



## Multidetector-row computed tomography in the planning of abdominal perforator flaps<sup>☆</sup>

J. Masia<sup>a,\*</sup>, J.A. Clavero<sup>b</sup>, J.R. Larrañaga<sup>a</sup>, X. Alomar<sup>b</sup>,  
G. Pons<sup>a</sup>, P. Serret<sup>a</sup>

<sup>a</sup>Plastic Surgery Department, Hospital de la Santa Creu i Sant Pau, Universitat Autònoma Barcelona, Sant Antoni M. Claret 167, 08025 Barcelona, Spain

<sup>b</sup>Radiology Department, Clínica Creu Blanca, Reina Elisenda Moncada 17, 08034 Barcelona, Spain

Received 16 March 2005; accepted 8 October 2005

### KEYWORDS

Multidetector CT scan;  
Microangiography CT;  
Perforator flaps;  
DIEP;  
SIEA

**Summary** An accurate preoperative evaluation of the vascular anatomy of the abdominal wall is extremely valuable in improving the surgical strategy in abdominal perforator flaps. The multidetector-row computer tomography offers thin slice coverage of extended volumes with an extremely high spatial resolution. From October 2003 to December 2004, 66 female patients had breast reconstruction surgery in our department using the deep inferior epigastric artery perforator flap. Our multidetector-row computer tomography studies were performed using a 16-detector-row computer tomography scanner. The image assessment was carried out using the following protocol: we first identified the best three perforators from each side of the abdomen. Then we conducted a three-dimensional reconstruction of the abdomen by identifying exactly where the three best perforators emerged from the rectus abdominis fascia. We then transferred the data obtained from the image to the patient using a coordinate system. In addition, we also placed the dominant perforators in the patient by using a conventional hand-held Doppler. During the operation we compared intra-operative findings, Doppler results and computer tomography outcomes. Neither false positive nor false negative results were found in the computer tomography outcome. Multidetector-row computer tomography provides us with an easy method of interpreting the virtual anatomic dissection in three dimensions. It has high sensitivity and specificity and provides a good quality evaluation of the perforator vessels. This information allows reduction of operating time and safer performance of surgery. The multidetector-row computer tomography is a highly effective tool in the preoperative study of abdominal perforator flaps. © 2006 The British Association of Plastic Surgeons. Published by Elsevier Ltd. All rights reserved.

<sup>☆</sup> This paper was presented during the 8th International Course of Perforator Flaps in Sao Paulo, Brasil on 7th September 2004.

\* Corresponding author. Tel.: +34 629709146.

E-mail address: [jmasia@santpau.es](mailto:jmasia@santpau.es) (J. Masia).

Over the last 5 years, abdominal perforator flaps have become the first choice in breast reconstruction in our department. The DIEP flap (deep inferior epigastric artery) and the SIEA flap (superficial

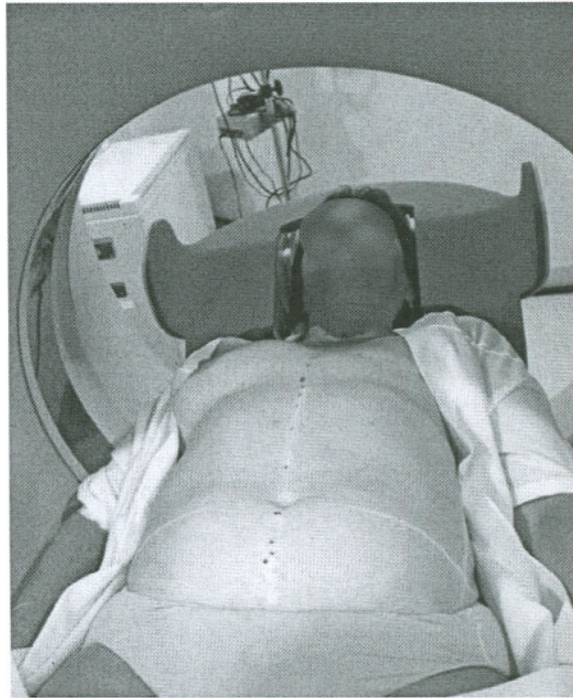
inferior epigastric artery) are now routinely used. A systematic knowledge of the dominant perforating vessels is not possible because there is high variability of the vascular plexus between individuals and even between hemi-abdomens of the same person. Therefore, it is not easy to predict how many perforators are present, their calibre, where they exit the overlying fascia or what their course through the muscle may be. In addition, without a preoperative investigation, the surgeon may not be aware of previous surgical damage, scar formation or anatomical variants. An accurate preoperative evaluation of the vascular anatomy of the abdominal wall is extremely valuable in improving our surgery strategy and performing safer and faster procedures.

