The Value of the Multidetector Row Computed Tomography for the Preoperative Planning of Deep Inferior Epigastric Artery Perforator Flap

Our Experience in 162 Cases

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Abstract: A preoperative abdominal wall study was conducted using a multidetector scanner in 162 women who had undergone breast reconstruction with abdominal perforator flaps. A map of the abdominal perforator vessels dependent on the deep inferior epigastric artery was created. In the first 36 cases, anatomic dissection of all perforators was performed during surgery. The outcome was then compared with the radiologic findings. In the following 126 cases, the perforator vessel chosen preoperatively by the multidetector scanner was located and dissected directly.

In the first 36 cases, an absolute correlation was observed between the radiologic information and intraoperative findings. In the following 126 cases, surgery time and the rate of postoperative complications decreased significantly.

The multidetector scanner provides valuable preoperative information enabling identification of the most suitable perforator in view of its caliber, location, course, and anatomic relationships. Once located, we can proceed directly to its dissection during surgery, making it a faster and safer technique.

Key Words: perforator flap, preoperative planning, multidetector row tomography

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The first option in breast reconstruction with autologous tissue is currently the abdominal perforator flap due to the similarity of this tissue and that of the breast. Vascular anatomy of the abdominal wall varies greatly, especially in the case of the perforator branches of the deep inferior epigastric artery. The location, number, caliber, and intramuscular trajectory of these branches differ not only from one individual to another but also from one hemiabdomen to the other. For this reason, a presurgically established vascular map can facilitate surgical planning in each patient.[1] Due to its ease of use, Doppler ultrasound has been routinely used since the early days of microsurgery to locate the best perforator vessels prior to surgery. However, despite its simplicity, it presents a significant number of false positives. Other techniques, such as Doppler duplex color, have proved effective but also have their drawbacks.[2,3] Over the last 3 years in our hospital, we have routinely used the multidetector scanner for the preoperative study of DIEP- and SIEA-type abdominal flaps in breast reconstruction. The high spatial resolution of this examination allows multiplanar evaluation of the vessels and provides a tridimensional view, showing anatomic images which are easy to interpret. This information is used in surgery to locate the dominant perforator vessels. To the best of our knowledge, prior to our preliminary study in a small patient sample,[4] no scientific literature had explained the use of the multidetector scanner in locating and evaluating the deep inferior epigastric artery and its abdominal perforator vessels. The objective of this present study was to evaluate our results after 3 years of using the multidetector scanner and to characterize the anatomic findings. We describe the working method, establish an actuation algorithm, and reach new conclusions which may be of considerable use for breast reconstruction surgery using autologous tissue.

MATERIALS AND METHODS

Between October 2003 and May 2006, we carried out breast reconstructions using DIEP-type abdominal perforator flaps in 162 patients, 26 of whom underwent bilateral reconstruction. Their average age was 51.8 years, and average height and weight were 1.62 m and 62.3 kg, respectively.

All cases involved breast reconstruction after mastectomy in the context of neoplasia. Other than breast pathology, the majority of patients had no medical antecedents that might represent an added risk factor for microsurgery.

In the majority of cases, reconstruction was performed as a delayed primary procedure.

This was a 2-stage study. The goal of the first stage performed in 36 patients was to check the reliability of the multidetector CT-scan (MDCT) by correlating these radiologic results with the intraoperative findings. This correlation was confirmed. In the second stage, in 126 patients, we directly located and dissected the vessel that had been chosen preoperatively using the multidetector scanner.

We also compared the postoperative complications in the last 100 DIEP flap cases performed in our department before the introduction of the MDCT with the last 100 cases performed using this technology.

Radiologic Study Technique

MDCT studies were obtained by means of a 64-detector-row CT scanner (Aquilion 64; Toshiba Medical, Tokyo, Japan). Patients were positioned supine on the CT table exactly as they would be during surgical intervention. CT scans were performed using the following parameters: 0.4-s gantry rotation speed, 0.5-mm slice thickness (×64), 53-mm table travel per rotation, and pitch, 1.656. X-ray tube voltage was 120 kV and tube current was 250–300 mA. All scanning took place after IV administration of 100 mL of nonionic iodinated contrast medium at a concentration of 300 mg I/mL (Xenetix 300 [Iobitridol]; Guerbet, Paris, France). The contrast material was mechanically injected (injector TC Missouri XD 2001; Ulrich GmbH &co. K, Ulm, Germany) at a rate of 4 mL/s through an 18-gauge IV catheter inserted into an antecubital vein. The scanning delay was set by an automatic triggering system (Sure Star, Toshiba).

