

## Lower Limb Perforator Propeller Flaps – Clinical Applications

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### Rezumat

#### ***Lambourile pe vase perforante tip "propeller" de la nivelul membrului inferior - aplicații clinice***

**Introducere:** În reconstrucțiile membrului inferior au fost utilizate o mare varietate de lambouri începând cu lambourile pe circulație întâmplătoare, lambourile axiale, transferul liber microchirurgical și multe variante ale acestora. Odată cu aprofundarea cercetărilor asupra vascularizației cutanate și îmbunătățirea tehnicilor microchirurgicale, lambourile pe vase perforante tip "propeller" au început să fie studiate și utilizate în clinică.

**Material și metodă:** Un lambou tip "propeller" este definit ca un lambou insular mobilizat printr-o mișcare de rotație axială în jurul unui pedicul vascular perforant pentru a acoperi defectul ce trebuie reconstruit. În concordanță cu literatura de specialitate și cu studiile efectuate la cadavru aceasta lucrare prezintă o clasificare a acestor lambouri în funcție de mai multe criterii: 1) poziția vasului perforant la nivelul lamboului; 2) forma insulei cutanate în funcție de necesitățile reconstructive; 3) pediculul vascular al lamboului; 4) necesitățile estetice și funcționale ale defectului de părți moi ce trebuie reconstruit. Bazându-ne pe datele din acest studiu am putut stabili indicațiile specifice ale fiecărui tip de lambou.

**Concluzii:** În strategia reconstructivă la nivelul membrului

inferior lambourile pe perforante tip "propeller" reprezintă prima opțiune pentru defectele de dimensiuni mici și medii în anumite zone considerate "critice". Cunoașterea lungimii pediculului și a suprafeței lamboului permite alegerea optimă a acestuia pentru reconstrucția unui anumit defect topografic.

**Cuvinte cheie:** membru inferior, reconstrucție, lambouri pe vase perforante tip "propeller", aplicații clinice

### Abstract

**Background:** A great variety of flaps have been used in lower limb reconstructive surgery: random pattern flaps, axial flaps and free microsurgical transfers with many variants. After further research on the cutaneous blood supply and improvement of microsurgical techniques, perforator propeller flaps began to be studied and used.

**Material and method:** A propeller flap is defined as an insular flap mobilized through an axial rotation on a perforator pedicle in order to cover a defect that has to be reconstructed. According to the specialized literature data and to the studies we made on cadavers, this paper establishes a classification based on several criteria: 1) the position of the supplying perforator; 2) the reconstructive necessities and the skin island; 3) the flap blood supply; 4) the aesthetic and functional demands of the reconstructed areas. Based on this study we established the specific reconstructive indications for these propeller flaps.

**Conclusions:** The reconstructive lower limb strategy allows the use of the perforator propeller flaps as first therapeutic option for small and medium defects in certain areas

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considered as “critical”. Knowledge of the pedicle length and the surface of the flaps facilitates the optimum flap choice in the reconstruction of a certain area.

**Key words:** lower limb reconstruction, perforator propeller flaps, clinical applications

## Introduction

Complex wounds need complex reconstructions and this was not possible until different types of flaps were developed. The important contribution of describing the fascial and muscle to skin circulation through septocutaneous and musculocutaneous vessels was the first step in the evolution of flaps and led to an “explosion” in the use of musculocutaneous flaps for reconstruction (1). However, the impact of using fasciocutaneous flaps was minor compared to that of musculocutaneous flaps, but also led to a more detailed research of the skin vascular supply. Thus, the angiosome concept was born and, based on cadaveric injection studies, the vascular territories of the body were described (there were 21 angiosomes in the lower extremity) (2). The source vessels for the skin of the thigh are the superficial and profunda femoris arteries through their musculocutaneous and septocutaneous branches with 30 to 50 skin perforators. In the popliteal fossa, the superficial femoral artery becomes the popliteal artery which gives birth to the three main vascular sources of the leg: the anterior and posterior tibial arteries and the peroneal artery with their corresponding musculocutaneous and septocutaneous perforators (there are 20 to 40 perforators). In the foot region, the posterior tibial artery branches in medial and lateral plantar arteries, the anterior tibial artery becomes the dorsalis pedis artery and the peroneal artery ends as the lateral calcaneal artery. There are multiple anastomoses between them that make it difficult to define vascular territories at this level. These vessels are the origin of small musculocutaneous and septocutaneous perforators (2).

The last 20 years of reconstructive surgery development were marked by the appearance of some new flaps based on perforator blood vessels. In 1989 Koshima and Soeda used for the first time the term “perforator flap” for a paraumbilical skin flap based on a muscular perforator. The following researches carried out especially in the Asian schools have led to the appearance and description of numerous flaps based on perforator blood vessels and implicitly to the appearance of numerous confusions and controversies. The Gent Convention clarified and standardized the terminology and classification of perforator flaps (3).