In recent years, technical developments of MDCT (multidetector-row computed tomography) have dramatically changed the use of CT angiography in the assessment of vascular pathologies.<sup>1,2</sup> The simultaneous acquisition of multiple thin collimated slices in combination with enhanced gantry rotation speed offers thin slice coverage of extended volumes with extremely high spatial resolution. It has been shown to be very useful, not only in evaluating aorta and peripheral arteries,<sup>3,4</sup> but also as a promising noninvasive technique for the detection, visualisation and characterisation of stenotic coronary artery disease.<sup>5,6</sup> The idea of studying the vascular anatomy of the lower abdominal wall by focusing on the visualisation of the perforators arose from this.

## Material and methods

Our multidetector computed tomography studies were performed using a 16-detector-row CT scanner (Aquilion 16; Toshiba Medical, Tokyo, Japan) with the following parameters: 120 kVp, 80-120 mA (0.4 s gantry rotation period), detector configuration 16×1 mm, 23-mm table travel per rotation, 512×512 matrix, and a 180-240 field of view. All scanning was performed during IV administration of 100 ml of nonionic iodinated contrast medium with a concentration of 300 mg I/ml (Xenetix 300 [Iobitridol]; laboratories Guerbet, Paris, France). The contrast material was mechanically injected (injector TC missori XD 2001); Ulrich GmbH and Co. K, Ulm, Germany) at a rate of 4 ml/s. through an 18-gauge IV catheter inserted into an antecubital vein.

The patient is placed in a supine position on a CT table in the exact manner that will be used on the

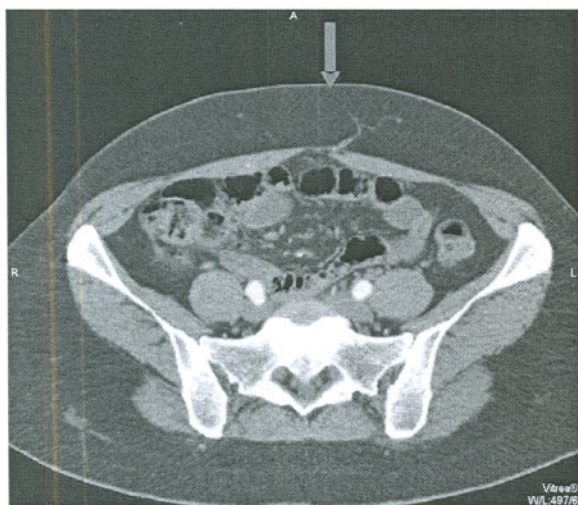


**Figure 1** Patient is placed in a supine position on a CT table in the exact manner that will be used on the day of surgery.

day of surgery (Fig. 1). Sections are obtained from 5 cm above the umbilicus to the lesser trochanter of the hip during a single breath-hold. The approximate time of acquisition is 10-12 s. The entire procedure takes less than 10 min and is, therefore, very well tolerated by the patient. The volumetric data acquired is then used to reconstruct images with a slice width of 1-mm and a reconstruction interval of 0.8-mm. The resulting complete set of reconstructed images is automatically transferred to a computer workstation (Vitrea version 3.0.1, Vital Images, Plymouth, MN, USA), which generates the reformatted images in multiple planes (coronal, axial, sagittal and oblique) and in three-dimensional volume rendered images. This system allows measurements to be taken so that different planes of space can be automatically correlated. Data are stored in an interactive compact disc (e-Film Medical Inc., Toronto, Canada) which can easily be used and managed using a standard computer.