Sections were obtained from 5 cm above the umbilicus to the lesser trochanter of the hip in a single breath hold.

Once acquired, the volumetric data were reconstructed with a slice width of 1 mm and a reconstruction interval of 0.8 mm. Multiplanar reformatted images and 3D volume-rendered images were generated on a Vitrea computer workstation (Vitrea version 3.0.1; Vital Images, Plymouth, MN).

Protocol Image Analysis

All cases were evaluated by consensus between the radiologist and plastic surgeon at the workstation using the following protocol:

Step 1

In the axial view, the deep inferior epigastric artery was evaluated along its entire length from its origin in the external iliac artery, paying special attention to its intramuscular course, identifying its main trunk and the existence of divisions, along with their predominance (Fig. 1). Second, we studied the perforator arteries, which are dependent on the deep inferior epigastric artery. Their caliber, course, and anatomic relationships were evaluated, locating the exact point of emergence through the aponeurosis of the abdominal rectus (Fig. 2). The objective was

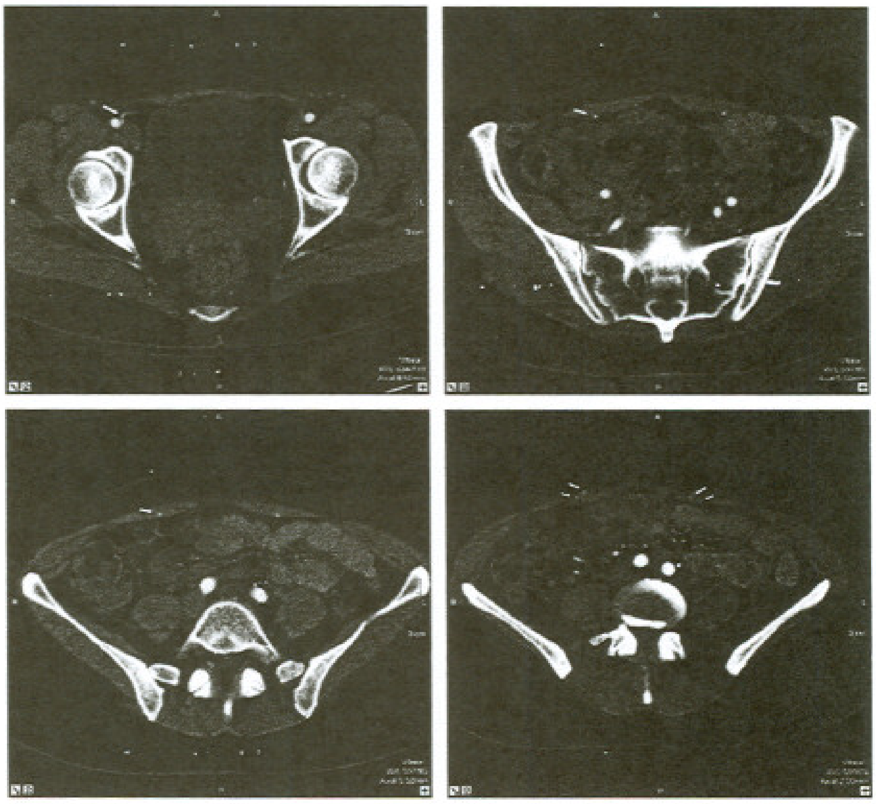

FIGURE 1. Axial view. Deep inferior epigastric artery. Left, Above, Origin. Right, Above, Retromuscular course. Left, Below, Intramuscular course. Right, Below, Intramuscular branching.