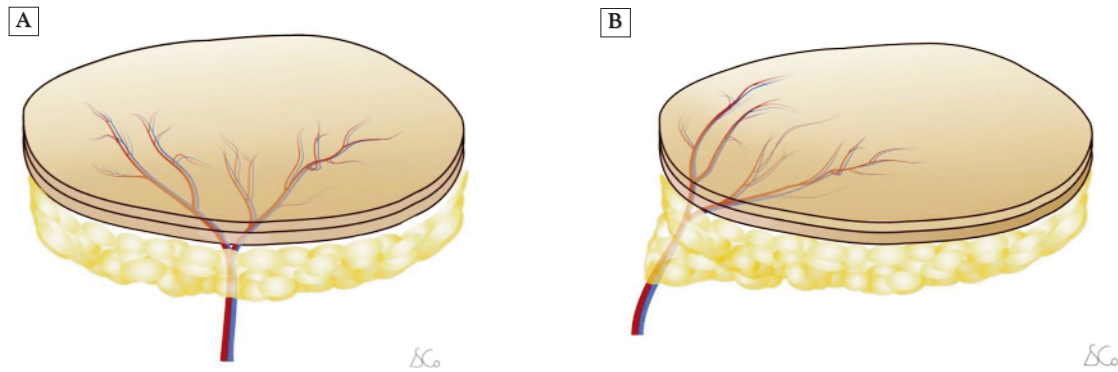
The refinement of the surgical procedures and the research concerning the perforator blood vessels have been followed by the discovery of a new type of perforator flap - the “propeller” type flap. The term was introduced by Hyakusoku in 1991 in order to describe an insular skin flap based on a randomized

subcutaneous pedicle which may be rotated 90 degrees around the pedicle similar to a propeller’s rotation. Hallock uses the same name for a flap like the one described by Hyakusoku, but this time the flap was based on a skeletonized perforator vessel. The growing interest for these flaps and the clinical applications in reconstructing soft tissues losses have imposed the standardization of their definition and terminology at the Tokyo convention in 2009.

A propeller flap is now defined as an insular flap mobilized through an axial rotation in order to cover the reconstructed defect, thus excluding from the definition of such a flap advanced insular flaps, type V-Y flaps or rotated peninsular flaps. The perforator propeller flap is a propeller type flap whose skin island is centred on a perforator vessel which corresponds to the pivot point of the flap. The two portions of the skin island (the blades or paddles of the propeller) may be equal or unequal and they may rotate around the pedicle according to the reconstructive necessities between 90-180 degrees, similar to a propeller’s movement. Even if the difference in dimensions and forms between the paddles of the skin island makes the resemblance to a propeller less obvious, such a flap is not excluded from the definition. The rotation degree and the dimensions of the two portions of the skin island of the propeller flap are determined by the position of the accommodated perforator flap to the tissue defect that must be reconstructed. The 180 degrees rotation might be obtained if there is enough tissue that can be mobilized through axial rotation in the extension of the axis connecting the defect with the pivot point of the perforator vessel. The closer the position of the perforator vessel to the defect is, the more will the dimensions of the two paddles of the skin island become unequal (4,5,6,7).

Classification according to the position of the supplying perforator vessel, the reconstructive necessities and the form of the skin island used for reconstruction, the flaps’ blood supply, the aesthetic and functional demands of the defect (8,9,10):

- 1) perforator propeller flaps can have:
  - a central axis (the skin island is centred by the perforator vessel and the paddles of the skin island are equal in dimension; flaps can have an axial rotation between 90-180 degrees in order to cover the defect; closing the donor area is difficult, sometimes skin grafts are necessary (*Fig. 1A*))
  - an eccentric axis (the perforator vessel is located to an extremity of the flap and the two paddles of the skin island have different dimensions; flaps can be rotated 180 degrees in order to cover the defect located in the extension of the long axis; their common use is for reconstruction of the limbs, where flaps can be projected in the extension of the long axis of the respective limb; the donor area may be primarily closed (*Fig. 1B*)).
- 2) According to the reconstructive necessities and the form of the skin island perforator propeller flaps can be:
  - bilobed flaps (the propeller flaps initially described in the beginning of the propeller flap use);



**Figure 1.** The position of the supplying perforator vessel: (A) - central pedicle; (B) - eccentric pedicle

- polilobed flaps, indicated especially for scar contracture release;
- hockey stick flaps indicated for the optimal coverage of some defects and avoidance at the same time of some physical obstacles (external fixtures) or anatomical areas (scars);
- “free style” flaps – such flaps imply an identification of the pivot point and of the flap’s rotation arc; offers freedom in modification of the form and dimensions of the skin island according to the defect during surgery.

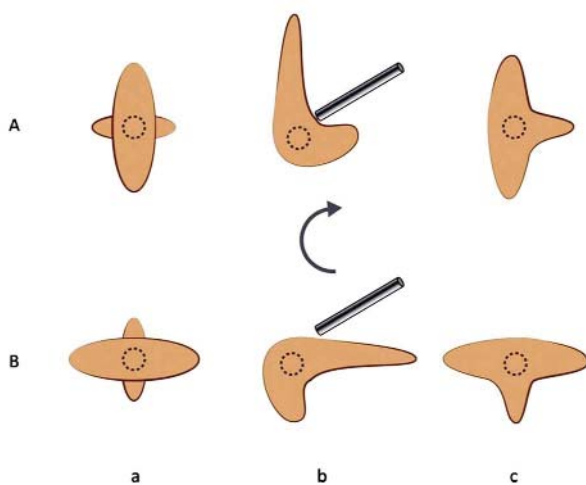
3) According to the flap blood supply, perforator propeller flaps can be supercharged - this type of flap has an eccentric axis and needs to skeletonize two perforators; the flap rotates around the dominant perforator and the other perforator located at the distal extremity is anastomosed to a recipient blood vessel at the level of the defect. (Fig. 3A)

4) According to the aesthetic and functional demands of the defect, perforator propeller flaps can be ultrathin; a micro-

