

## Anatomy of Lateral Femoral Circumflex Artery Perforators in Planning of Anterolateral Thigh Flap: Utility of CT. Pilot Study

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### Abstract

**Purpose:** To evaluate the utility of 64-multidetector computed tomographic (CT) angiography with 3D reformations for preoperative vascular anatomy evaluation, lateral femoral circumflex artery and course of perforator vessels assessment in anterolateral thigh flap planning.

**Material and Methods:** Informed consent and institutional review board approval were obtained. Seven patients underwent 64-multidetector CT angiography to identify the lateral femoral circumflex artery perforators prior to oncologic and post-traumatic reconstruction surgery (3/7 patients analyzed bilaterally). Preoperative color Doppler US evaluation was performed. Surgical findings were correlated to imaging using a 0-3 scale Image Relevance Score (IRS) of the multidetector CT.

**Results:** Perforator arteries suitable for surgery were identified in 7/7 patients. Surgical findings were consistent with CT findings for perforator caliber and course. CT identified several anatomical variants. In 1 patient preoperative imaging was performed with no difference in management (IRS=0); in 3 patients moderate intraoperative difficulties were found with increase of operative time (IRS=1); in 2 patients major intraoperative difficulties were encountered, with need for intraoperative change of surgical technique (IRS=2). In the remaining patient CT findings avoided surgical failure (IRS=3).

**Conclusion:** 64-multidetector CT angiography accurately mapped vessels for preoperative evaluation of lateral femoral circumflex artery perforators in anterolateral thigh flap planning in 7 patients.

**Keywords:** Anatomy; Anterolateral thigh flap; Perforator; Computed tomography

### Introduction

The anterolateral thigh flap (ALTF) was popularized for clinical applications by Song et al. and later modified by Koshima [1,2]. In recent years there has been a gradual increase in literature establishing the ALTF as a preferred option for different reconstructions [3,4]. Advantages of ALTF include reduced donor site morbidity, long pedicle with excellent vessel diameter, availability of different tissues with a large amount of skin and vascular adaptability [5]. ALTF is used in various anatomic sites in oncologic and traumatic settings [4-8]. However, this flap is technically difficult requiring intricate perforator dissection. Perforators evaluation is essential to flap survival and crucial in preoperative planning due to several anatomic variations in size, number and pathway [4,9,10]. Color Doppler ultrasonography examination is currently performed to localize perforators at the midpoint of a line between the anterior superior iliac spine and superior-lateral corner of the patella [4-8,11]. Most cutaneous vessels are located in a circle with a 3 cm radius centered at this point and usually the most proximal perforators is chosen because of its relatively large diameter.

Multidetector CT angiography with three-dimensional (3D) reformations has recently emerged as noninvasive technique to map perforator vessels and its pedicle, allowing a detailed reconstruction of the vascular structure in the flap donor area [12]. Multidetector CT angiography with 3D reformations can support the surgeon in estimating operating time, flap design, and surgical technique [13]. The guidelines of preoperative in the Pamplona Forum in 2008 [14] defined

multidetector CT angiography the most reliable option to accurately map vessels up to 0.3 mm of caliber for the deep epigastric artery perforator (DIEP) flap, which has a relevant anatomic variability.

Therefore the purpose of our study is to evaluate the utility of 64-multidetector CT angiography, with 3D reformations for preoperative evaluation of lateral femoral circumflex artery (LCFA) perforators in planning of ALTF.

### Materials and Methods

#### Subjects

Institutional review board approval was guaranteed and all patients gave their written informed consent to the procedure.

From November 2008 to September 2009, seven consecutive patients underwent ALTF procedure. The mean patient age was 59 years

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(age range, 27-77 years). Inclusion criteria were clinical indication for reconstruction with the ALTF and age older than 18 years. Exclusion criteria were a history of allergy to iodinated contrast media and a serum creatinine clearance less than 40 mL/min.

All patients underwent preoperative 64-multidetector CT angiography by 5-12 days before surgery. Two radiologists in consensus with 8 and 6 years of experience in vascular radiology and a highly qualified radiology technician with 8 years of experience in angiographic CT reconstructions performed all scans and evaluated CT angiographic results. All surgical procedures were performed by the same micro surgeon with 10 years of experience in flap surgery, with standardized techniques.

