Orthopaedics and Traumatology Institute, USP medical School, Hospital das Clínicas
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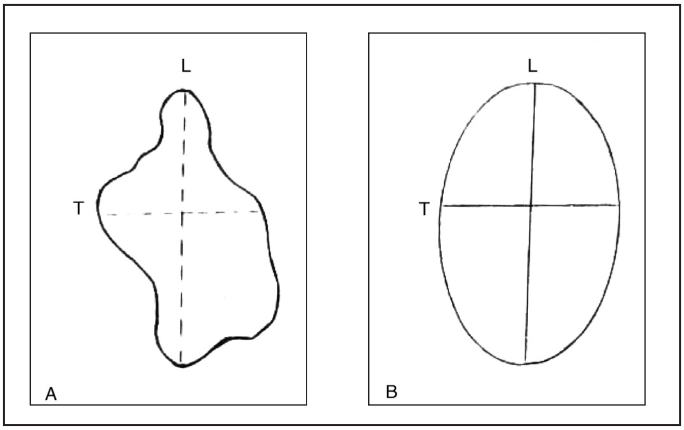

Figure 1 - *A- Schematic illustration representing the boundaries of a skin injury and its longest longitudinal (L) and transversal (T) axis. B-Overlay of a regular ellipse over injury axis, this area being regarded as the approximate value of the injury area. The ellipse area is calculated by a simplified formula: S = Pi x (L/2) x (T/ 2) where: S = injury area; Pi = 3,14; L = longest longitudinal axis; T = longest transversal axis.*

Surgical technique

The procedure is performed with exsanguination by gravity and by placing a garrote around the limb.

Skin and subcutaneous incision is made on a previously designed drawing (Figure 2), the deep fascia is identified and, for safety reasons, incised with a 1-cm wider margin than superficial planes. By means of a blunt and careful subfascial dissection, the perforating vessels are identified on the areas previously marked by the echodoppler.

Once perforating vessels were identified, these were carefully dissected up to its origin vessel, being fully skeletized.

All perforating vessels identified during subfascial probing were dissected and preserved. After building a flap and releasing the garrote, they were selectively clamped for checking their ability to provide supply to the patch. For patches where no important rotation was planned, we could maintain more than one vessel. For those where the required rotation was 180^0, only one perforating vessel was preserved, selecting the one that associated two aspects: closer position to the injury and wider gauge (Figure 3).

For all cases, the correlation of the mapping with echodoppler and the peroperative findings was recorded.

The flap was positioned on the receptor area and sutures were made only through skin/ tension and the amount of stitches is gradually adjusted and in accordance to the evaluation of patch perfusion. The donor area had its size reduced by approximation of its edges, the residual bloody area was grafted (Figure 4). Prior to dressing, patch perfusion was assessed through its entire extension by digital pressure, checking for the presence and time for capillary filling.

A well padded and loose dressing was placed. In all procedures, we applied a casted immobilization for patient comfort and to avoid tension to the patch.

The final evaluation of the patch integrity was performed at the end of 3 postoperative weeks, moment in which we determined how successful the procedure had been.

RESULTS

The patches were of fasciocutaneous type in 18 cases, fasciolipous in 1 case, and musculocutaneous in 1 case (Table 2).

Perforating vessels originated from the fibular artery in six patients, from the posterior tibial artery in ten patients, and from the anterior tibial artery in four. In 19 patients, the selection of the original artery of the perforating vessel followed a pre-established methodology; only in case nr. 3, due to a bloody granulation area on the anterior surface of the leg, a patch based on the posterior tibial artery was selected for covering anterior tendons (Table 1).

The dimensions of the injury areas were: Mean width: 3.9 cm; Mean length: 7.32 cm; Mean area: 23.6 cm2. Figure 5 shows a comparative visual scale for injury areas and their corresponding patches.

The number of perforating vessels assessed preoperatively was, in average, 2.8, and 2.4 postoperatively. In only one patient more than one perforating vessel was used (Table 2). The accuracy rate of the evaluation with the echodoppler for perforating vessel location was 88.2%.

In 19 patients, the patch was rotated 180° over the vascular pedicle, in one 110 degrees (Table 2).