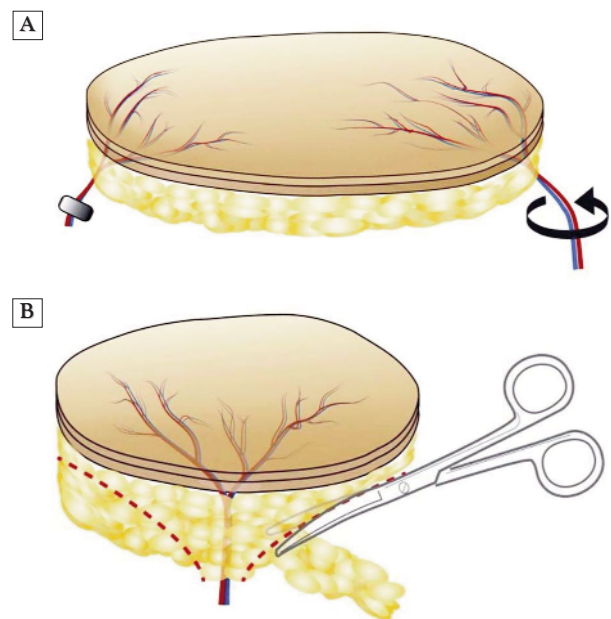
surgical dissection of the subcutaneous adipose tissue is needed; the survival of the flap is based on the subdermal vascular plexus. (Fig. 3B)

Unlike other areas of the body, the anatomical and functional particularities of the lower limb make the coverage of defects very difficult at this level. Perforator propeller flaps have won a great popularity in the reconstruction of the lower limb due to their multiple advantages versus other techniques. Their use with reconstructive purpose implies the knowledge of the type of the perforator vessel, its localization, the pedicle’s length, the rotation degree and the maximum skin surface of the flap that may be used.

At the level of the thigh a great variety of propeller type flaps based on the deep and superficial femoral artery branches have been described.



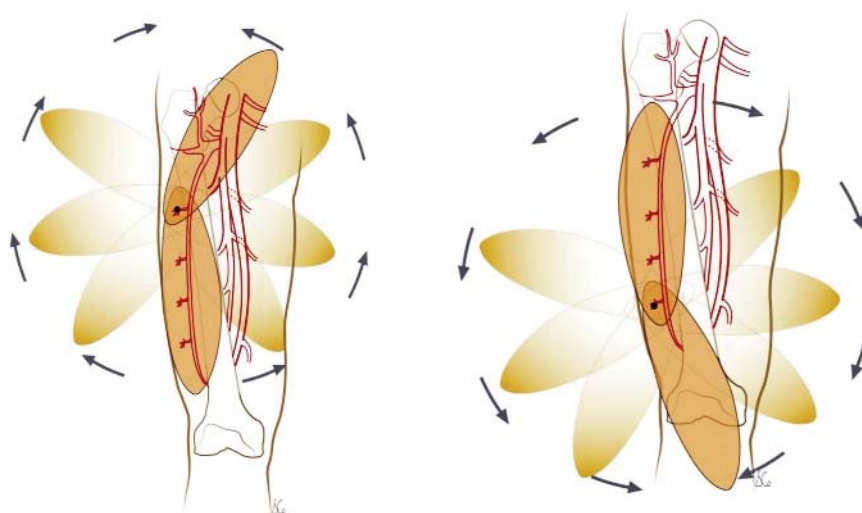
**Figure 2.** Different shapes of a “propeller flap”: a – bilobated flap, b – hockey stick flap; c – trilobated. A – “in situ” aspect – flap before the rotation; B – “final” aspect after the rotation



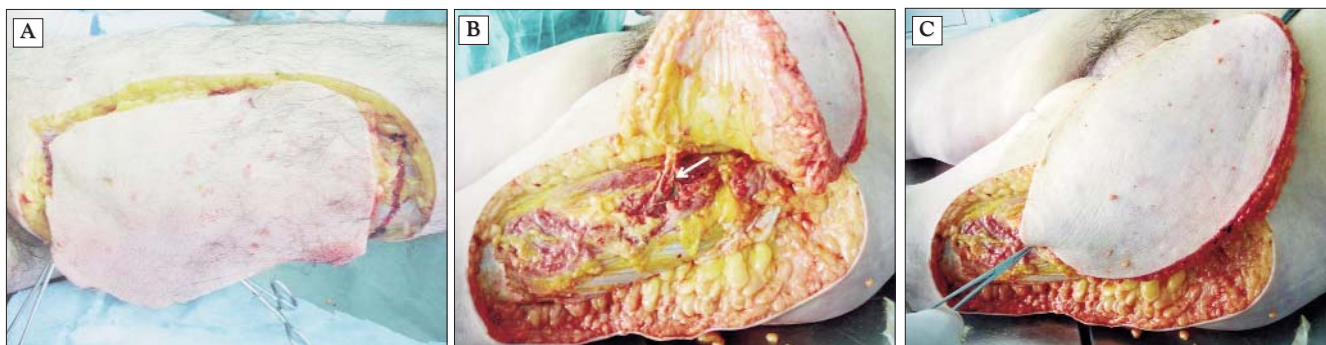
**Figure 3.** (A) - Supercharged “propeller” flap (x – dominant perforator which will be the axis of rotation; y- perforator to be anastomosed to a recipient vessel) (B) – Ultra thinned “propeller” flap