In 4/7 patients the surgeon required the length of the LCFA's descending branch preoperatively due to the distance between the flap's final position and recipient vessels (2 head and neck reconstruction and 2 post-traumatic lower limb reconstruction). In one patient a scar on the right thigh gave virtually only one choice to perform the flap (30 x 10 cm ALT flap from the left thigh (coverage of a post-traumatic foot dorsum). In the remaining 2 patients, the ALTF was planned as a reverse flow flap for the coverage of the knee; therefore the definition of its structure and caliber and the visualization of the anastomotic branches with the superior lateral genicular artery was crucial. In 3/7 patients the study was performed bilaterally (10 thighs evaluated).

The preoperative planning of the flap was completed in all patients by a color Doppler ultrasonography identification and a cutaneous marking of the perforators the day before surgery.

Postoperatively, the micro surgeon established an Image Relevance Score (IRS), assigning a number 0 - 3 to the importance of the multidetector CT angiography images in decision-taking about the surgical procedure (Table 1).

Multidetector CT angiography was performed with a 64-row scanner (Light Speed; GE Healthcare, Waukesha, Wis). Detector configuration was 64x0.65mm with 39 mm table travel per rotation (0.8-second gantry rotation), 512 x 512 matrix. In 3/7 cases we used a large field of view (50 cm) for the choice of the donor side (vascular study performed bilaterally), while in 4/7 cases we used a small field of view (36 cm) focusing on single patient's thigh previously identified. The volumetric data acquired was used to reconstruct images with a slice width of 0.625 mm. A reconstruction interval of 0.625 for all 10 thighs was performed. Thin sections were obtained with filters for the reduction of helical artifacts to obtain better image quality. The tube voltage was 120 kVp, with a Smart mAs (GE Healthcare) dose (noise index set to 20).

All scans were performed in a cranial-caudal direction set from the anterior superior iliac spine to the upper margin of the patella (or to the knee joint, in two cases when planning a reverse flow flap needed the evaluation of the distal anastomotic branches connecting to the superior lateral genicular artery). In 2 cases, the lasts, we positioned a small metallic mark on the skin as a reference, to locate precisely the point of emergence of the best perforator vessel from the fascia.

Scans were performed during the intravenous administration of 130 mL of non-ionic iodinated contrast medium at a concentration of 400 mg of iodine per milliliter. Contrast medium was injected with a double-barrel injector through a 16-Gauge intravenous catheter insert in an antecubital vein. In one case we used an 18-Gauge catheter, tested for high flow. Contrast medium was injected using a double-bolus technique: first injection of 70 mL of contrast medium at a rate of 4 mL/sec, followed by a second injection of 60 mL of contrast medium at 3 mL/s; no saline solution was administered.

The scanning protocols are worthy of discussion: the Smart Prep (GE Healthcare) option of the scanner, with region of interest localized on the appropriate vessel, common femoral artery in general (identified on the basis of a single scan performed before contrast medium administration or on a single image of reference) was used to synchronize the scanning with arterial peak opacification.

The data set was analyzed on a dedicated workstation (Advantage Windows 4.1; GE Healthcare) by the radiology technician with the aid of the radiologist and the micro surgeon, then stored in a PACS Kodak system.

Three-dimensional reconstructions are essential to achieve the images of interest. Volume-rendered (VR, and Volume of Interest -VOI) and subvolume maximum intensity projection (MIP) reconstructions are commonly used [10,14].

Perforator vessels were identified on axial and sagittal subvolume maximum intensity projection reconstructions and their course was assessed on multiplanar reconstruction, with particular attention to the precise point of emergence from the fascia (Figure 1). Subvolume maximum intensity projection reconstructions are optimal for pedicle and intramuscular course of perforators' demonstration, showing the course in the subcutaneous fat (Figure 1).

Volume-rendered reconstruction were generated to obtain perforator-location and anatomical vascular maps [5,15], allowing a good identification of the arterial branches and in the meantime showing the relationships between anatomical structures using different opacity levels (Figures 2-4).

A virtual coordinate system was created on a volume-rendered superficial reconstruction of the thigh, and the perforating pedicles were marked on this reconstruction (Figure 5).

In 2 patients flaps had to be tailored of limited size. We analyzed the distance from the metallic marker positioned on the skin at the midpoint between the superior-lateral corner of the patella and the superior anterior iliac spine to locate the point of emergence of the best perforator vessel from the fascia and take measurements (Figure 6).