Patient	Age	Gender	Etiology	Exposure	Origin area
1	29	M	Tr	Medial malleolum	Posterior Tibial
2	43	M	Tr	Lateral malleolum	Fibular
3	30	M	Tr	Anterior tendons	Posterior Tibial
4	33	M	Tr	Lateral malleolum	Fibular
5	38	M	Tr	Achilles tendon	Posterior Tibial
6	37	M	Tu	Lateral malleolum	Fibular
7	43	M	Tr	Lateral malleolum	Fibular
8	36	M	Tr	Anterior tendons	Fibular
9	19	M	Tr	Lateral malleolum	Anterior Tibial
10	80	M	Dm	Anterior tendons	Anterior Tibial
11	64	M	Dm	Lateral malleolum	Fibular
12	63	F	Dm	Anterior tendons	Anterior Tibial
13	36	F	Cr	Achilles tendon	Posterior Tibial
14	65	F	Dm	Achilles tendon	Posterior Tibial
15	48	F	Tr	Medial malleolum	Posterior Tibial
16	24	M	Tr	Medial malleolum	Posterior Tibial
17	23	M	Tr	Lateral malleolum	Anterior Tibial
18	27	M	Tr	Medial malleolum	Posterior Tibial
19	45	F	Cr	Achilles tendon	Posterior Tibial
20	24	M	Tr	Medial malleolum	Posterior Tibial

Tr: Trauma/ Dm: Chronic ulcer resulting from Diabetes Mellitus/ Cr: Chronic ulcer associated to corticosteroids use/ Tu: Tumor.

Table 1 – *List of patients/ age/ gender/ etiology/ exposure area/ original artery of the pedicled perforating vessel patch.*

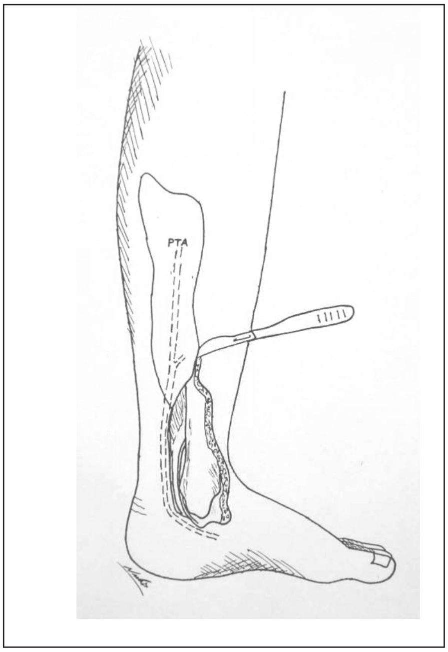

Figure 2 – *Schematic illustration of an injury on the medial malleolum with exposed underlying structures, and patch planning along the axis of the posterior tibial artery (PTA).*

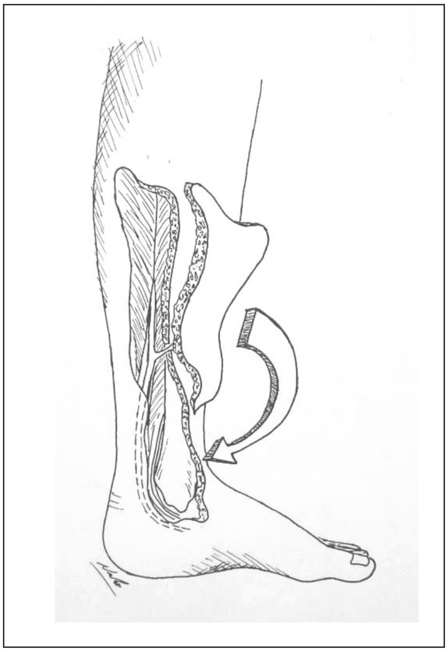

Figure 3 - *Dissected patch supplied by a single pedicle of a perforating vessel of the posterior tibial artery. The arrow indicated that the patch will be rotated at 180⁰.*

