

# Computed Tomography Angiography, Perforator Flaps, the Surgeon, and Osirix

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## Abstract

Through their experience with 144 patients, the authors evaluate the use of the free open-source DICOM viewer OsiriX for Mac in the preoperative planning of perforator flaps with three objectives: 1) increase the present knowledge related with the preoperative planning of perforator flaps with computed tomography angiography (CTA), 2) evaluate the application in the image post-processing of perforator flaps, and 3) evaluate the performance of the image post-processing when performed by a surgeon. The experience demonstrated that the use of OsiriX allowed an adequate evaluation of different structures and parameters of great preoperative interest in perforator flap surgery: 1) source artery, 2) diameter of artery and vein/s at the hypothetical site of microsurgical anastomoses, 3) course and branching pattern of the flap pedicle, 4) perforator course in the subcutaneous fat (theoretical flap axis), 5) measurement of the skin and fat where the perforator pierced the deep fascia (theoretical flap thickness), 6) measurement of the distance between the point of entrance of the perforator in the subcutaneous fat to the source artery (theoretical maximal pedicle length), and 7) measurement of the perforator diameter where it pierced the deep fascia. For the home user, OsiriX is an efficient alternative, comparable to the more professional applications only available in Radiology services and dedicated professional PACS workstations.

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**Categories:** Plastic Surgery, General Surgery

**Keywords:** ct angiography, cta, osirix, computed tomography angiography, perforator flap

## Introduction

Whether or not CTA is justified in the preoperative planning of perforator flaps is still under debate but there is a growing evidence of the associated benefits [1] and, despite the lack of randomized multicentric studies, a substantial and growing amount of bibliography supports the use and security of CTA [1-2]. CTA has demonstrated to improve the surgical results, aid in the selection of the best perforators, minimize surgical trauma and donor site sequelae, reduce economic costs and minimize the surgeon's surgical stress [3-7]. Its potential role in the evaluation of recipient vessels has also proven to be high [8]. Very popular in breast reconstruction with abdominal flaps, its use has rapidly expanded to other body regions because the technique is readily available, extremely fast and shows a low interobserver variability [9-11]. However, computed tomography has drawn experts' attention because of its relatively high radiation dose per study [12-14]. In this scenario, different measures are imperative: 1) a correct indication of CT studies, 2) the improvement of technology and 3) the optimization of the acquisition parameters to minimize the radiation dose following the ALARA (As Low As Reasonably Available) principle [4, 15-16]. At present, only magnetic resonance angiography can rival CTA [17-18], although some reports have found that the technique is still far from it because of a lesser resolution, higher cost and limited availability [19-21]. OsiriX is a

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free open-source imaging software that transforms an Apple Macintosh into a PACS DICOM workstation to process and visualize medical images [22]. Free in its 32-bit version, the paid 64-bit version gives an extended usage of the processor's RAM memory. The recently released MD version has obtained the Class II Medical Advice certification by the FDA for clinical use. iPhone and iPad HD versions open up a new portable dimension to radiological studies.

Materials And Methods

A retrospective review was made of the authors' experience in the preoperative evaluation of perforators with CTA with three objectives: 1) widen the present knowledge of the use of CTA in preoperative planning of perforator flaps, 2) evaluate the OsiriX application in the DICOM image post-processing of perforator flaps and 3) analyze the performance of the post-processing when done by a surgeon (non-specialist in Radiology). After the appropriate Institutional Ethics Committee approval from the Hospital Fremap Majadahonda and the corresponding written patient informed consent, the research included the studies of 144 consecutive patients who undertook a CTA as one of the routine studies in the preoperative planning of a perforator-based free or pedicled flap reconstruction (Table 1).

Flaps		Number of Studies
Free flap	Anterolateral thigh (ALT)	79
	Deep inferior epigastric (DIEP)	32
	Superficial inferior epigastric (SIEA)	4
	Superior gluteal (SGAP)	2
	Superolateral thigh (SLT)	5
	Thoracodorsal (TDAP)	12
Pedicled propeller flap	Anterior tibial perforator (ATP)	3
	Posterior tibial perforator (PTP)	7
Total		144

TABLE 1: Preoperative planning of perforator flaps with computed tomography angiography. Patient study

The series included 56 females and 88 males with ages raging between 23 and 67 years of age (mean 42.6). All the studies were performed with a 64-slice CT (Lightspeed VCT, GE Healthcare, US) between March 2008 and February 2011. The acquisition parameters [4-16], adjusted for an optimal relationship between radiation dose and image quality following the ALARA principle [23], are shown in Table 2.