## Results

Results are summarized in Table 2 as reported below (IRS=Imaging Relevance Score).

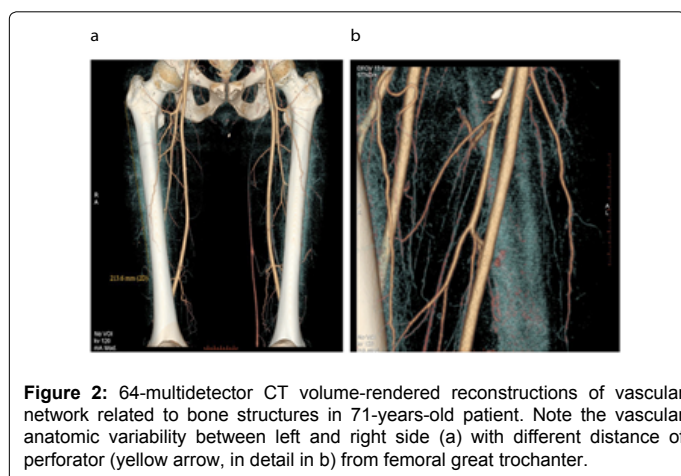
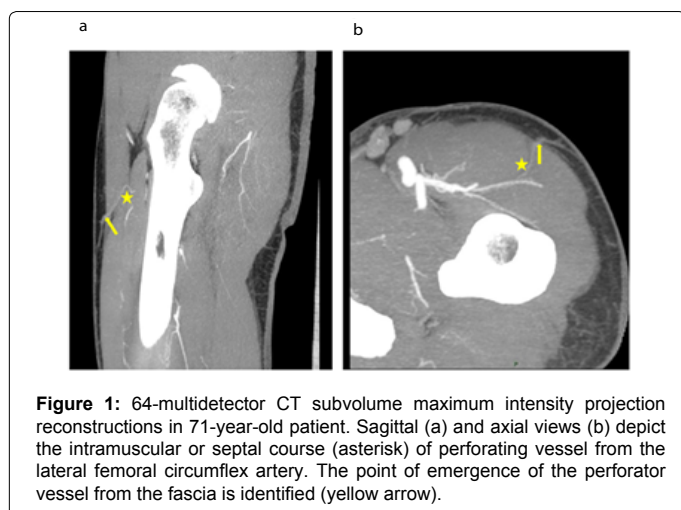
The anatomy of the LCFA and its descending branch or branches

IRS	Difficulties predictably encountered without preoperative imaging
0	No differences
1	Moderate intraoperative difficulties: probable increase of total operative time
2	Major intraoperative difficulties: need for intraoperative change of surgical technique (change side, vascular grafting, etc.)
3	Surgical failure (intra- or post-operative need for a new, different flap)

Table 1: CT Technique and Image Analysis

Case/Age/Sex	Flap style	Site of reconstruction	Anatomy	Recipient vessel	Side	Image detail	Complications	IRS
1/27/M	Free	Left leg, open fracture	Intramuscular perforator from descending branch	Anterior tibial (T-T)	L+R	Good	None	0
2/77/M	Free	Laterocephal + oral	Right: thin descending branch, perforator not identified Left: intramuscular perforator from the descending branch	Inferior thyroid (T-T)	L+R	Fair	None	2
3/71/M	Pedicle reverse flow	Left knee	Septal perforator from the descending branch	-	L	Good	Venous congestion (STSG)	1
4/74/M	Free	Tongue + oral floor	Right: double descending branch Left: descending branch originating from profunda femoris, distally to LCFA	Contralateral facial (T-T)	L+R	Excellent	None	2
5/75/F	Pedicle reverse flow	Left knee	Descending branch trifurcation, perforator arising from superficial intermuscular branch; anastomoses with the genicular system with deeper intramuscular branches	-	L	Good	-	3
6/44/M	Free	Foot dorsum	Double descending branch with intermuscular route; intramuscular perforator	Pedial (T-T)	L	Excellent	None	1
7/46/M	Free	Left hand dorsum	Intramuscular perforator from descending branch	Dorsal branch of radial (T-T) R	R	Excellent	None	1