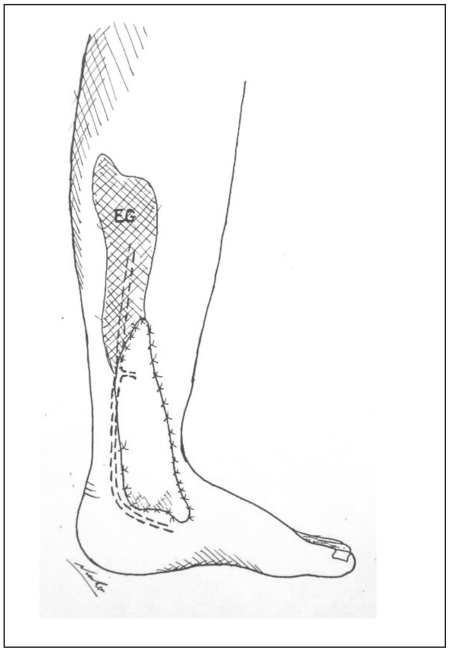

Figure 4 - *Patch positioned on the receptor bed. Donor area closed with skin graft (EG).*

Patient	MD	PIOP	%Accuracy	UP	Rot.	DL	DR	TR	SF	Res.
1	2	2	100	1	180	4x5	4x7	Fc	95	total
2	3	2	66	1	180	3.5x8	4x14	Fc	100	total
3	2	1	50	1	110	4x7	4,5x13	Fc	100	total
4	3	3	100	1	180	8x8	8,5x12	Fc	100	total
5	2	2	100	1	180	2.5x7	3x10	Fc	100	total
6	3	2	66	1	180	5x8	5x19	Fc	100	total
7	2	2	100	1	180	4x8	6x12	Fc	100	total
8	3	3	100	1	180	7x9	8x15	Fc	100	total
9	3	2	66	1	180	2.5x8	3,5x10	Fc	60	failure
10	4	3	75	1	180	3x4.5	4x12	Fc	70	part.
11	2	2	100	1	180	3x8	4x22	Fc	100	total
12	3	2	100	1	180	2x5.5	2,5x6	Fc	70	failure
13	4	3	75	2	180	3x6.5	5x10	Fc	70	failure.
14	2	2	100	1	180	2.5x5	3x6	Fg	100	total
15	2	2	100	1	180	5x8	6x10	Fc	100	total
16	3	3	100	1	180	4x6	6x16	Fc	90	total
17	3	2	66	1	180	5x12	6x20	Fc	100	total
18	4	4	100	1	180	4x8	5x16	Mc	85	failure
19	3	3	100	1	180	4x9	5x11	Fc	100	total
20	3	3	100	1	180	2x6	4x12	Fc	100	total

MD: number of perforating vessels mapped by the echodoppler/ PIOP: number of perforating vessels identified peroperatively/ %Accuracy: mapping accuracy rate/ UP: used perforating vessels/ Rot: Patch rotation/ DL: width vs. length of injuries/ DR: width vs. length of patches/ TR: Kind of Patch/ Fc: Fasciocutaneous/ Fg: fasciolipous/ Mc: Musculocutaneous/ SF: percentage of patch survival area / Res.: Resolution of the cases.

Table 2 – *List of patients/ perforating vessels assessment/ measurements of the injuries and patches axis/ patch survival/ resolution of the case.*

Only on patient nr. 14 the use of donor area grafting was not required, due to primary closing potential.
Total resolution was attributed to every case where the coverage of the initial bloody area and of the exposed critical structures was solved by the pedicled perforating vessel patch. Cases 1 and 16 showed partial necrosis, but this occurred out of the original bloody area, at the opposite end, adjacent to donor area. We regarded as partially resolved cases those in which the initial injury coverage required complement with partial skin graft. In case nr. 10, a superficial necrosis of the patch on the previous injury coverage area was found, without tendon exposure, being re-grafted subsequently. We defined as failure cases those where total or partial necrosis of the patch occurred on the topography of the initial injury, with subjacent structures exposure, being required an additional patch for resolution. Total resolution was achieved in 75% of the cases, partial resolution in 5%, and procedure failure in 20% (Table 2).
In young patients with traumatic injuries, a rate of 15.4% of procedure failure was found and 33.3% in patients with associated morbidities.