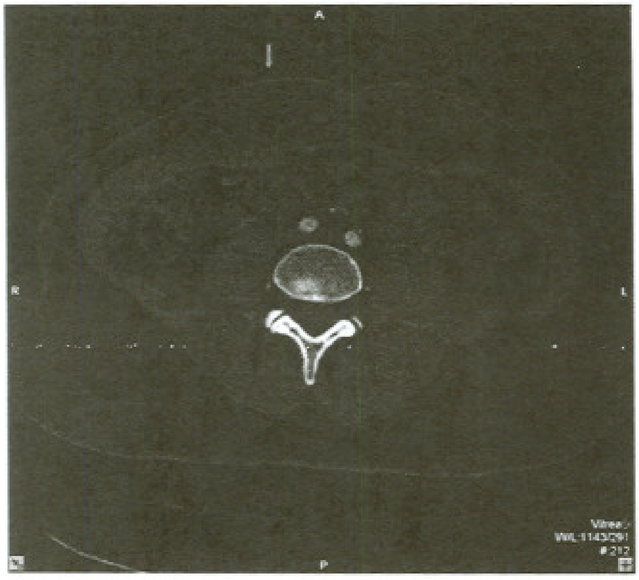

FIGURE 2. Axial view. Dominant perforator piercing the fascia is marked with an arrow.

to choose the most appropriate perforator to constitute the flap pedicle and determine its exact location at the level of the fascia of the rectus.

Criteria for Choosing Perforators[1,4,5]

1. Caliber. The largest caliber, proportional to the blood flow 0.6 to 3.2 mm, was established as the useful range diameter.
2. Location. We chose a perforator that allowed a flap design enabling a direct and esthetic closure. This was preferably centered in the tissue to be transferred, although this was not indispensable.
3. Anatomic relationships. We selected a perforator whose course facilitated dissection. A direct branch from the deep inferior epigastric artery was preferred since it was expected that the intramuscular course would be shorter, with fewer muscular branches. We also took into account whether the perforator vessel emerged from a tendinous band as this kind of perforator usually follows a retromuscular course that makes its dissection easier.

According to these criteria, we identified the best 3 perforators in each hemiabdomen, marked them with an arrow, and chose the most suitable of the 6.

We also studied the superficial epigastric system. We verified the existence of the superficial inferior epigastric artery and studied its course and caliber. In view of this information, we considered the possibility to perform an SIEA flap (Fig. 3).

Step 2

We studied the selected perforator vessels in the sagittal and coronal views, verifying their quality and locating them on the 3 planes (Fig. 4).

Step 3

We performed a 3-dimensional reconstruction of the abdominal skin surface. The arrows were placed at the exact point where the chosen perforator vessels emerged from the rectus abdominis muscle fascia. According to a coordinate