**Table 2:** Table showing the results on the basis of case, age and sex



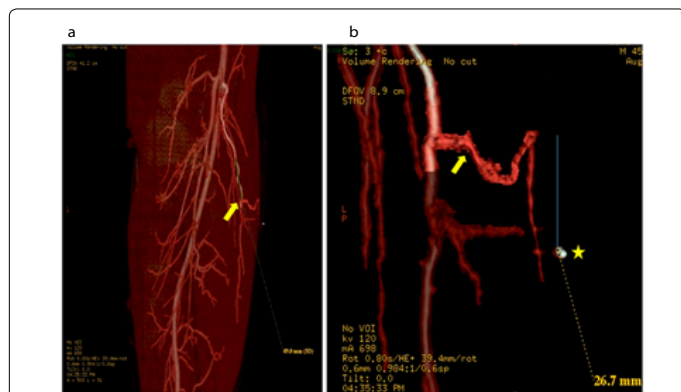
was clearly defined in all 7 patients (10 thighs). Vessels were studied and reconstructed bilaterally in 3/5 flaps planned as microsurgical transfers. Imaging was carried out on the affected limb in those planned as local reverse flow flaps (n=2) and in the remaining 2/5 microsurgical transfers.

Terminal perforator vessels were only partially recognizable and not always clearly definable as septal or intramuscular perforators when the exam was carried out on both thighs simultaneously (image detail defined good). The emerging point of the most proximal perforator from the descending branch of the LCFA was always visible in the axial images, but in one case its 3D reconstruction implied the presence of a conspicuous amount of noise in the resulting images (image detail defined fair).

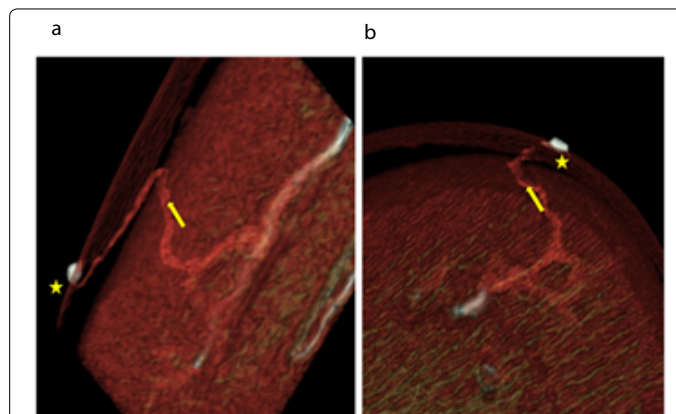
Perforators were more clearly visible when the exam was focused on one single thigh area and their course (which was intramuscular in all cases but one) could be described (image detail defined excellent). In both cases where the flap had to be used for head and neck reconstruction, the preoperative images gave us confidence about the pedicle length being sufficient to reach recipient vessels (contralateral facial artery in one case, and inferior thyroid artery in the other), without need of interpositional vascular grafts.

In one case, the vessel nourishing the ALTF originated from the deep femoral artery distal to the LCFA on one side, making the pedicle significantly shorter, and its dissection considerably more difficult; therefore we had to plan the flap on the opposite side. In another case, the descending branch divided into two minor branches 2 cm after its origin, one of which ran deep in the belly of the vastus lateralis muscle; this information was important to avoid accidental injury of the deep branch in its point of emergence during pedicle isolation.

One patient with lower limb trauma (distal third of the leg) had an anterior tibial artery only patent in its upper third according to preoperative multidetector CT angiography; the flap was harvested



**Figure 3:** 64-multidetector CT volume-rendered reconstructions in 46-year-old patient. Vascular structures are visible related to muscular and fascial planes (a) with enhancement of the descending branch of the lateral circumflex femoral artery (yellow arrow; in detail, b) and perforator vessel. Note the presence of a small metallic marker (asterisk, b) on the skin surface (positioned at the midpoint between the superior-lateral corner of the patella and the superior anterior iliac spine) to localize point of emergence of the perforator vessel from the fascia in case of a flap to be tailored of limited size.