In this study, image assessment was done by the same radiologist and the same plastic surgeon (who performed all study flaps) using the following protocol:

**Step 1:** In the axial view we studied the deep inferior epigastric artery course from its origin, through the muscle, to 5 cm cranial



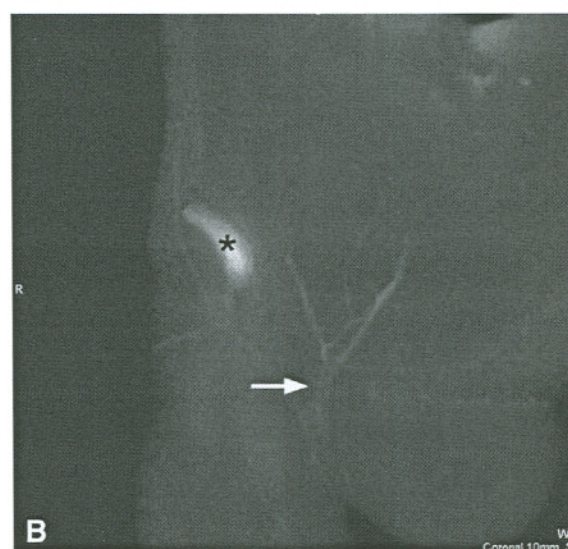
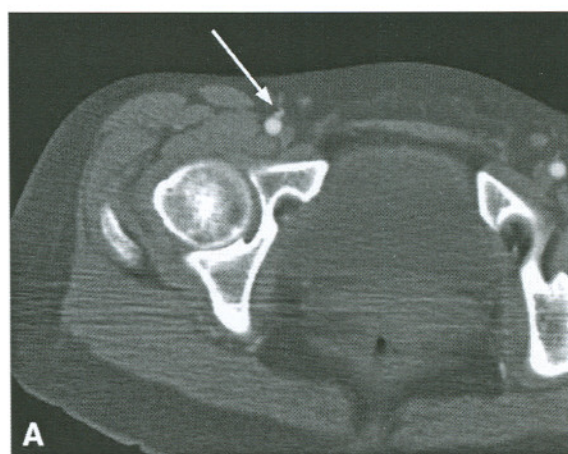
**Figure 2** Axial view: The precise location of the emerging perforator from the rectus abdominis fascia is marked with an arrow.

to the umbilicus. We identified the three best perforators on each side of the abdomen, marking them with an arrow (Fig. 2) and classifying them according to their external calibre into three categories (small, medium, large). We also studied the superficial epigastric system, defining the calibre of the artery at its origin. Vessel size greater than 1.6 mm can potentially be used for raising a SIEA flap (Fig. 3(A) and (B)).

**Step 2:** We reviewed the sagittal (Fig. 4) and coronal views in order to double check the quality of the chosen perforators and to place them in three planes.

**Step 3:** Then we performed a 3D reconstruction of the abdomen in order to locate precisely the points on the skin surface where the three best perforators emerged from the fascia of the rectus abdominis muscle. Then we used a virtual coordinate system with the umbilicus at the centre. Following that, all the information was transferred to a data form sheet (Fig. 5(A) and (B)) so that the perforators were mapped in a format that allowed us to transpose their position preoperatively onto the abdominal skin of the patient.

On the day before surgery, the patient is first assessed for dominant perforators using the conventional method of the hand-held Doppler ultrasound with a 8 MHz probe to obtain unidirectional Doppler signals (Huntleigh diagnostics Dopplex II Model SD2 VP8). The perforators identified by the



**Figure 3** Superficial inferior epigastric artery. (A) Axial MDCT scan shows the right superficial inferior epigastric artery arising from the external iliac artery. (B) Coronal superficial multiplanar reformation from MDCT images shows the superficial epigastric artery (arrow) course across the subcutaneous fat, parallel to the vein. (\*: antero-superior iliac spine).