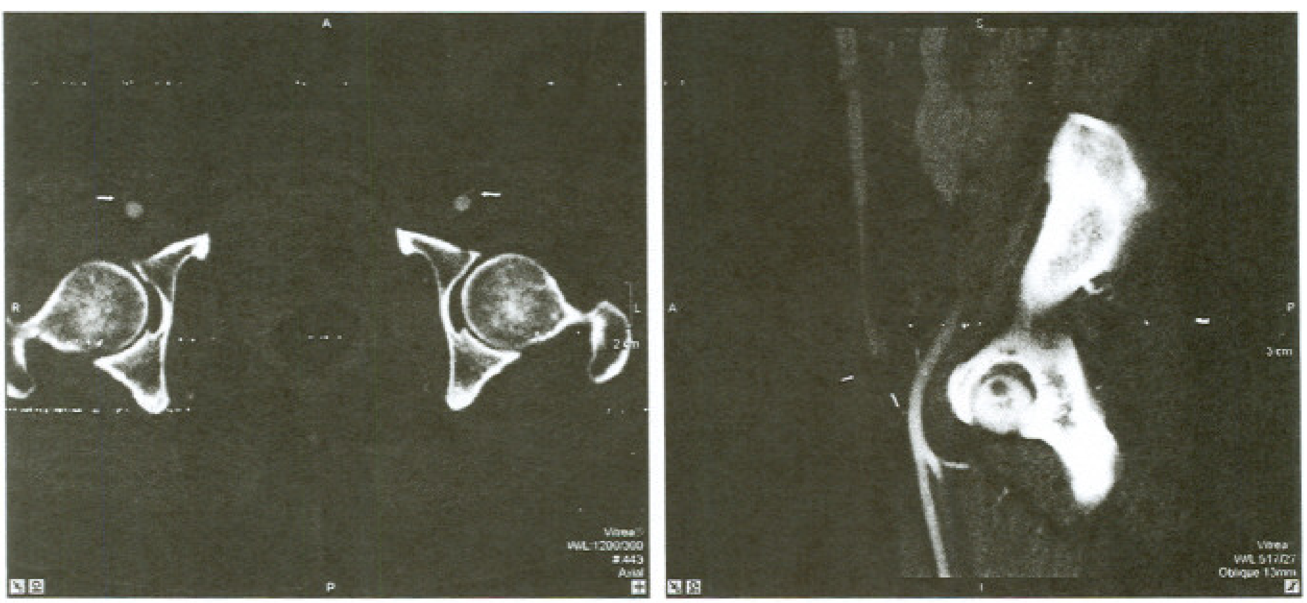

FIGURE 3. Assessment of the superficial epigastric system. Left, Axial view. Origin; caliber assessment. Right, Saggital view. Course from the origin to the subcutaneous abdominal tissue.

FIGURE 4. Sagittal view. Perforator emerging from the rectus fascia is marked with an arrow.

system whose center is the umbilicus, we associated each perforator with a coordinate point.

Step 4

Using this simple coordinate system, the perforator map was transferred to the data registration sheet before transfer to the patient's skin surface. Perforator location points were marked in green. Simultaneously, during the comparative study, we performed a Doppler ultrasound examination, marking the points where the perforators were located in red. The final map of perforators on the skin surface was recorded by digital photography (Fig. 5).

Surgical Technique

In the first 36 cases, each existing perforator was located and examined during flap elevation. The superficial inferior epigastric system was also studied. The intraoperative findings were compared with the radiologic information given by the MDCT. Any discrepancy was recorded on paper and by digital photography. In these first 36 cases, following the surgical procedure, the same radiologist and plastic surgeon reviewed the radiologic images. In the next 126 patients, we directly identified and dissected the perforator vessel chosen according to the images provided by the MDCT, and the postoperative review of the radiologic images was repeated only when intraoperative findings differed.

RESULTS

During the evaluation of the radiologic image for each of the 162 patients studied, at least 1 appropriate perforator was identified as suitable for surgery. An average of 2.3 perforators on each hemiabdomen was found useful for surgery. In 4.9% of cases, only 1 perforator vessel was found to meet selection criteria because abdominal tissue was scarce; supraumbilical perforators could not be chosen since abdominal wall closure might be compromised. Only 1 suitable infraumbilical perforator was found in these patients. Its location and study by means of radiologic imaging contributed significantly to the success of the surgical procedure.

In some cases, we found perforators that followed a totally extramuscular course. These vessels initially followed a retromuscular plane and then pierced the muscular fascia right in the abdominal middle line (linea alba). They were therefore paramuscular perforators rather than musculocutaneous perforators. We named these flaps pararectal DIEP flaps. In our criteria, such perforators could be ideal as they have an excellent caliber, an exactly central location, and a course that facilitates dissection (Fig. 6).

It was also important to study whether the perforator vessels selected as appropriate for surgery emerged from the fascia of the rectus through the muscle or through a band of tendon. Analysis of the dominant perforator in each of the 2 hemiabdomens showed it emerged through a band of tendon in more than half the cases (52.9% for the right hemiabdomen and 67.6% for the left). Conversely, the majority of the other perforator vessels emerged directly through the muscle. The chosen perforators had an average caliber of 2.1 mm on the right side and 2.0 mm on the left. Among the selected vessels, the perforator with the largest caliber had a diameter of 3.3 mm as compared with 0.5 mm for the smallest.

Analysis of the distribution of all perforators and all dominant perforators revealed that anatomy varied greatly not only among individuals but also between the 2 hemiabdomens of each individual.

During the first phase of the study, all the data obtained were compared with the evidence from surgery, and neither false negatives nor false positives were found in the identification and location of the dominant perforator, that is, the one considered most suitable for use in surgery. In the analysis of other potentially appropriate perforator vessels, 1 false-negative was found. Postoperative revision of the radiologic images revealed this was due to an error in the interpretation of the image, probably because it was one of the first cases analyzed.