Scanner	Lightspeed VCT, GE Healthcare, US
Scan direction	Craneo-caudad or caudo-craneal depending on the area of study
Range	
Collimation	0.625 mm
Voltage	120 kV
Tube current	180-200 mAs
Rotation time	0,37 s
Contrast material	
Contrast	Ultravist 300, Schering AG, Berlin, Germany
Injection system	GE-Nemoto Dual-Shot Injector,GE Healthcare, Waukesha, Wisconsin, US
Volume	100 cc
Speed	4 cc/s
Saline flush	
Volume	50 cc
Speed	4 cc/s
Reconstruction thickness	0,625 mm

**TABLE 2: Acquisition parameters and contrast media**

The images were processed and analysed by the first author with a 24-inch screen iMac and the 64-bit version of OsiriX. The different reconstruction 2D and 3D modes were used as shown in Table 3.

Study Parameter	Mode
First overall anatomical evaluation	Orthogonal 2D MPR
Analysis of small caliber vessels (below 3-4 mm)	Curved 3D MPR
Distance between points of interest	Orthogonal 2D MPR
	3D MPR
Measurement of flap thickness	Orthogonal 2D MPR
	3D MPR
Measurement of maximal theoretical length of flap pedicle	Curved 3D MPR
Perforator course in subcutaneous fat	Orthogonal 2D MPR
3D anatomical evaluation and photographic presentation	3D VR

TABLE 3: Reconstruction modes

Different parameters of interest in perforator flap surgery were evaluated with OsiriX: 1) source artery, 2) diameter of pedicle's artery and vein at the hypothetical suture site, 3) course and side-branching of the flap pedicle, 4) measurement of the distance between the point where the perforator pierced the deep fascia and the hypothetical suture site (theoretical maximal pedicle length), 5) measurement of the perforator diameter at the point where the perforator pierced the deep fascia, 6) measurement of the skin thickness at the perforation point (theoretical flap thickness), and 7) perforator course in the subcutaneous fat (theoretical flap axis and guiding parameter to flap thinning) (Table 4).

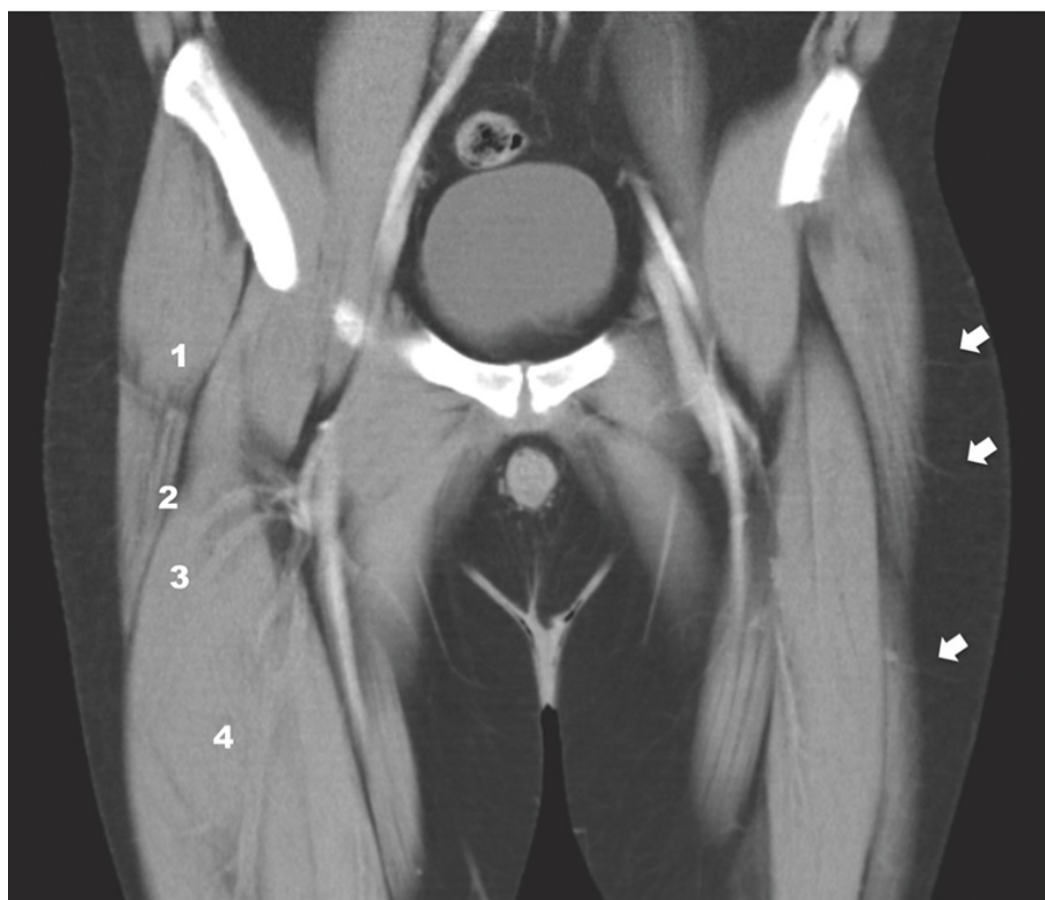
Studied Parameters and Structures	
1.	Source artery
2.	Diameter of pedicle artery and vein at the hypothetical suture site
3.	Course and side branching of flap pedicle
4.	Measurement of the distance between the suture site and the point where the perforator pierces the deep fascia
5.	Measurement of the perforator diameter at the point of deep fascia perforation
6.	Measurement of skin thickness at the point of deep fascia perforation (theoretical flap thickness)
7.	Perforator course and disposition in the subcutaneous fat (theoretical flap axis)