Doppler are then marked in red on the patient's abdominal skin where a coordinate map has been drawn using the umbilicus as the centre point.

Then the data obtained from the MDCT investigation is transposed on to the map in green. The result is then recorded by taking a digital image with a standard digital camera (Fig. 6).

We always begin the operation by looking for the superficial epigastric system for two reasons. Firstly, if the calibre of the superficial epigastric artery is big enough (known in advance from the MDCT) we routinely decide to do a SIEA flap. Secondly, if the calibre proves to be too small, we also dissect the superficial system in order to have



**Figure 4** Sagittal view: A perforator emerging from the rectus fascia is marked with an arrow.

an alternative venous drainage system to solve complications. Then, if we decide to do a DIEP flap, we look for the best perforator that we located with the MDCT. We always compare the results from the intra-operative findings, the MDCT and the Doppler sonography. Specifically, we analyse the false positive and false negative results of the MDCT and Doppler methods to help us determine which method is more accurate and effective.

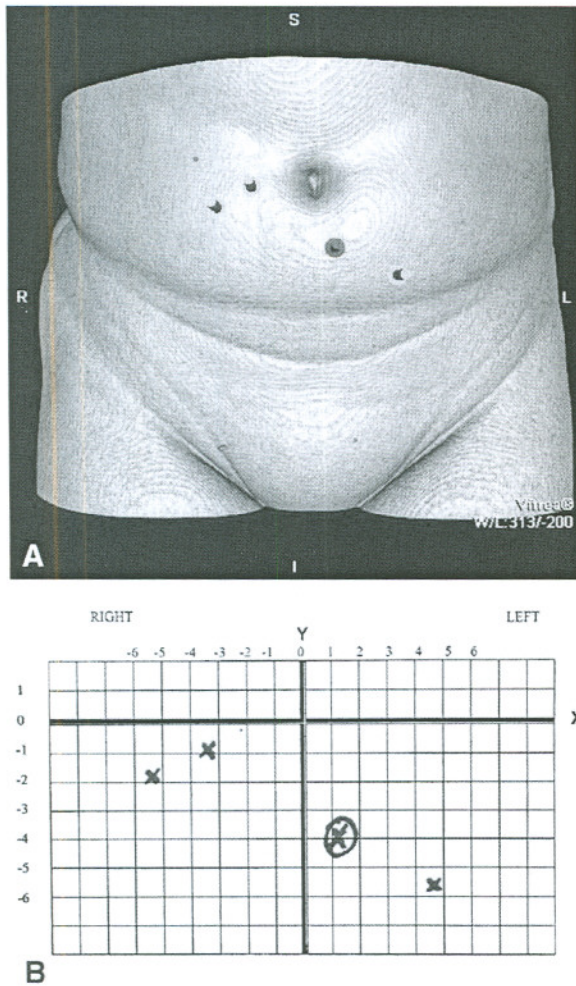
## Results

In our department, over the last 5 years, the total number of breast reconstruction cases by DIEP flap was 196. Of these cases, the last 66 cases were done using the MDCT. From these 66 cases, the first 36 were done by removing the entire flap region while simultaneously identifying and inspecting all the perforators, in order to compare the intra-operative findings with previous MDCT results to study the validity of the anatomic information from MDCT. The last 30 cases from the aforementioned 66 cases, were conducted by using the anatomic information generated from the MDCT which allowed us to go to the dominant perforator directly while not having to spend time on the tedious task of identifying and inspecting all perforators, as had been done in previous cases. These last 30 cases were compared to the last 30 cases that were

performed by our department before the application of the MDCT technique.