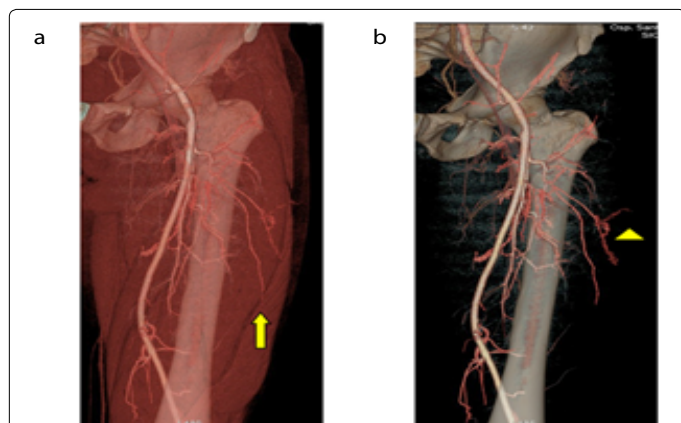
**Figure 6:** 64-multidetector volume-rendered reconstruction (Volume of Interest=VOI; a,b) in 74-year-old patient detailing the course of vessels through intermuscular planes, the point of emergence of perforator from the fascia (yellow arrow) and the metallic marker on the skin surface (asterisk).

with a 12 cm pedicle, but intraoperative retrograde dilatation of the vessel allowed a more distal safe anastomosis which persuaded us to shorten the harvested pedicle to avoid kinking.

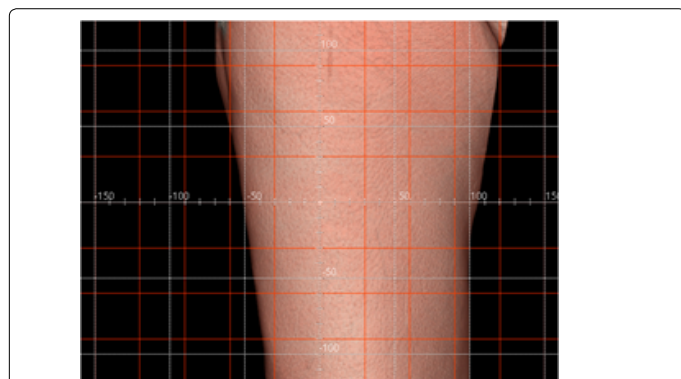
The flap used for the coverage of a foot dorsum and lateral malleolus was of extreme size (30 x 10 cm), and the authors wanted to be sure of vessel caliber and of the presence of at least two main perforators for an efficient vascular supply of the entire fasciocutaneous paddle (proximal and distal tips were going to have the delicate job of covering and protecting metatarsal and malleolus exposed bone segments).

In 2 patients studied to plan reverse flow ALT flaps, vascular anastomosis between the descending branch of the LCFA and the superior lateral genicular artery were not clearly visible. In one of these, the descending branch divided into 3 minor arteries 2 cm distal to the emergence of the first perforator. The more superficial of the three, running in the septum between the vastus lateralis and vastus intermedius muscles, and giving origin to both visible perforating branches, could not be followed distally to the second perforator, while the two deeper branches, running inside the fibers of the vastus lateralis, could be visualized much more distally, and some anastomotic interconnection with the genicular network could be hypothesized with good confidence. Three-dimensional images showed a very deep intramuscular route of these vessels, which would have predictably made their dissection extremely complicated and time-consuming, if ever feasible (IRS=3). In the other reverse-flow case, we decided to carry out the procedure anyway and assessed the presence of a reverse arterial flow intra-operatively after temporarily clamping the dissected descending branch above the first perforator.

Our Image Relevance Score (IRS) to define the importance of the multidetector CT angiography in planning of ALT flaps (IRS) is based on the surgeon's subjective opinion, but yet helps to obtain a better retrospective idea about the real need for such an expensive (for both its economical and biological cost) procedure in the planning of ALT flaps. Considering our limited series, this procedure could have been avoided with virtually no difference in surgical times and outcome in one patient in (IRS=0). However, this procedure contribute to avoid minor intraoperative difficulties in 3 patients, mainly just shortening anesthesia time (IRS=1) and in 2 patients predicted need for intraoperative change of surgical technique (IRS=2). In the remaining patient, CT findings avoided surgical failure (intra or post-operative need for a new, different flap; IRS=3). Concordance with



**Figure 4:** 64-multidetector volume-rendered reconstructions in 75-year-old patient. Anatomic variant with double descending branch, both with intermuscular course; from the deeper branch (arrow, a) don't arise any perforating vessel. From the superficial one (arrowhead, b) arises two perforators reaching the skin surface.