TABLE 4: Studied parameters and structures

In each study, different points of interest were marked to evaluate and measure the regions of study: 1) reference points with a surface translation (umbilicus, anterior superior iliac spine, greater trochanter, malleoli), 2) point of piercing of the deep fascia by the perforator and 3) site of pedicle emergence from the source artery. The study included the following measurements: 1) distance between previously defined points of interest and 2) external diameter of small-calibre vessels (smaller than 3-4 mm) at the hypothetical suture site and at the piercing point of the deep fascia.

## Results

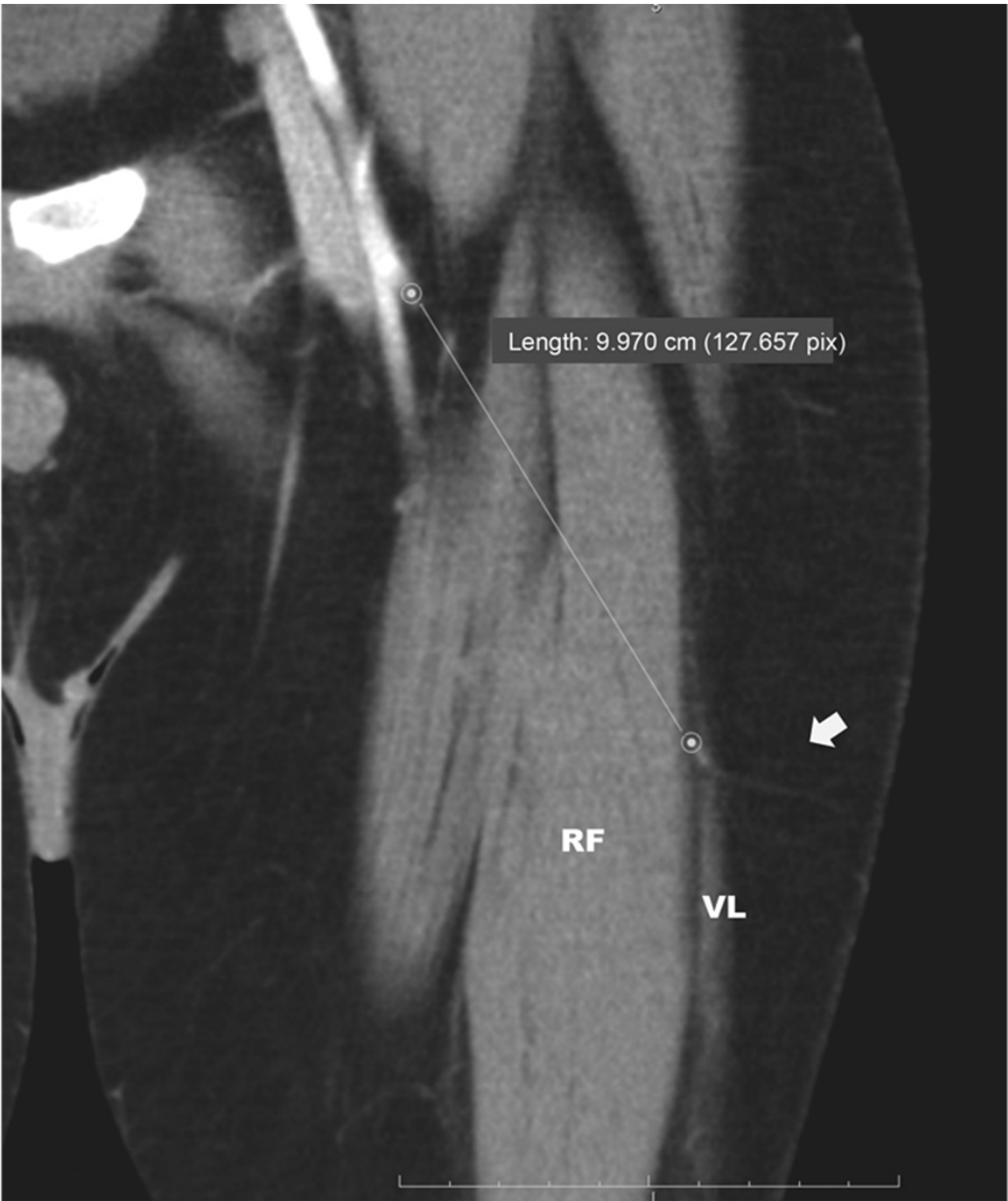
Overall, CTA demonstrated an excellent competence in the visualization of the vascular and musculoskeletal anatomy. As expected, the orthogonal 2D MPR and 3D MPR were the most valuable and easy to learn modes of visualization (Figure 1).