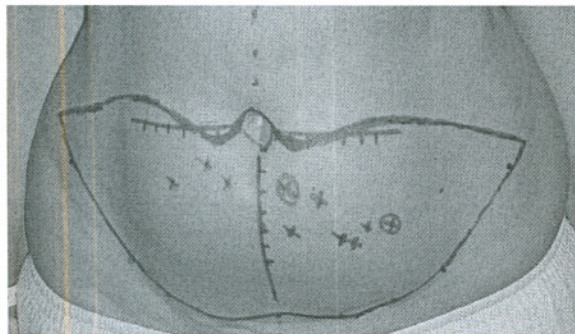
In all cases, the flap side with the dominant perforator chosen preoperatively was raised by the same surgeon, while, the contralateral side was raised by the trainee under the supervision of the surgeon following the same criteria. Immediately after finishing surgery, notes were made regarding the false positive or false negative presence of perforators on both sides of the abdomen. Post-operatively, an additional review of the recorded MDCT data was conducted by both the radiologist and the surgeon to cross-check the results.

The 66 DIEP flap cases completed using MDCT were performed from October 2003 to December 2004. On average, from these 66 cases, three acceptable perforators were found on each side of the abdomen (range of 1-5). The degree of variability in localisation of perforators is often the same on either side of the abdomen. In 18% (12/66) of cases only one side of the abdomen presented an ideal perforator in terms of calibre and placement. In 88% (58/66) of cases the chosen perforator was found to emerge through tendinous intersections. In addition, the chosen perforator had its origin in the medial branch of the deep inferior epigastric artery in 61% (40/66) of cases. The highest concentration of good perforators was found in an area between 2 cm cranially and 5 cm caudally of the umbilicus, and between 0.5 and 4.0 cm laterally of the linea alba. Comparing the



**Figure 5** Multiplanar and 3D superficial volume rendering reformation (A) and the data form sheet (B) where the perforator information is transferred.

MDCT with the intra-operative findings, neither false positive and nor false negative results were found. Only in one early case, while interpreting the MDCT, a good perforator was missed.



**Figure 6** Preoperative MDCT data transposition to the abdominal skin using a coordinate system where the umbilicus is the centre.

During our comparison of the last 30 cases without MDCT and the last 30 cases with MDCT (in which we went directly to the dominant perforator), the average operating time saved per patient was 1 h and 40 min. Moreover, in the last 30 cases without MDCT, one total failure and two partial necrotic cases resulted while in the last 30 cases with MDCT no total failures and one partial necrotic case resulted.

## Discussion

In perforator surgery, a reliable method for the precise identification of the dominant perforator with regard to its position, course and calibre would be extremely valuable.

Improving our preoperative planning by identifying the three-dimensional position of the largest perforator included in the flap allows us to reduce both operating time and surgeon stress concerning the intra-operative decision of selecting the best perforator with regard to its calibre and position. As a result, valuable time is saved during surgery as it is no longer necessary to perform an extensive overview of all the perforators. In addition, preoperative planning ensures that any highest-flow perforators that may be on the midline of the abdomen are not missed. Previously, the surgeon might have been reluctant to cut further and would have settled for an inferior perforator or might take the surgical decision to perform a TRAM conversion. It also allows us to plan our operating strategy in order to preserve the contra-lateral side of the abdomen until the dominant perforator has been selected and completely dissected. It is clearly useful for the surgeon to be assured that the flap always contains the abdominal perforator with the highest-flow.

Unidirectional Doppler sonography is the most common instrument for preoperative location of individual vessels. It is a handy and inexpensive tool to investigate the position and flow of the perforator. However, it only offers a limited amount of information and cannot distinguish perforating vessels from main axial vessels. Furthermore, false positive localisation of perforators can appear if the axial vessels run superficially—which results in low-specificity for this technique. In addition, Doppler sonography may be too sensitive because even minuscule vessels that are not vigorous enough to support a perforator flap can often be detected. If the perforator course from the exit point of the muscle fascia to the surface of the skin (through the subcutaneous fat) is not

roughly perpendicular to the skin, the Doppler localisation of the perforator will be incorrect.