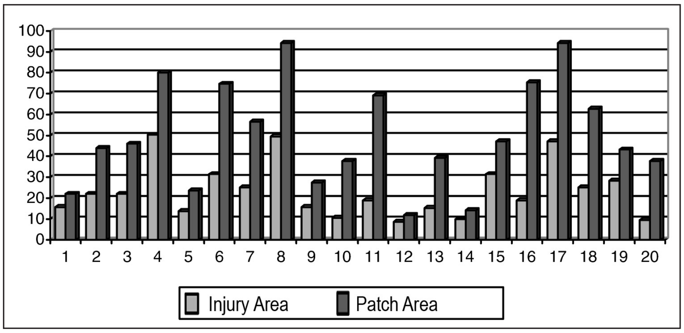

Figure 5 - *Correlation between injury and patch areas*

CLINICAL CASES

In order to better illustrate the use of the perforating vessel patch in its rotation form, we will present 2 clinical cases:

Clinical Case 1

A 29 year-old male patient, with open leg bones fracture and treated with bridge plate evolved with suture dehiscence, which, after successive cleaning procedures, showed a bloody area on the medial surface of the distal third of the leg, with synthesis material exposure. Skin coverage with rotation perforating vessel patch was selected, obtained after a study with the echodoppler. (Figures 6 - 9)

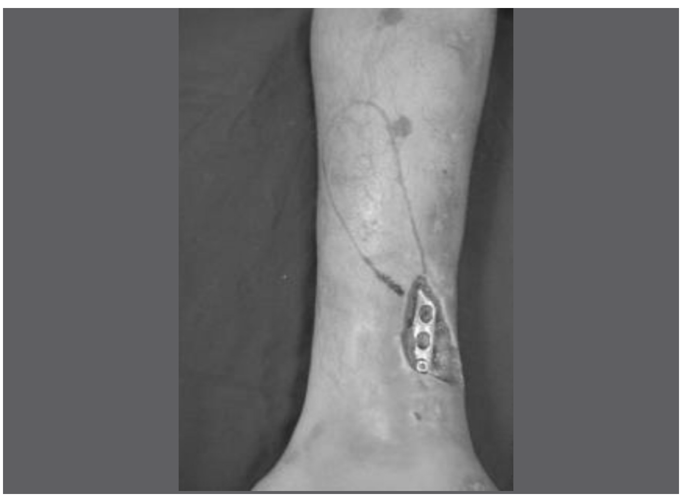

Figure 6 – *29 year-old patient with synthesis exposure on the medial surface of tibial distal third. Previous markings of perforating vessels of the posterior tibial artery and patch planning can be noticed here.*

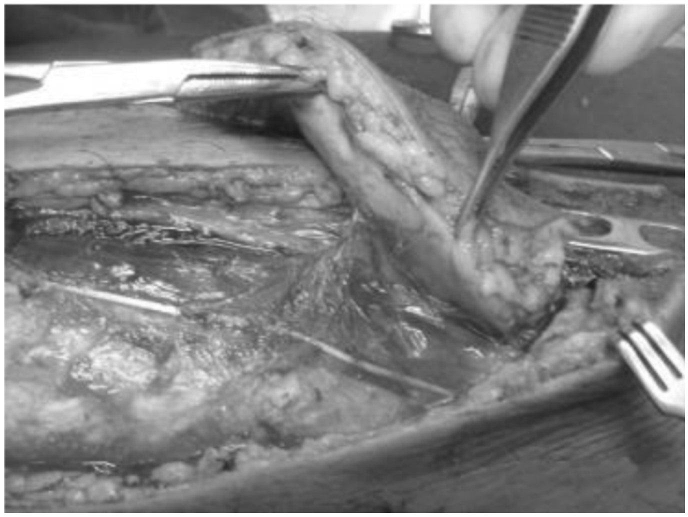

Figure 7 – *Building the flap.*

Figure 8 – *Early postoperative period. Patch rotated at 180 degrees and sutured without tension. A grafted donor area is noticed here.*

Figure 9 – *Postoperative period (4 weeks).*

Clinical Case 2

A 64 year-old male patient initially treated for tibiotalar arthrosis with lateral access arthrodesis, evolved to local infection process, which after successive cleaning procedures, showed a deep wound (2 cm), with lateral malleolum and fibular tendons exposure. Clinically, this patient presented a picture of cardiac failure and diabetes. We chose to cover the skin with a perforating vessel patch based on the fibular artery. Again, after study with echodoppler, the identification of a good perforating vessel proximally to the injury area and the patch planning were enabled, as presented on the sequence below. (Figures 10-14).