**FIGURE 1: 2D MPR (coronal) where three perforators (arrows) and the different branches of the lateral circumflex femoral artery can be seen**

2D MPR (coronal) where three perforators (arrows) and the different branches of the lateral circumflex femoral artery can be seen (1. Ascending branch. 2. Transverse branch. 3. Oblique branch (inconstant). 4. Descending branch).

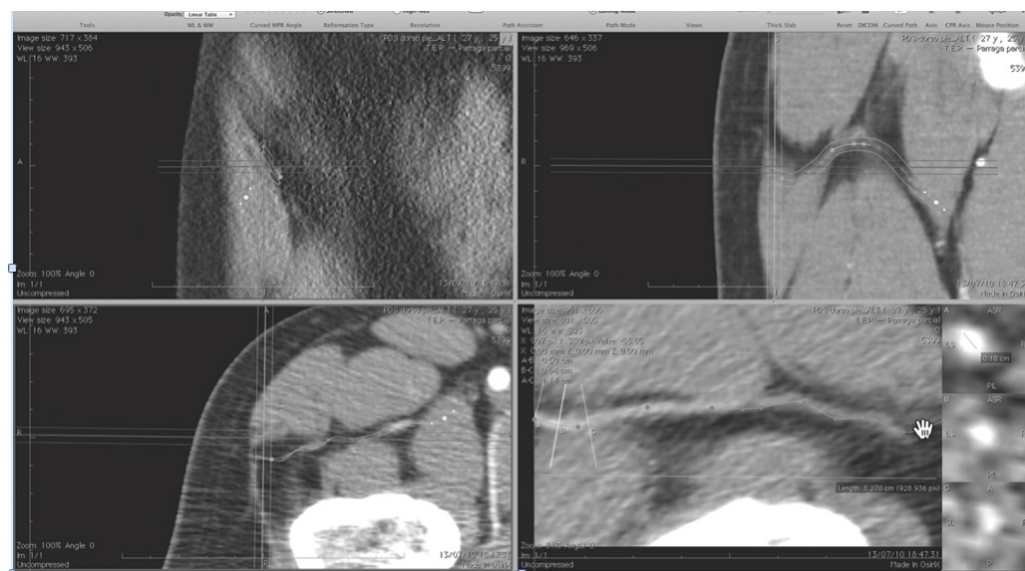
They allowed a comprehensive evaluation of the muscle/vessel anatomy and easy measurement of distances among the marked points of interest (Figure 2).



**FIGURE 2: 2D MPR (coronal)**

2D MPR (coronal). Perforator of the descending branch of the lateral circumflex femoral artery.

The curved 3D MPR demonstrated to be the best mode for a global vessel evaluation because it can "stretch and straighten" vessels. Of the two possible views (*straightened* and *stretched*), the latter preserves the isometry and allowed an approximate measurement of the vessel length despite its tortuous course (Figure 3).