Colour Duplex imaging offers much more information.<sup>7,8</sup> This imaging system provides good evaluation of the main axial vessels, their branches and perforators. Moreover, the calibre and haemodynamic characteristics of the perforators can be observed directly. The high sensitivity and the 100% predictive value of this technique have made it an excellent diagnostic tool in the planning of DIEP flaps.<sup>7</sup> Unfortunately, this technique also has some drawbacks. It is time consuming for the hospital staff and the patient is often uncomfortable as they have to remain in the same position for nearly an hour.<sup>7,8</sup> It also requires the presence of highly-skilled scanning personnel who have knowledge of perforator flap surgery. In addition, the information cannot be reproduced so that the procedure must be repeated by the radiologist.

MDCT allows a study of the donor area, which is very easy to interpret, not only by the radiologist but also by the plastic surgeon as it provides anatomical images. It also permits the option of doing a virtual anatomy dissection of the patient on the computer because the pictures obtained are three-dimensional anatomy reconstructions. The data is stored in a CD which can easily be used and managed with a standard computer and can be reviewed as often as necessary. This technique is also well tolerated by patients because is simple and speedy.<sup>9</sup> The main disadvantages are the cost and the radiation. However, the effective dose of radiation used in this study is 5.6 mSv which is less than that which is used for an opaque enema or a conventional abdominal CT scan. Also, the average dose of radiation during exposure is 321 mGy cm—which is less than reference doses used for exploration in the pelvis and the abdomen (570 and 780 mGy cm, respectively) approved by European Union in the document: 'European Guidelines on Quality Criteria for Computed Tomography'.

By deciding preoperatively which perforators are most suitable, we can reduce the amount of stress for the surgeon who can now go straight to the

chosen perforator with confidence and can ligate the other perforators safely without wasting time. The amount of time saved in the operating room can be balanced against the extra cost of the investigation. This technique also allows us to plan the flap size and shape using the best vascularised tissue supplied by the dominant perforator. As a result, fat necrosis and partial flap loss has been shown to be reduced in our studies. This information is also extremely valuable if a patient has had previous surgery in the abdominal area such as liposuction or a hysterectomy.

The high sensitivity, specificity and the 100% positive predictive value of this noninvasive and easy-to-interpret preoperative mapping technique have made it a highly-promising diagnostic tool in the planning of DIEP flaps.

## References

1. Hu H, He D, Foley D, Fox SH. Four multidetector-row helical CT: image quality and volume coverage speed. *Radiology* 2000;215:55.
2. Schoepf UJ, Becker CR, Bruening RD, et al. Multislice CT angiography. *Imaging* 2001;13:357.
3. Lawler LP, Fishman EK. Multidetector row computed tomography of the aorta and peripheral arteries. *Cardiol Clin* 2003;21:607.
4. Jacobs TF, Wintersperger BJ, Becker CR. MDCT imaging of peripheral arterial disease. *Semin Ultrasound CT MR* 2004;25:145.
5. Ropers D, Baum U, Pohle K, et al. Detection of coronary artery stenoses with thin-slice-multidetector-row spiral computed tomography and multiplanar reconstruction. *Circulation* 2003;107:664.
6. Schoepf UJ, Becker CR, Ohnesorge BM, Yucel EK. CT of coronary artery disease. *Radiology* 2004;232:18.
7. Blondeel PN, Beyens G, Verghaeghe R, et al. Doppler flowmetry in the planning of perforator flaps. *Br J Plast Surg* 1998;51:202.
8. Hallock GG. Doppler sonography and colour duplex imaging for planning a perforator flap. *Clin Plast Surg* 2003;30:347-57.
9. Voet DVAM, Petrovic M, Masia J, et al. Preoperative planning. In: Blondeel PN, Morris SF, Hallock GG, Neligan PC, editors. *Perforator flaps. Anatomy, technique and clinical applications*. St Louis: Quality Medical Publishing; 2006.