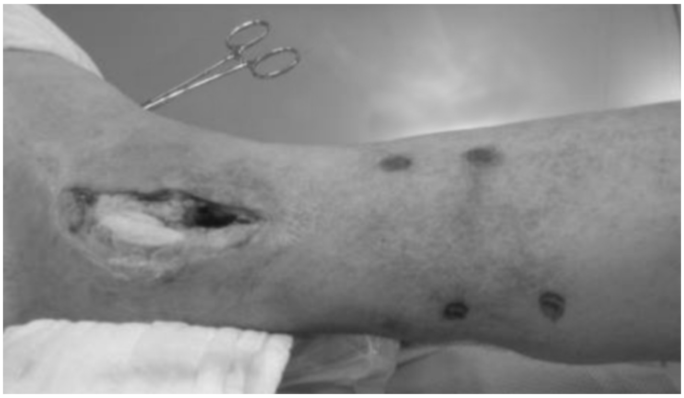

Figure 10 – *Diabetic patient with chronic ulcer of the lateral malleolum after ankle arthrodesis.*

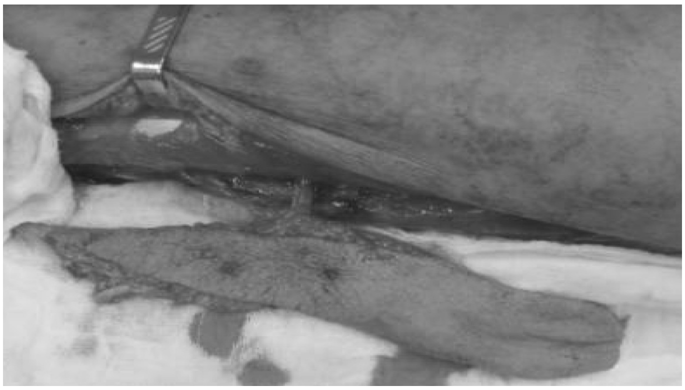

Figure 12 – *Flap built and pedicled on a perforating vessel of the fibular artery*

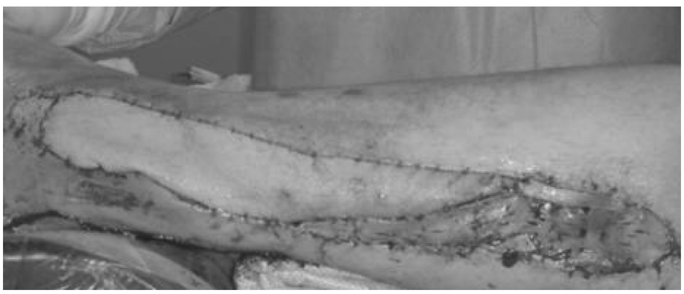

Figure 13 – *Early postoperative period.*

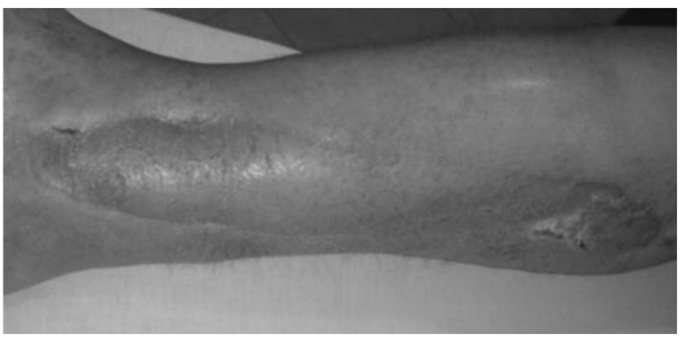

Figure 14 – *Postoperative period (3 weeks).*

DISCUSSION

Skin coverage of the distal third of the leg remains being a challenge for reconstructive surgery. In this segment, there are no interposing muscle tissues between critical structures and the tegmentum, and this has limited extensibility and mobility. These characteristics make the random use of skin grafts and rotation patches inappropriate for injuries reaching the entire skin width. Thus, relying on more complex procedures such as microsurgical patches[4] or reverse-flow islands of pedicled patches[2,3] is required.

In a considerable number of patients, the use of microsurgery seems to be an excessive treatment, because the wounds to be covered, although reaching deep planes, are relatively small. Microsurgical patches require better technical skills from a surgical team, are more expensive and show a long surgical time, and higher morbidity rates. Thus, we prefer using pedicled patches that may be withdrawn from the surroundings of the area to be repaired. In these conditions, the medial and proximal thirds of the leg, with a large skin coverage area and muscle mass are valuable tissue donor area to be used in a pedicled form[5].