During the second phase of the study, when the dominant perforator was directly located and dissected, we reduced the harvesting time from 3 hours and 20 minutes to 1 hour and 40 minutes (average time from the first skin incision to the autonomization of the flap). In one of the 126 cases, during surgical dissection, we identified a perforator vessel of acceptable caliber which had been overlooked during the preoperative evaluation using the multidetector scanner. This finding was interpreted as a false negative in the identification of potentially useful perforators for surgery. As in the first phase, no false positives or negatives were found in locating and identifying the dominant perforator.

The results of the comparative study between the postoperative complications in the last 100 DIEP flap cases performed before the introduction of the multidetector CT scan and the last 100 cases performed using this technology are shown in Table 1.

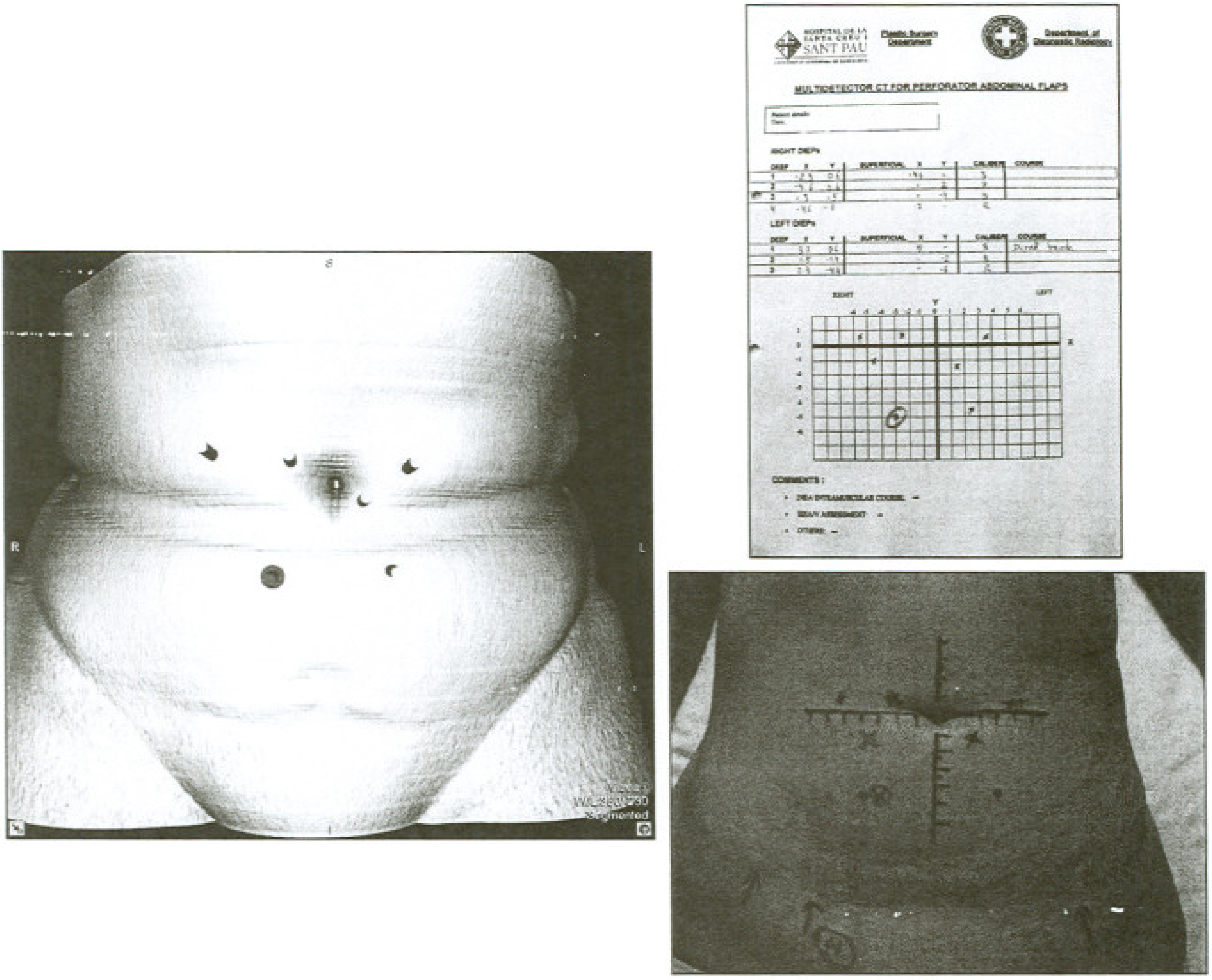

FIGURE 5. Left, Multiplanar 3D superficial volume rendering reformation. Right, Above, Data form. Right, Below, Skin marking.