**Table 1.** Perforator propeller flaps from the lateral circumflex femoral artery (LCFA)

Name of the flap	Type, number of perforator vessels	Length of the pedicle	Maximum surface of the flap	Clinical applications (rotation arch)
Anterolateral thigh flap described by Song (8,11,12,13,14,15,16)	3-5 septocutaneous/musculocutaneous perforators from the vastus lateralis (the descendent branch from LCFA)	8-15 cm	35/25 cm	Lower abdomen, groin, ischium, great trochanter, peripatellar
Tensor fascia lata perforator flap described by Deiler (12,15,17)	1-2 musculocutaneous perforators from tensor fascia lata (the ascending/transversal branch from LCFA)	5 cm	17/10 cm	Lower abdomen, groin, anteromedial thigh
Anteromedial thigh flap (15,18)	Septocutaneous/musculocutaneous perforators from the rectus femoris (the medial descending branch of LCFA) or SFA	8-12 cm	15/30 cm	Groin, anteromedial thigh, defects around the knee

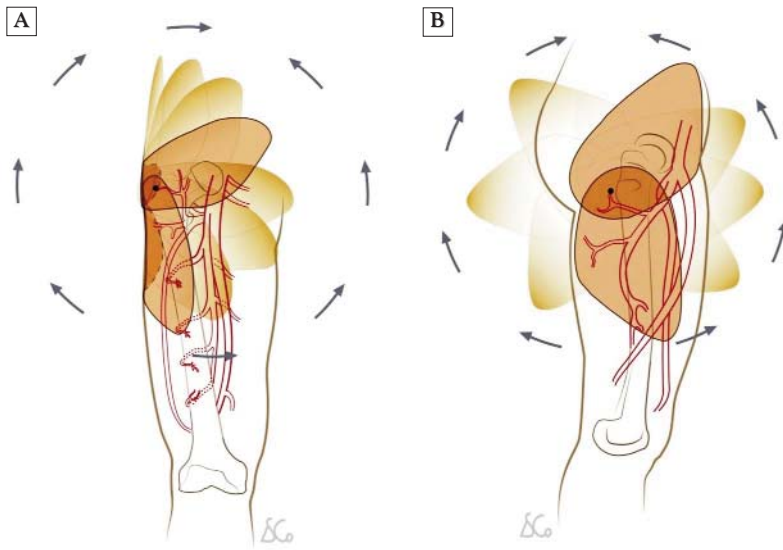


**Figure 4.** Anterior lateral thigh “propeller” flap:  
**(A)** Anterior lateral thigh flap with proximal pedicle;  
**(B)** Anterior lateral thigh flap with distal pedicle

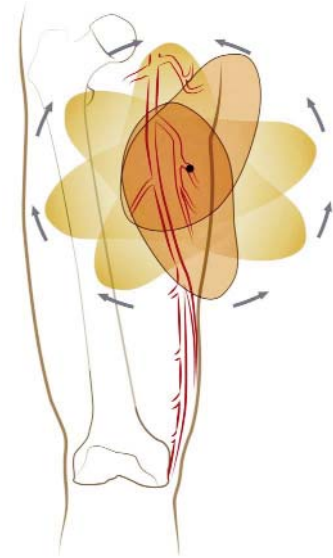


**Figure 5.** Cadaver study of the “propeller” anterior lateral thigh (ALT) flap: **(A)** “propeller” ALT flap in situ; **(B)** perforator supplying the ALT flap; **(C)** “propeller” ALT flap rotated





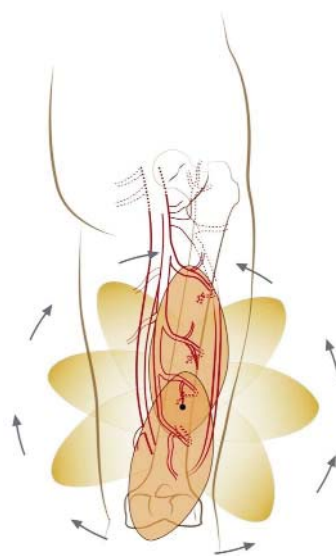
**Figure 6.** Tensor fascia lata perforator flap: (A) front view; (B) lateral view



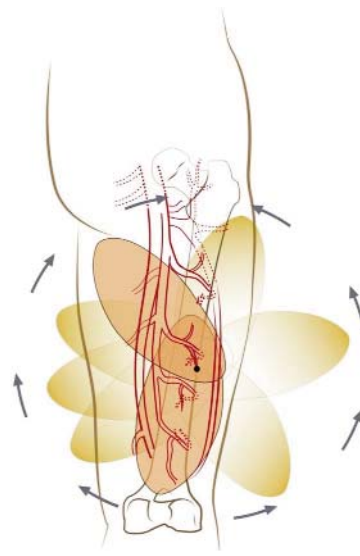
**Figure 7.** Anterior medial thigh perforator flap