Several pedicled patches of the own leg have been described in the last two decades: Distal base muscle patches[6,7], reverse-flow fasciocutaneous patches of the posterior and anterior tibial, and fibular arteries[8], lateral supramalleolar patch[2], neurocutaneous patch of the sural artery[3] and pedicled perforating vessels patches.

Distal base muscle patches, such as hallux long flexor's patches[6] and anterior tibial muscle patches[7], have a relevant morbidity, because they sacrifice the function of the muscles employed. Similarly morbid, the reverse-flow fasciocutaneous patches of the anterior tibial, posterior tibial and fibular arteries, which must be connected to provide rotation to the correspondent patches [8,9].

The lateral supramalleolar, sural and pedicled perforating vessels patches have similar applications, but present individual technical peculiarities. The lateral supramalleolar patch, described by Masquelet[2] raised little interest from other authors. Touam et al.[10] in a comparative study between this patch and the sural one, described an incidence of partial and total necrosis of 18.5% for the lateral supramalleolar patch. More recently, Voche et al.[11] in a series with 41 cases, reported a necrosis rate of 7.3%. However, these two authors agree that the lateral supramalleolar patch shows a high level of technical challenge, and they report using it today as an alternative to sural patch. The sural patch, described by Donski[3], was more deeply studied, as shown by literature data. In his series of 36 sural patches, Touam[10] reported an outstanding result, with a necrosis rate as low as 4.8%[10]; an outcome quite different from the one reported by Almeida et al.[12] with 25.3% of necrosis in 71 cases. Baumeister[13] published an analysis of 70 sural patch cases in patients with clinical comorbidities, especially diabetes mellitus, reporting a necrosis rate of 36%.

In the present study with pedicled perforating vessels patches, we found 20% of failures. But this result assumes a different configuration when we consider age and clinical comorbidities: among the 13 patients with traumatic injuries (mean age of 32.1 years), a rate of 84.6% was found for total resolution. Of the diabetic patients (mean age of 68 years), we found 50% for total resolution, 25% for partial, and 25% for failure. We can say that the unsuccessful rates of the three techniques compared here are not different among each other.

In 1967, Fujino had reported the importance of perforating vessels for skin nutrition[14]. However, only after angiossomes were mapped by Taylor and Palmer[15], followed by clinical reports published by Kroll and Rosenfeld[16] and Koshima and Soeda[17] a new concept of surgical patch was developed uniquely based on muscular perforating branches. Currently, the use of some perforating vessels patches in their free forms are well established, such as: Anterolateral of the Thigh[18,19], Perforating Vessel of the Upper Gluteus Artery[20], Perforating Vessel of the Fascia Lata Tensor[21], Perforating Vessel of the Large Dorsal[22]; but few reports are available in literature with the clinical use of pedicled forms, especially for covering the distal third of the leg.