The superficial epigastric system was assessed in both stages of the study. We verified the existence of the superficial inferior epigastric artery in 62% of the cases in the radiologic images. A SIEA flap was considered suitable in 24% during the radiologic analysis (vessel diameter greater than 1.5 mm approximately) and was finally performed in 19% of cases. All SIEA flaps were conducted in the group considered radiologically suitable to undergo this type of flap. In most cases where the superficial inferior epigastric artery did exist, a connection between this artery and the largest-caliber perforator from the deep system was shown (Fig. 7).

DISCUSSION

Doppler ultrasound is routinely used by microsurgeons to locate the perforator arteries prior to perforator flap elevation and is the most commonly used instrument for preoperative localization of individual vessels. However, this technique can be imprecise at times.[2,3] Furthermore, it provides only a limited amount of information, it cannot distinguish perforating vessels from main axial vessels, and it can create false-positive localization of perforators if the axial vessels run superficially, resulting in a low specificity. It may also be too sensitive because even minuscule vessels that would be unable to support a perforator flap can be detected.

Color duplex imaging provides a good evaluation of the main axial vessels, their branches, and perforators. Moreover, the caliber and hemodynamic characteristics of the perforators can be observed directly. Its high sensitivity and 100% predictive value have made it an excellent diagnostic tool in the planning of DIEP flaps.[2] Unfortunately, this technique also has several drawbacks: it is time-consuming for physicians; it is often uncomfortable for the patient, who must remain in the same position for nearly an hour; the images provided do not clearly show the relationship of the perfora-