**Table 2.** Perforator propeller flaps from the profunda femoris artery (PFA)

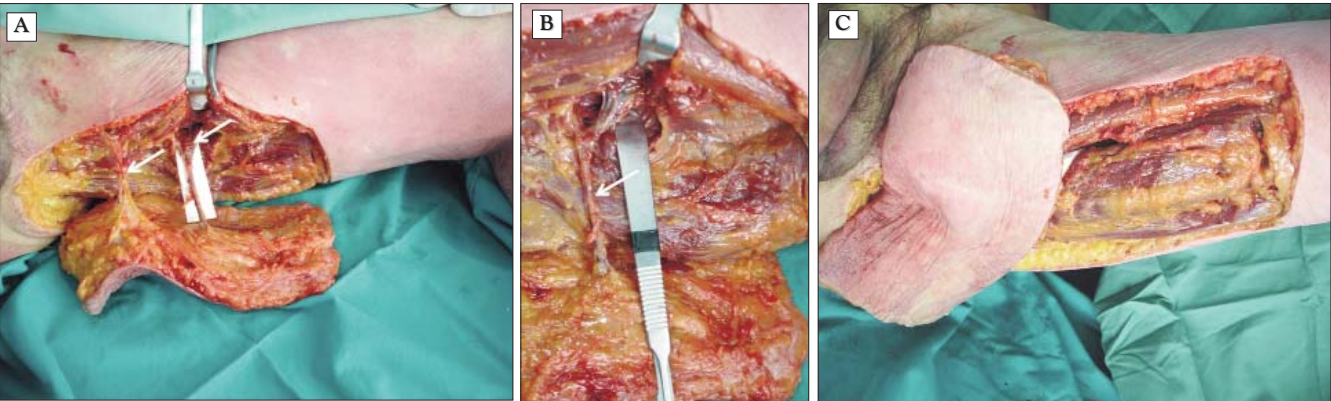
Name of the flap	Type, number of perforator vessels	Length of the pedicle	Maximum surface of the flap	Clinical applications (rotation arch)
Lateral thigh flap (15,19)	The second septocutaneous perforator from PFA or musculocutaneous perforators from the biceps femoris	5-7 cm	8/18 cm	great trochanter, ischium
Adductor perforator flap (15,17,19)	First musculocutaneous perforator from adductor magnus (first medial perforator of PFA)	8-9 cm	25/30 cm	Great trochanter, ischium, perineal defects
Posterior thigh flap described by Song (15,19)	The third septocutaneous perforator from PFA	5-6 cm		Popliteal fossa, defects around the knee



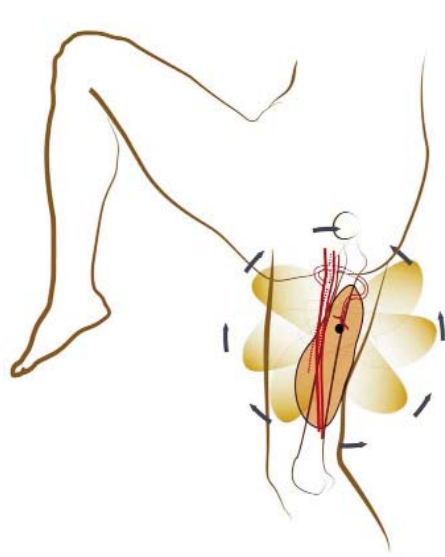
**Figure 8.** Lateral thigh flap



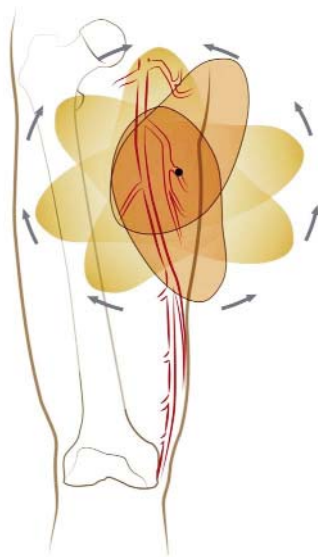
**Figure 9.** Adductor perforator flap



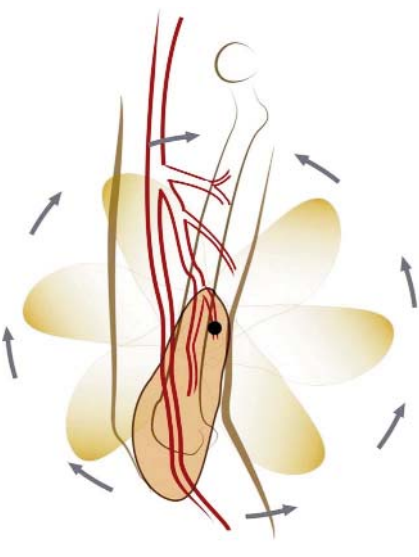
**Figure 10.** Cadaver study of the adductor perforator flap: (A) elevated flap and perforators; (B) perforator (detail); (C) rotated flap