**Figure 5:** 64-multidetector volume-rendered reconstruction of the thigh surface in 27-year-old patient. Dominant perforator vessels are identified with a virtual coordinate system, where the zero point is the midpoint between the superior-lateral corner of the patella and the superior anterior iliac spine. This allows to report the result with a marker on patient's skin before surgery. 3D= three dimensional.

operative findings was found with 64-multidetector CT angiography. Radiological reporting concerning image detail was scored "good" in 3 patients (4 thighs), "excellent" in 3 patients (4 thighs), "fair" in 1 patient (2 thighs). In our limited series we found a large anatomic variation, which is according to the literature 64-multidetector CT angiography facilitated rapid intraoperative dissection and minimized surgical errors in vascular anatomy identification.

## Outcomes

There were no immediate complications arising from the use of computed tomography angiography: none of our patients underwent allergic reactions or renal impairment after the injection of the contrast medium. All microsurgical flaps in the small series had an uneventful postoperative recovery (100 percent success rate of flap surgery, with no partial or total flap losses). The reverse flow pedicled flap showed venous congestion in the immediate post-operative period, which led to a partial superficial necrosis, treated with debridement and split-thickness skin grafting on post-op day 21. One of the patients operated for oral reconstruction died ten months after surgery for tumor recurrence and metastases.

The dose-length products reported by our CT scanner indicated an estimated dose of 10 mSv for each patient.

## Discussion

Color Doppler ultrasonography is a handy inexpensive tool to analyze flow velocity, resistivity, change in diameter and pedicles, origin and anatomic variations of perforator arteries. However, some data about the use of the color Doppler ultrasonography are still debated such as operator dependence, a steep learning curve, false positives in detection of perforators and the amount of time taken for the hospital staff and patient; the information cannot be reproduced and the procedure must be repeated by radiologist [14]. In comparison multidetector CT angiography is less operator dependent and provides more impressive images to the surgeon than US [14]. Moreover 3D anatomic images guarantee best perforator evaluation (with regard to its caliber and position) in preoperative time, allowing most appropriate side selection. As a result, a lot of time is saved during surgery avoiding extensive perforators overview [15,16].

Multidetector CT angiography with 3D reconstruction has shown to be an extremely useful tool if pedicle length and morphology informations are required in ALT flaps planning [16]. In a preoperative setting, patients with difficult anatomy, most appropriate side and perforator can be identified. CT allows operative time sparing, minimize soft tissue damage, and reduce risks and pitfalls in flap harvesting. Moreover CT may modify operative technique and surgical approach [15]. Up-to-date CT is the most accurate modality for perforator mapping (sensitivity and positive predictive value=99,6% in clinical studies) [15]. Studies are underway to investigate magnetic resonance (MR) angiography ALTF surgery planning [14].

In our study the aim of preoperative multidetector CT angiography was to avoid unnecessary procedures and reduce complications. In our study perforator anatomy was clearly identified helping plastic surgeons in pre-operative planning. Recipient vessels were clearly identified and this process is not easy to be guaranteed with US [14]. In 3 patients CT avoided minor intraoperative difficulties shortening anesthesia time, in 2 patients CT predicted intraoperative change of surgical technique preventing possible intraoperative difficulties. Moreover a concordance with operative findings was always found. The large anatomic variation detected in this study reinforced the feeling that a

preoperative assessment guaranteed a rapid intraoperative dissection and minimized surgical errors in vascular anatomy identification. The main criticisms of multidetector CT angiography are x-ray exposure and use of iodinated contrast media. Although measurement of x-ray exposure was not a primary objective of our study the estimated dose in the population of our study was consistent with values reported in literature [14].

We acknowledge that there were some limitations to our study, in particular the small series of patients. A prospective study with more patients involved is warranted.

Another limitation is that Image Relevance Score is based upon a post-surgical evaluation therefore a retrospective analysis of all cases was performed. In addition, we didn't perform a comparison between the color Doppler data and the multidetector CT angiography finding. Further studies are needed to perform this comparison.

In conclusion, multidetector CT angiography resulted a useful technique for identifying and mapping perforating vessels used for reconstruction with an ALTF, with a contributive impact on surgery in seven patients.

## Acknowledgment

The authors declare that they have no conflicts of interest to disclose.

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