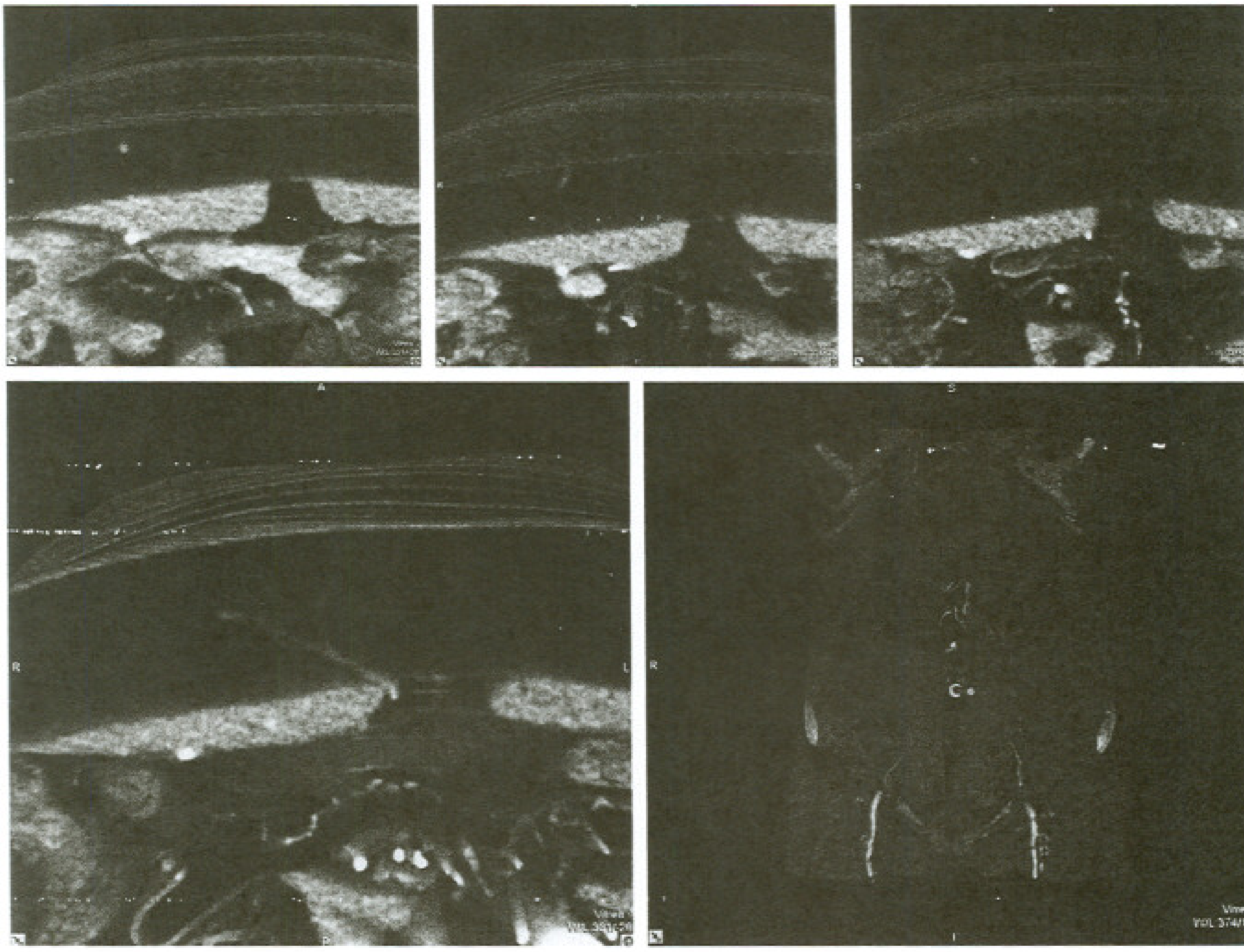

FIGURE 6. 3D Rendered image. Left, Above, Retromuscular course of the EPI. Center, Above, Retromuscular course of pararectal perforator. Right, Above, Pararectal perforator reaching linea alba. Left, Below, Pararectal perforator piercing the fascia. Right, Below, 3D Reconstruction at muscular plane, arrow marking the piercing point of the pararectal perforator.

TABLE 1. Postoperative Complications Before and After Using MDCT

	Before MDCT	After MDCT
Partial necrosis (<20%)	6%	2%
Partial necrosis (>20%)	6%	0%
Total necrosis	4%	1%
DIEP to TRAM conversion	1%	0%

tor with the other structures along its course; and, most important, it requires highly skilled scanning personnel who have knowledge of perforator flap surgery, making it a technician-dependent procedure.

MDCT using multiple detectors provides a greater amount of thin-slice data in a shorter period of time, optimizing the use of endovenous contrast and obtaining excellent images of the vascular tree. The increased spatial resolution has provided greater accuracy in multiplanar and 3D reconstruction images.[6–9] A further advantage of MDCT is its possible application in the extension study of oncologic patients, allowing simultaneous study of the perforators at the donor site without additional morbidity.

In comparison to Doppler ultrasound and Doppler duplex color, the MDCT presents some disadvantages such as availability, costs, and radiation exposure. This technique is not available in all medical centers. Our center does not dispose of an MDCT scan, and patients are sent to a private hospital for the mapping procedure. This way, the cost of the MDCT is approximately 300 Euros. The effective dose of radiation used in this study is 5.6 mSv, which is less than that used for a conventional abdominal CT scan.

Our present results show the MDCT is a highly reliable tool in identifying and locating the dominant abdominal perforator, with a positive predictive value of 100%. Regarding the evaluation of other perforator vessels considered