**Figure 11.** Posterior thigh flap



**Figure 12.** Medial groin flap



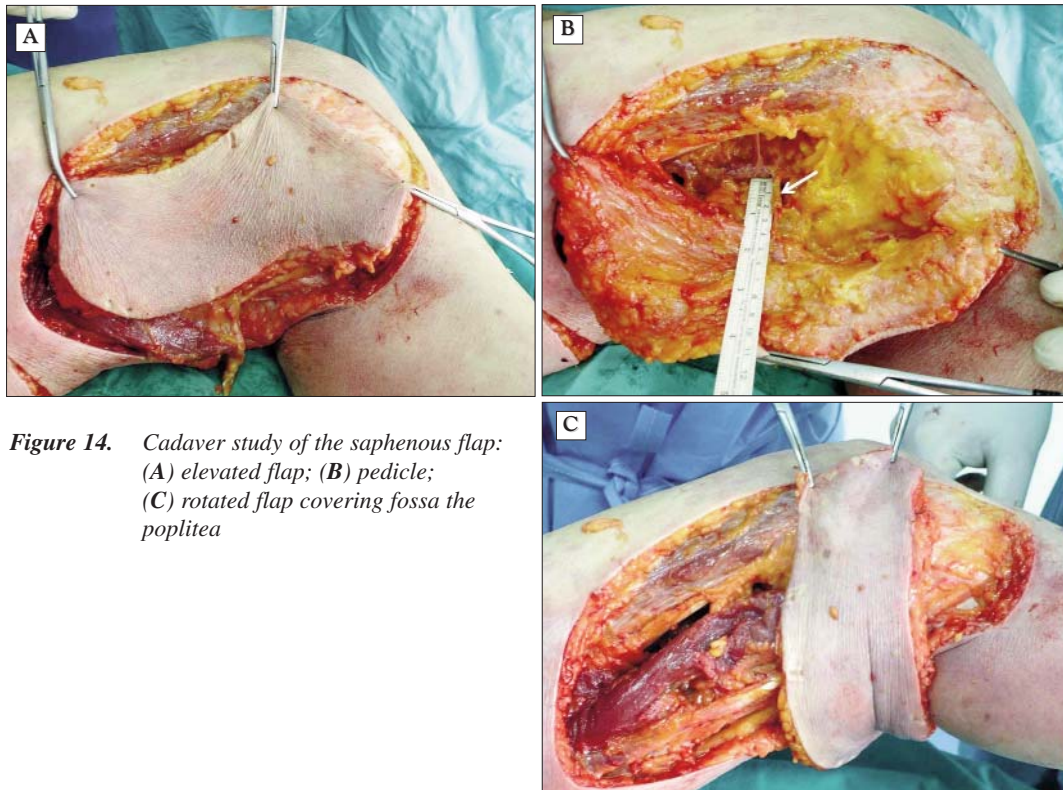
**Figure 13.** Saphenous flap

**Table 3.** Perforator propeller flaps from the medial circumflex femoral artery (MCFA)

Name of the flap	Type, number of perforator vessels	Length of the pedicle	Maximum surface of the flap	Clinical applications (rotation arch)
Medial groin flap (15,17)	1-2 musculocutaneous perforators from the gracilis muscle	6 cm	12/30 cm	perineum, vagina, groin, ischium

**Table 4.** Perforator propeller flaps from the descending genicular artery (DGA)

Name of the flap	Type, number of perforator vessels	Length of the pedicle	Maximum surface of the flap	Clinical applications (rotation arch)
Saphenous flap described by Acland (15)	1-4 septocutaneous perforators from saphenous artery	5-15 cm	29/8 cm	Defects around the knee, proximal tibial region, popliteal fossa



**Figure 14.** Cadaver study of the saphenous flap: (A) elevated flap; (B) pedicle; (C) rotated flap covering fossa the poplitea

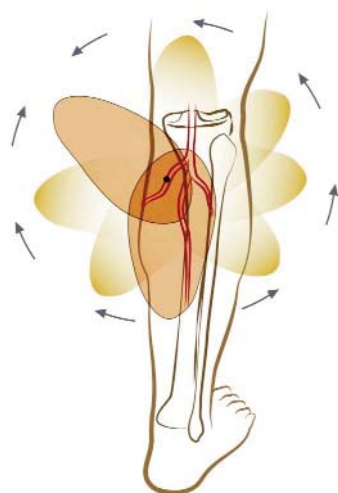
**Table 5.** Flap on perforators from the popliteal artery

Name of the flap	Type, number of perforator vessels	Length of the pedicle	Maximum surface of the flap	Clinical applications (rotation arch)
Popliteal posterior flap described by Maruyama & Iwahira (15)	1-3 septocutaneous perforator from popliteal artery	4.5-9 cm	110 cm <sup>2</sup>	Poplitea fossa, defect around the knee

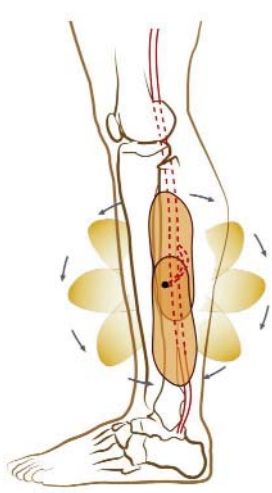
**Table 6.** Calf Perforator flaps

Name of the flap	Type, number of perforator vessels	Length of the pedicle	Maximum surface of the flap	Clinical applications (rotation arch)
Medial sural artery perforator flap (15,17,19, 21,22,23)	1-3 musculocutaneous perforators from medial gastrocnemius muscle	10-15 cm	12/15 cm	Defects around the knee, popliteal fossa
Posterior tibial artery perforator flap (posterior tibial artery flap described by Zhang) (12,15,23,24,25)	5-7 septocutaneous perforators from posterior tibial artery located in the medial and inferior third of the leg	3-4 cm	19/13 cm	ankle, heel, achilean region, medial and inferior third of the tibia
Peroneal perforator flap (15,23,25)	3-7 musculocutaneous perforators from peroneus longus and brevis and flexor halluci longus in the proximal third of the leg and septocutaneous perforators in the distal third of the leg	4-5 cm	8/22 cm	Ankle, heel, achilean region and medial and inferior third of the tibia
Anterior tibial artery perforator flap (15,23)	6-14 musculocutaneous perforators from tibialis anterior and extensor digitorum longus muscles located in the proximal and inferior third of the tibia	3-4 cm	6/18 cm	Ankle, heel, achilean region, proximal and inferior third of the tibia