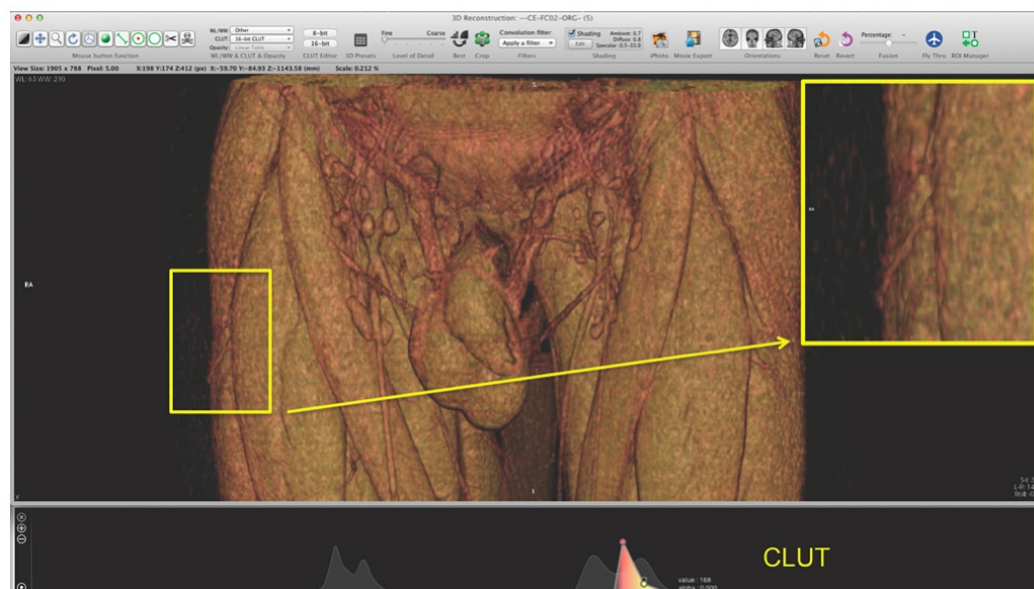


**FIGURE 3: The curved 3D MPR mode permits the evaluation of the pedicle**

The curved 3D MPR mode permits the evaluation of the pedicle. Also, it allows a reliable measurement of the pedicle diameter at the suture site and an approximate measurement of the perforator where it pierces the deep fascia.

The difficulty of an exact measurement of the external diameter of small vessels (mainly below 2 mm) has been previously reflected in the literature, and none of the OsiriX tools and extensions (*plugins*) demonstrated a good performance. However, any of the 2D/3D modes permitted an approximate measurement of the external diameter of the vessel/perforator. Another limitation found, due to the tomography technique, is the poor visibility of the small calibre vessels running close the bony structures. The 3D VR mode exhibited excellent capabilities to evaluate and show the 3D anatomy. The manipulation of the colour look-up table (*CLUT*) values permitted the assignation of a colour and opacity to each of the intensity table values to make the fat invisible and see the perforators in the subcutaneous fat. The manipulation of the *CLUT* values on an individual basis permitted a suitable 3D view of the studied perforators (Figure 4).





**FIGURE 4: 3D VR showing a septocutaneous perforator of the lateral circumflex femoral artery**

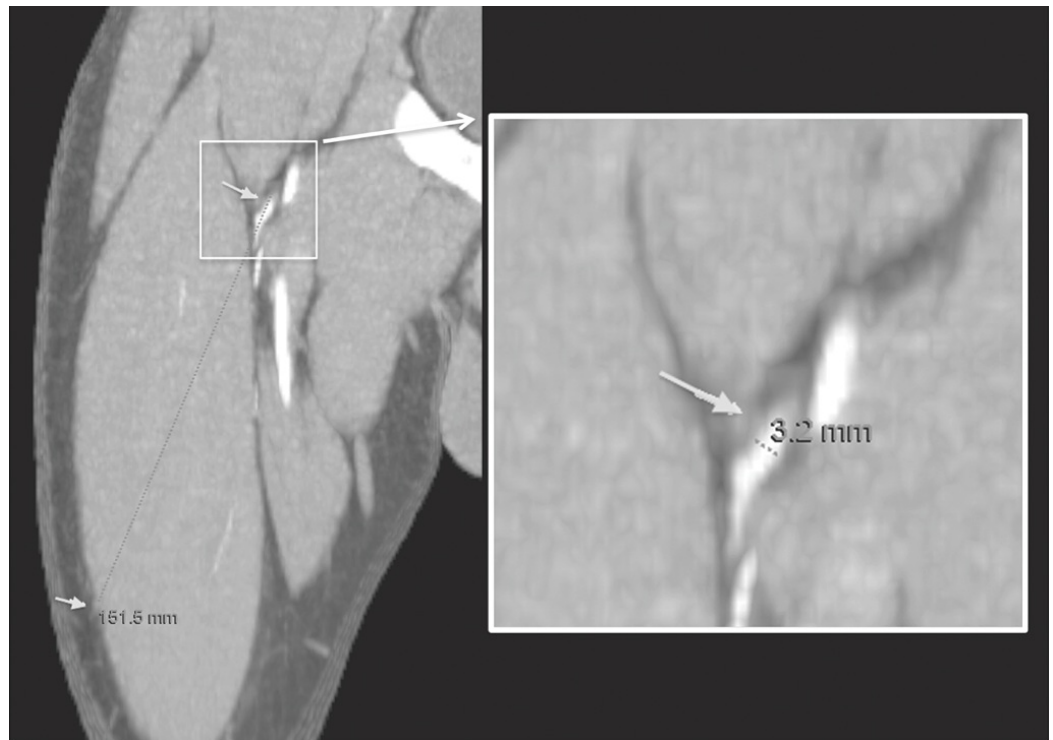
3D VR showing a septocutaneous perforator of the lateral circumflex femoral artery. The manipulation of the CLUT values provides illustrative images.

