The impact of CTA in preoperative planning of deep inferior epigastric artery perforator flap

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Learning objectives

To demonstrate usefulness of CT angiography (CTA) in preoperative planning of deep inferior epigastric artery perforator (DIEAP) flaps.

To illustrate the imaging protocol and anatomic findings variations of DIEAP.

Background

Autologous breast reconstruction after mastectomy in breast cancer patient is increasing. Currently the deep inferior epigastric artery perforator (DIEAP) flap has become the preferred treatment in both primary and secondary breast reconstruction. Our institution has seen a dramatic increase in perforator flap breast reconstruction over the past 6 years.

During the evolution of surgical techniques from the pedicle transverse rectus abdominis myocutaneous (TRAM) flap, to the free TRAM, to the muscle-sparing free TRAM, to DIEAP flap, there has been a constant battle between attempts to minimize morbidity to the patient by reducing the dissection of the anterior abdominal wall, while maximizing flap blood flow and viability. Thus the DIEAP flap is used to harvest fat and skin (adipocutaneous tissue) without muscle and has resulted in fewer abdominal wall complications - including hernia, bulge and weakness - and shorter hospital stays, with a cheaper overall cost of treatment when compared with alternative surgical techniques.

The elevation of DIEAP flap is technically demanding, requiring meticulous dissection of the perforator vessels, sparing the muscular structure with its segmentary motor nerves. It requires selection of a suitable dominant perforator to support the flap and then retrograde intramuscular dissection of the perforator to the deep internal epigastric artery. In the past, this process was often achieved solely on the basis of intraoperative exploration, although the majority published series with high successful rates of DIEAP flap elevation, all emphasise the role of preoperative investigation of the anterior abdominal wall perforator system. A systematic knowledge of the dominant perforating vessels is not possible because there is a high variability of the vascular plexus between individuals and even between hemi-abdomens of the same person.

Several methods have been proposed to identify the vascular supply to perforator flaps, including physical exam, eco-doppler imaging, CT angiography and magnetic
resonance imaging (MRI)\textsuperscript{2,6}. Despite the two-dimensal color flow doppler imaging provides significant good preoperative information about the location of the abdominal wall perforators and the flow velocities within the blood vessels, however, it is too time consuming and also it was report by Giunta et al.\textsuperscript{8} a high rate of false positives with the use of this technique.

CT angiography and MRI angiography are currently the best methods available to map the vasculature of donor sites of perforators flaps\textsuperscript{7}. Data regarding MRI are also lacking, although in a study including 56 patients Masia et al found a 100% correlation between MRI angiography and intra-operative findings\textsuperscript{9}.

The use of preoperative CT angiography for imaging the abdominal donor site before breast reconstruction is well described in the literature, and we have been using it as our preferred preoperative imaging modality. The inconvenience of CT angiography include radiation exposure, exposure to contrast, the possibility of extravasation injury, and increased cost. However, the benefits of CT angiography are many and include precise localization and size determination of all perforator choices, delineation of the relative perimuscular anatomy, and confirmation of continuity with source vessels.

**Findings and procedure details**

**Anatomy and surgery implications**

The deep inferior epigastric artery (DIEA) is an important artery of the abdominal wall and rises from the external iliac artery and passes up via the transversalis fascia to the arcuate line where it pierces the rectus abdominis.

The branching pattern of the DIEA was first described by Moon and Taylor and is widely accepted between the different authors\textsuperscript{10} (Figure 1). It includes three main types. Types I (one branch) and II (bifurcation in two branches) are more frequent than type III (division in more than two branches). The other relevant characteristics are the caliber of the trunk and any intramuscular course. Usually, the DIEA enters the rectus sheath superficial to the arcuate line and courses superiorly between the posterior layer of the rectus sheath and the rectus muscle. It is not uncommon for one or both of the DIEA to penetrate and course within the rectus muscle for some part of their length\textsuperscript{11} (Figure 2).