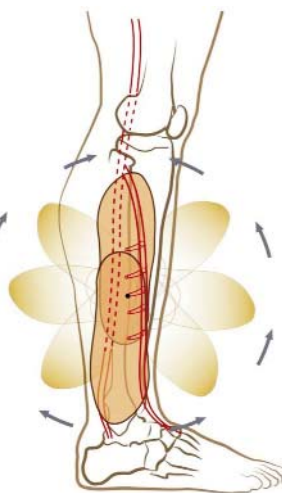




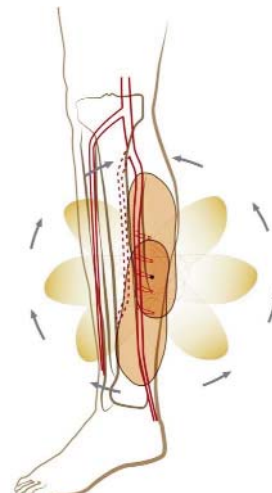
**Figure 15.** Medial sural artery perforator flap



**Figure 16.** Peroneal perforator flap



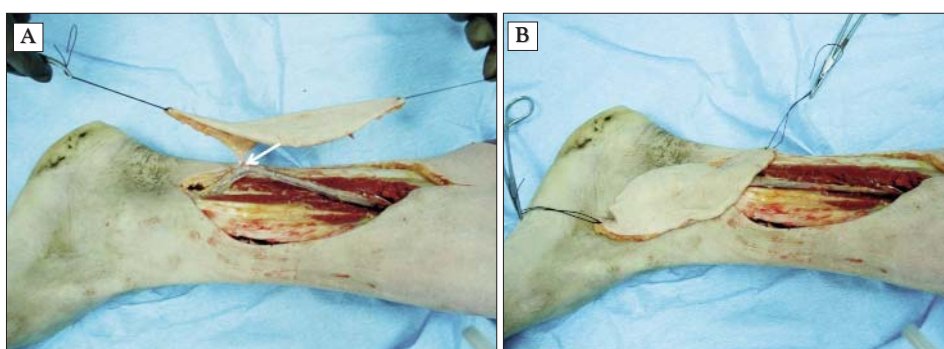
**Figure 17.** Anterior tibial artery perforator flap



**Figure 18.** Posterior tibial artery perforator flap



**Figure 19.** Cadaver study of the medial sural artery perforator flap: (A) medial sural artery perforator flap design; (B) elevated flap and pedicle; (C) flap rotated to cover a popliteal fossa defect



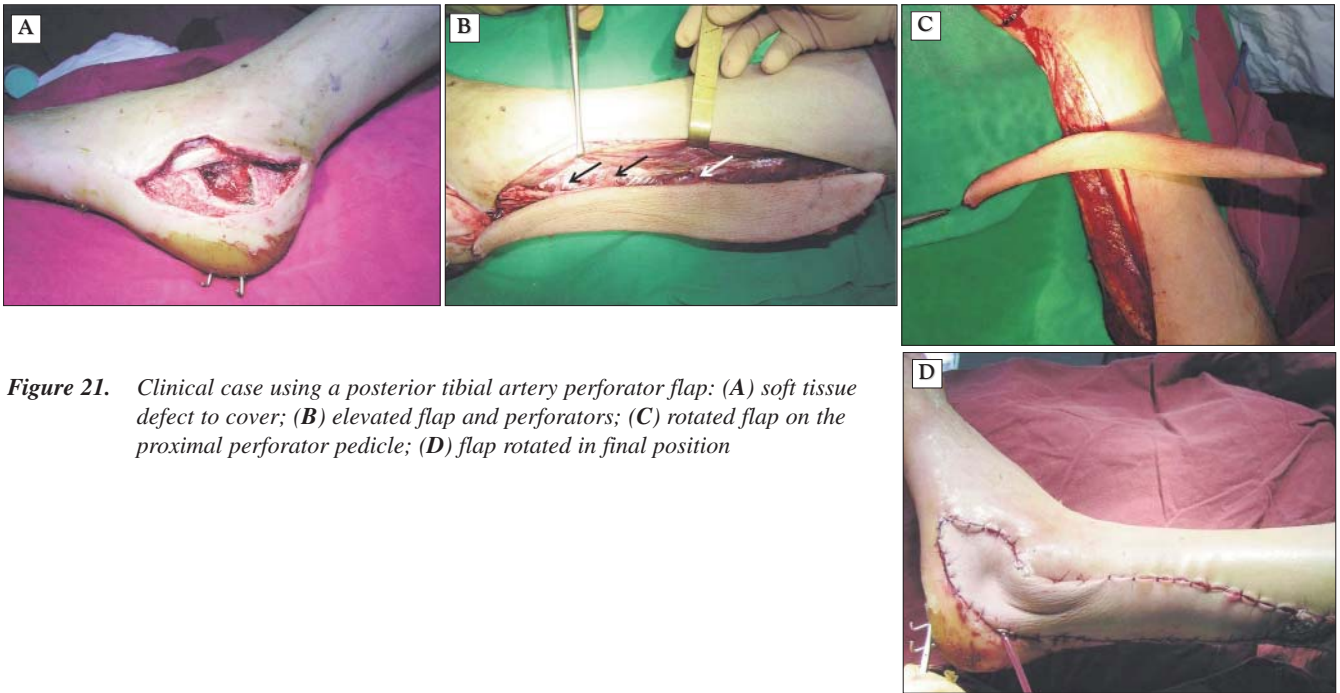
**Figure 20.** Cadaver study of the posterior tibial artery perforator flap: (A) elevated flap and pedicle; (B) rotated flap

At the level of the calf perforator propeller flaps are based on the perforator vessels of the three major vascular axes (peroneal artery, posterior and anterior tibial arteries).

At the level of the foot the reconstructive possibilities

through this technique are limited, flaps based on perforator vessels from the medial plantar artery and lateral calcaneal vessels being described.