## Discussion

Despite the growing body of literature regarding the benefits of CTA in perforator flap surgery, no publication specifically addresses which specific data can be obtained from the technique. Based on the study, the authors have found that CTA can provide valuable information regarding perforator flap surgery:

1. Detection of possible vessel malformations or obstructions that might even contraindicate the surgical flap (typical examples would be the distal obstruction of the superficial femoral artery when planning an anterolateral thigh flap or the absence of the peroneal artery in fibula transfers).
2. Selection of the most beneficial (not necessarily the largest) according to its size, situation and pedicle length (Figure 5).

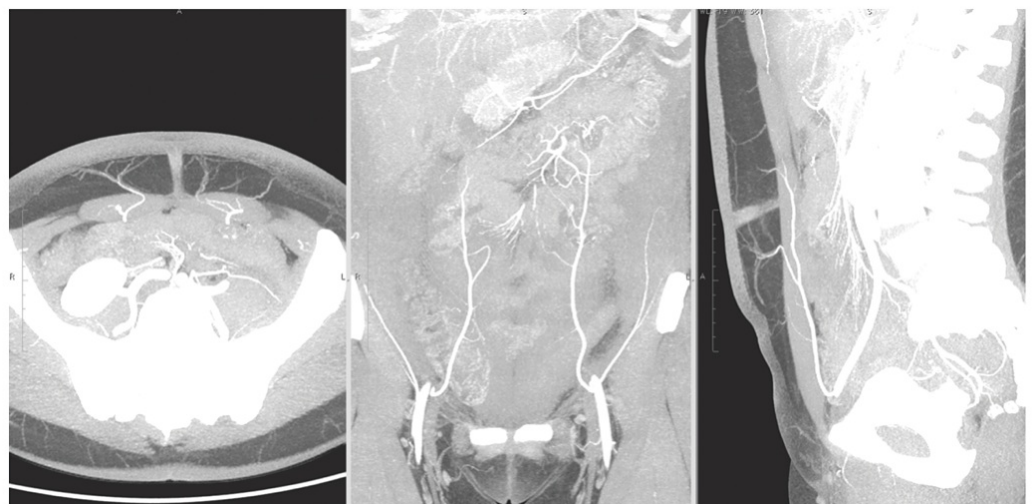




**FIGURE 5: 2D MPR mode (coronal)**

The 2D MPR mode (coronal) is also helpful in the measurement of the pedicle length, approximate external diameter of the perforator and flap thickness.

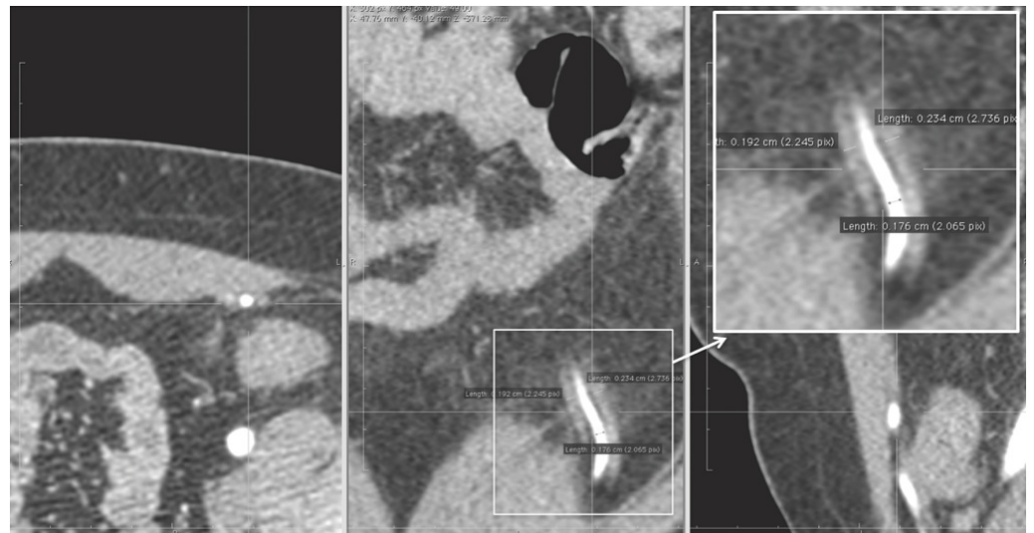
3. Evaluation of the flap pedicle from the source artery to the deep fascia. The technique allows the recognition of its length, course, approximate diameter, and relationships with neighboring structures (Figure 6).