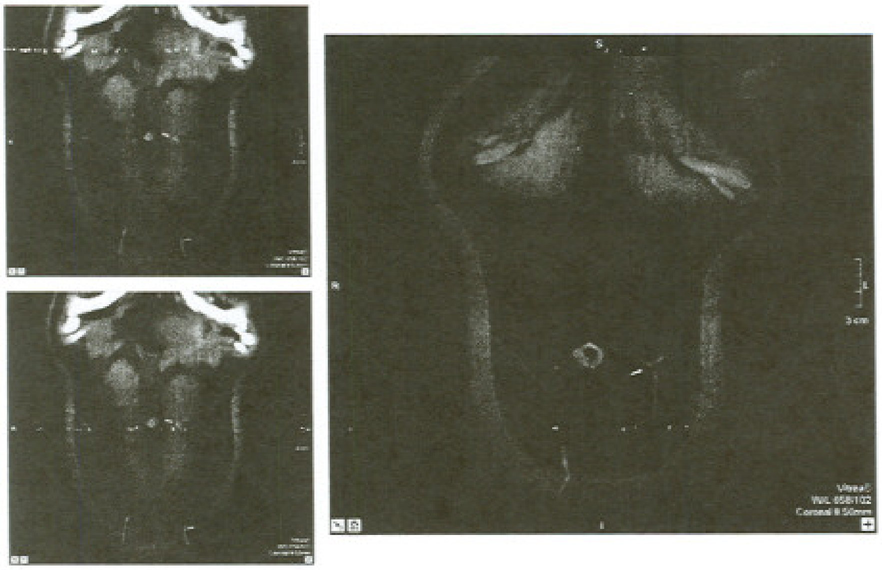

FIGURE 7. Coronal view. Left, Above, Piercing point of the dominant perforator (superior arrow), superficial epigastric system (inferior arrow). Left, Below, Intratissular course of the dominant perforator (superior arrow), intratissular course of the superficial epigastric artery. Right, Connection point between the superficial and the deep system through the dominant perforator.

acceptable for surgery, the power of MDCT diminished very slightly. In 2 cases, an adequate perforator seemed absent during the radiologic analysis. In one of these cases, this was due to the erroneous interpretation of the radiologic image as it occurred at a very early stage of the study. The second case was a real false-negative result.

The ability of MDCT to preoperatively detect the dominant perforator vessel leads to a significant saving in harvesting time, almost halved in our series, and in a reduction in surgeons' stress. Such advantages are well worth bearing in mind in surgery that may last over 4 hours as they not only benefit the patient and the surgical team but also ease the burden on health resources.

Regarding the superficial epigastric study, the difference between cases evaluated by MDCT as suitable for a SIEA flap (24%) and those that were in fact carried out (19%) was mainly due to the fact that in the early phases of our study we had little experience with this type of flap, and we found no consensus in the scientific literature about its reliability. On many occasions, therefore, in spite of positively evaluating a superficial epigastric system, we remained skeptical and opted for a DIEP flap. Little by little, we have been introducing the SIEA flap as it has proven to be a reliable technique when the indication is correct.

Another important finding in our study was a significant drop in postoperative complications, mainly those associated with partial necrosis of the flap and fat necrosis. Since the only new parameter introduced in our working method is the MDCT, this improvement may be the result of choosing, with the help of the MDCT, the best abdominal perforator vessel for each flap.

Information obtained from the MDCT allows development of a dissection strategy and even the possibility to opt for a certain perforator, bearing in mind not only its caliber but also its course and relationships with other anatomic structures, making its dissection safer or swifter.

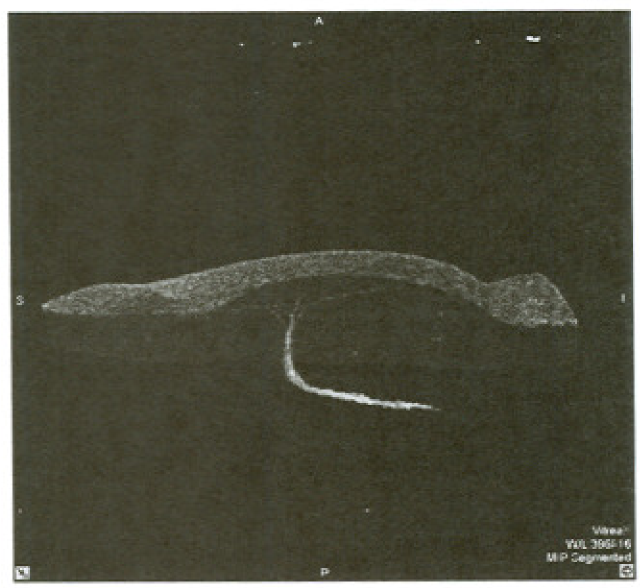

FIGURE 8. Lateral MIP (maximum intensity projection) image. Assessment of the perforator branching inside the DIEP flap.

This ability of MDCT for "virtual dissection" permits us to perform studies that were previously only possible through cadaver dissection. Significant morbidity is negligible, and the implications of parameters such as degrees of pressure or the functional state of the vessels can be evaluated in vivo. This technique will therefore enable us to study the intratissue distribution of perforator arteries and help us to understand more about the vascular physiology of this type of flap (Fig. 8).

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