Several authors published anatomical studies focusing the identification of perforating branches of the main arteries of the leg and their correspondent irrigation territories which serve as a theoretical support for the development of new patches.
Ferreira et al.[23] published their studies after dissecting 45 cadavers, finding an average of 30 perforating vessels on the whole posterior aspect of the leg originated from the posterior tibial and fibular arteries. Koshima[24], in an anatomical study with 25 cadavers, found an average of 3.1 perforating branches of the posterior tibial artery, with most of these branches being found between 7 and 14 cm proximally to medial malleolum. They conclude that patches based on these perforating vessels could be used in a pedicled form for repairing injuries of the distal third of the leg. Whetzel et al.[25] in an anatomical study with 31 cadavers determined the distribution pattern of perforating vessels and their respective skin territories of the Anterior and Posterior Tibial arteries, Fibular Artery and medial and lateral sural Arteries. Taylor[26] published a new article reviewing lag angiossomes with their clinical applications.
Although scarce, reports on the clinical application of patches based on pedicled perforating vessels for the distal third of the leg showed a large variation of the surgical technique and results description, rendering a comparative analysis of these results subjective. Ferreira et al.[23] report the application of distal base fasciocutaneous patches in 8 patients; on the surgical technique description, they do not explain if the patches are peninsular, preserving a cutaneous bridge on its base, or pedicled exclusively by perforating vessels. They report good results and do not mention complications. Koshima et al.[27] published a brief anatomical study complemented with a report of 10 cases. On the surgical technique, they perform a careful subfascial dissection until a perforating vessel is identified, pedicle skeletization and patch rotation (propeller) for covering a bloody area. The donor area was grafted: nine patches were lateral and based on a perforating vessel of the fibular artery, and one medial patch based on the posterior tibial artery. Two cases showed partial necrosis.
Chang et al.[8] propose the use of a perforating vessel of the fibular artery, 5 cm proximal to lateral malleolum, as a pedicle of a patch designed on the posterolateral surface of the leg. They recommend subfascial dissection of the patch and rotate it on a propeller style in order to reach the receptor area. They present a series of 7 cases. They did not report complications.
Cavadas and Landin[28] described the use of pedicled perforating vessel patches from the posterior tibial artery for covering a reconstructed Achilles tendon in a series of 8 patients. They make fasciolipous patches which are inverted in order to reach the receptor area. The donor area is primarily closed and the patch is grafted. The largest skin defect in their series was 5x12 cm. They don't describe failures, although reporting graft loss in some cases.
Ozdemir et al.[29], presented another anatomical study with perforating vessels of the posterior tibial artery accompanying the clinical report of eight patients. They identify three cases of postoperative venous congestion, one of these evolving to partial patch necrosis.
In our study, the selection of the main artery, from which the perforating artery is originated, was due to its closer location to the topography of the injury to be treated. This criterion is consistent to the guidelines published by Koshima[27] in his anatomical study: the posterior tibial artery prevails on the posteromedial surface of the distal third of the leg, anterior tibial the anterior face and fibular artery the posterolateral surface. Taking the anatomical axis of the leg's main vessels into account, one can empirically plan the longitudinal axis of the patch. However, we must select the closest perforating vessel to injury margin, which will be the rotation pivot, because the position of it will determine a patch's final length: the farther the perforating vessel to injury margin, the longer the patch will be. Chang et al.[8], Koshima et al.[27], Cavadas et al.[28], in their articles, mention the use of doppler for identifying perforating vessels.
In literature, many studies are found addressing the use of echodoppler on perforating vessels planning, especially for perforating vessel patches of the superficial epigastric artery [30-32]. According to Giunta[32], doppler is an important tool for preoperative patch planning, making easier the peroperative identification of perforating vessels. In our case series, the use of doppler achieved an accuracy rate of 88.2%. The application of the echodoppler specifically for the identification of perforating vessels on the leg was of much help on surgical planning, however its reproducibility deserves further studies.
In the technique we employed here – also known as propeller flap – an island of fasciocutaneous flap was build to be rotated over its pedicle, like a helix rotating over its central axis, for reaching the injury to be covered. A question is raised so as to whether pedicle torsion when rotating the patch would affect its vascular supply. Ahmet et al.[33], in an experimental study with rats, show that torsions up to 180 degrees do not impact patch feasibility, however, they can impair venous drainage. According to Ozdemir[28], three of his cases showed signs of venous congestion, with two evolving to improvement, and one to total necrosis. In our series, 19 patches were rotated at 180 degrees. all failure cases showed precedent signs of congestion. Aiming to mitigate this effect, we consider the skeletization of perforating vessels as important, thus preventing any fibrous band from causing pedicle compression at the moment of rotation. Overestimating patch size compared to the injury is another detail of the technique that should be mentioned, thus preventing closing under tension and increasing patch feasibility.
Another important aspect is concerned to maximum size a pedicled perforating vessel patch of the leg may reach. There is no appropriate technique available yet to establish those limits, which are currently assessed under an empirical perspective. On the series described by Chang[8] a 10x 25 cm patch can be found, while, in our series, the largest patch was 6x20 cm (92 cm2).
Perforating arteries patches present the advantage of lower morbidity to the donor area, preserving the function of underlying muscles, as well as a great flexibility. When used in the pedicled form, they provide the following additional benefits: ease of dissection, reduced surgical time, and sparing of main arterial branches. As disadvantages, we can mention the broad range of diameters and positions of the perforating vessels, determinant factors that may be overcome by the use of an echodoppler. The use of patches based on local pedicled perforating arteries emerges as a new alternative for recovering deep skin injuries. In our opinion, this technique can be adopted as a first choice for injuries of the distal third of the leg and ankle, at medium sizes.

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