**FIGURE 6: 2D MPR (coronal) (MIP 50)**

2D MPR (coronal) (MIP 50). The maximum intensity projection allows the evaluation of perforators and pedicle in DIEP flap.

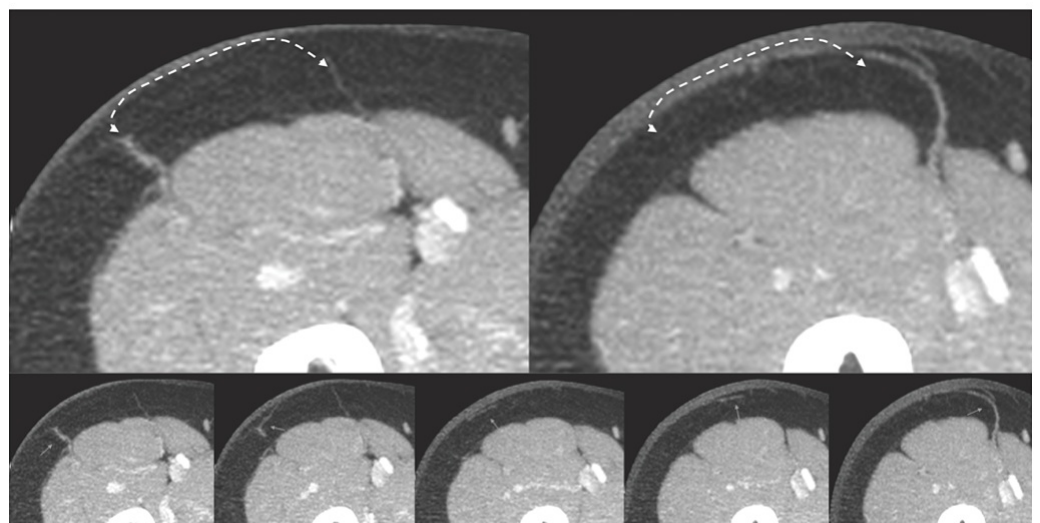
4. Evaluation of side branches arising from the flap pedicle, of great aid when planning a compound or free style free flap.
5. Evaluation of the number and size of pedicle veins at the suture site (Figure 7).



**FIGURE 7: 2D MPR**

2D MPR. CTA also permits the evaluation of the pedicle veins.