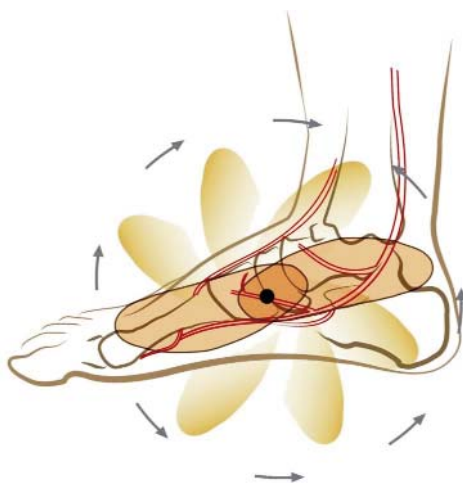




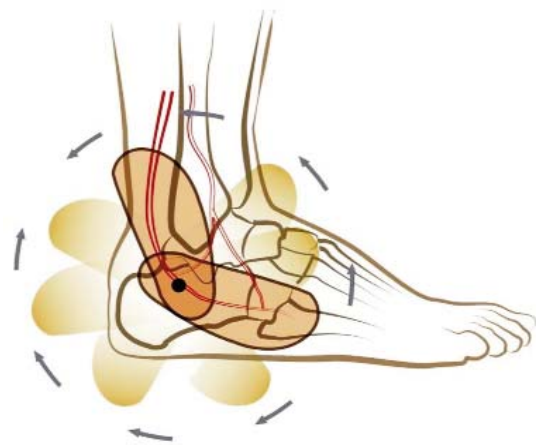
**Figure 21.** Clinical case using a posterior tibial artery perforator flap: (A) soft tissue defect to cover; (B) elevated flap and perforators; (C) rotated flap on the proximal perforator pedicle; (D) flap rotated in final position

**Table 7.** Foot perforator flaps

Name of the flap	Type, number of perforator vessels	Length of the pedicle	Maximum surface of the flap	Clinical applications (rotation arch)
Lateral calcaneal artery perforator flap (15)	direct perforator from lateral calcaneal artery	-	-	Achilean region, internal malleolus, heel
Medial plantar artery perforator flap (15,26)	septocutaneous perforator from medial plantar artery	2-3 cm	4/8 cm	Heel, achilean region, internal and external malleolus, dorsum of the foot



**Figure 22.** Lateral calcaneal artery perforator flap



**Figure 23.** Medial plantar artery perforator flap

## Discussions

Reconstructive surgery of the lower limb level represents a field in continuous development in which new strategies and new surgical techniques are permanently implemented. Perforator propeller flaps have won fast their popularity due to their multiple advantages versus other techniques.

These advantages of the perforator flaps are (9,27,28,29):

- presence in the same operating area with the defect to be reconstructed,
- reduction of the operating time,
- possibility to cover the defect with tissues having similar qualities,
- these flaps do not sacrifice deep musculature (they conserve the function),
- flaps can be raised together with other structures (fascia, nerve, muscle) for complex reconstructions,
- it is not needed to sacrifice the main vascular axis,
- perforator flaps don't require microsurgical anastomosis,
- these flaps allow to reduce the morbidity of the donor area (the axial rotation movement allows its partial coverage with the flap),
- a better aesthetic appearance can be achieved (they can be thinned through microsurgical procedures in order to cover joint surfaces),
- reconstruction of soft tissue defects with these flaps can be used also on patients with peripheral obstructive artery disease after revascularization,
- the free-style principle allows the adjustment of the flap's form and dimensions during surgery (12).

Perforator propeller flaps present also a series of disadvantages (30):

- multiple anatomical variants of the perforator vessels,
- these flaps require the preoperative identification of the perforator vessels,
- microsurgical abilities of the surgeon are needed,
- these flaps cannot cover defects with large surface (except for the flap on LCFA perforator).

The reconstructive strategy of the lower limb allows the use of perforator propeller flaps as first therapeutic option for the defects of small and medium dimensions in certain areas considered "critical" from the reconstructive point of view.

For trochanterian and ischiatic defects one can use perforator propeller flaps from:

- LCFA (anterolateral thigh flap)
- PFA (posterolateral thigh flap, adductor flap)
- MCFA (medial groin flap)

The defects from the groin area can be covered with perforator propeller flaps from:

- LCFA (anterolateral thigh flap, TFL perforator flap, anteromedial thigh flap)
- MCFA (medial groin flap)

Peripatellar defects can benefit from perforator propeller flaps from:

- LCFA (anterolateral and anteromedial thigh flaps)
- PFA (posterior thigh flaps)
- DGA (saphenous flap)

- Popliteal artery (popliteoposterior flap)
- Medial sural artery

For the defects from the popliteal fossa perforator propeller flaps can be raised from:

- DGA (saphenous flap)
- Popliteal artery (popliteoposterior flap)
- Medial sural artery

The defects from the achilean area, heels and ankle can be covered with perforator propeller flaps from:

- Tibial posterior artery
- Peroneal artery
- Anterior tibial artery
- Calcaneal artery
- Medial plantar artery

## Conclusions

Over the last years, perforator propeller flaps have enlarged the area of therapeutic options for the reconstruction of soft tissue defects at the lower limb level even becoming the first choice in case of soft tissue losses of small or medium dimensions, especially at the level of the lower leg and foot (24,31). In our country, among the variety of flaps and microsurgical procedures that are used for lower limb reconstruction (32,34) there is also an initial experience in using perforator propeller flaps for lower limb reconstruction in patients with peripheral arterial obstructive disease (34).

## Authors contribution

All authors had equal scientific contributions.

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