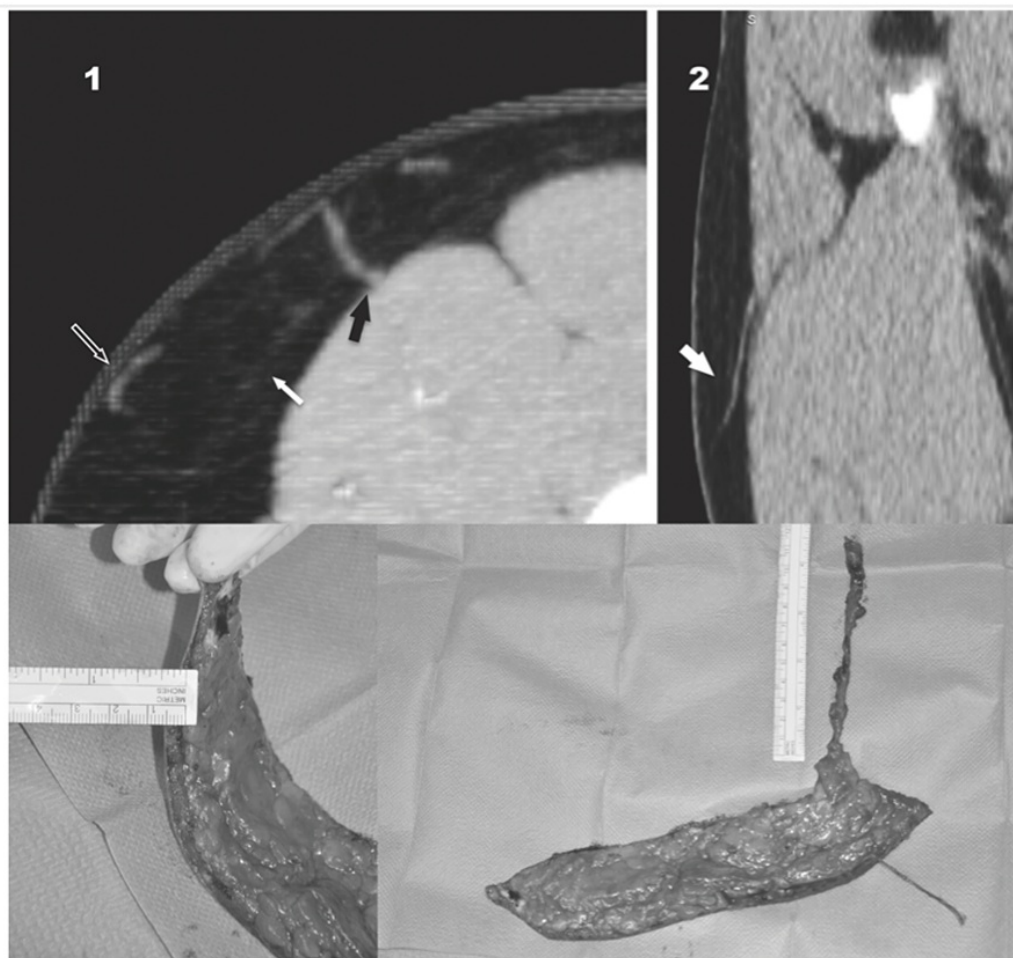
6. Optimized flap design. The perforator course in the subcutaneous fat defines the flap axis. The evaluation of neighbouring perforators allows their capture, thus enabling large, reliable flaps with minimal risk of marginal skin or fat necrosis (Figure 8).



**FIGURE 8: Neighboring slices**

The evaluation of neighboring slices translates the connection between perforasomes into images, thus guiding flap design with safety.

7. Estimation of the perforator course in the subcutaneous fat. A prevalent suprafascial course will advise against aggressive intraoperative flap defatting. On the contrary, a predominant subdermal course will advise a careful flap deepithelization (Figure 9).



**FIGURE 9: Perforator course in the subcutaneous fat**

The perforator course in the subcutaneous fat provides the key for an immediate, safe deepithelization and defatting of the flap. 1. With predominantly subdermal perforators, uncontrolled deepithelization should be regarded with caution in large flaps. However, defatting is reasonably safe (Black arrow. Perforator. Empty arrow. Predominant subdermal course of perforator. White arrow. Suprafascial course of perforator). 2. With predominantly suprafascial perforators, defatting, but not deepithelization, is hazardous.

8. Evaluation of the quality and distribution of recipient vessels and identification of possible degenerative or traumatic vessel lesions.

Radiologists are, of course, the specialists in image post-processing but only the surgeon is able to translate the image findings into surgical decisions. Consequently, more and more surgeons are showing interest in image post-processing but, in most hospitals, the availability of professional workstations is limited and their use is mostly restricted to radiologists under a

busy clinical activity. Built-in DICOM viewers included on the CD/DVD are reduced versions of the original applications with limited processing capabilities that do not allow a competent image post-processing. OsiriX fills the gap with efficiency and, at present, it is probably the best alternative for the home user. Two factors have a direct influence in image post-processing of DICOM files: software and informant. There is data enough to sustain the excellent performance of OsiriX in the management of DICOM files. OsiriX, except for the FDA/CE-approved MD version, is not certified as a commercial medical device for primary diagnostic imaging and its use in clinical practice might have ethical and legal implications. Consequently, although the benefit of using the application to improve the preoperative knowledge of the particular patient's anatomy is unquestionable, an adequate learning period is fundamental because a deficient use of the tool can cause erroneous information that might be potentially harmful for the patients.

## Conclusions

CTA has demonstrated to be of great aid in the preoperative planning of perforator flaps. Until a non-invasive non-radiating imaging technology can replace it, great efforts must be done to minimize the risk of radiation following the ALARA (*As Low As Reasonably Acceptable*) principle. From a surgeon's perspective, getting involved in image post-processing is beneficial to optimize the translation of image findings into surgical decisions. Until the professional imaging applications included in manufactured workstations are available to the individual user, OsiriX fills the gap with extreme efficiency.

## Additional Information

### Disclosures

**Human subjects:** Consent was obtained by all participants in this study. The Institutional Ethics Committee from The Hospital Fremap Majadahonda issued approval N/A. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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