Both type I (Figure 3) and type II (Figure 4) branching patterns have been shown to have perforators that have a shorter intramuscular course than do perforators in patients with type III branching patterns\textsuperscript{12}. Type II or III (Figure 5) bifurcation DIEA can also be classified as medial or lateral according to their location. Taken into account that
the rectus abdominis muscles are innervated laterally it is easy to understand that a more medial perforator means that dissection through the rectus muscle is less likely to denervate the muscle that receives its nerve supply laterally. Denervation is an important complication as it aborts the main advantage of the DIEP flap technique. Medial branches should be used, but lateral ones must be conserved. Preoperative knowledge of the DIEA branching pattern may therefore aid the surgeon’s choice of which perforator to use and the abdomen choice.

**Protocol**

CT angiography in the context of preoperative DIEA flap study are performed in our institution, using 64-MDCT scanner (64-row General Electrics Healthcare scanner). The patients are placed on a CT table in the supine position, the patient's arms are extended alongside the body and the patient's elbows are flexed to avoid artifacts. The CT parameters are a 0.5 second gantry rotation speed, 0.625 mm slice thickness, and pitch of 0.98. The x-ray tube voltage is 100 Kv with an energy of 255 mA. All scanning are performed after IV administration of 100 ml of nonionic iodinated contrast medium at a concentration of 350 mg/ml. The contrast material is mechanically injected at a 4 mL/s. The scanning delay is set by an automatic triggering system. The infrarenal aorta is observed with real time CT fluoroscopy, and helical acquisition is triggered automatically when the attenuation of the abdominal aorta increases 100H above the baseline value. Sections are obtained from 5 cm above the umbilicus to the lesser trochanter of the hip in a single breath -hold.

**Image Analysis**

The surgical planning and technique are influenced by perforator anatomy as we have seen previously.

A large caliber (>1mm in diameter) perforator with a large subcutaneous segment will supply a larger volume of adipocutaneous tissue, thus decreasing the number of postoperative complications, mainly regarded with necrosis of the flap. Knowledge of the subfascial segment is also desirable, as these segments require careful dissection. Extensive rectus muscle dissection is not desired and theoretically increases abdominal wall morbidity. Therefore, these characteristics should be identified and pointed out in the preoperative CT angiography.

MIP reconstruction (maximum intensity projection) can be used in an axial plane to confirm intramuscular and subcutaneous segments of the perforators (Figure 6). Thus, the perforator with the best characteristics (following those previously mentioned) are
chosen: larger caliper, less intramuscular trajectory and preferentially locate in a medial/periumbilical location.

The branching pattern of DIEA is subsequently determined by using a MIP reconstruction in a coronal section (Figures 3-5).

Then we perform a 3D coronal reconstruction of the abdomen in order to locate precisely the points on the skin surface where the best perforators emerge from the fascia of the rectus abdominis muscle, considering the umbilicus as a central reference position (Figure 7). A scaled grid can be applied to the image with the center point at the umbilicus.

Images for this section:

![Diagram of DIEA branching types](image)

**Fig. 1:** Classification of DIEA branching described by Moon and Taylor. Type 1 (single trunk); Type 2 (bifurcation into two trunks); Type 3 (division into more than two trunks). (x) umbilicus level. EIA - external iliac artery.
Fig. 2: Graphic illustration, on a sagittal view of a perforator course from its course at the DIEA between the posterior layer of the rectus sheath and the rectus muscle, its intramuscular segment within the rectus muscle, its subfascial segment between the anterior aspect of the rectus muscle and the anterior layer of the rectus sheath, and its subcutaneous segment within the subcutaneous fat of the anterior abdominal wall.
**Fig. 3:** MIP coronal reconstruction - DIEA, type 1 (single trunk) branching pattern on both hemiabdomens.
**Fig. 4:** MIP coronal reconstruction DIEA, type 2 (bifurcation into two trunks - blue arrow) branching pattern on both hemiabdomens.
Fig. 5: MIP coronal reconstruction DIEA, type 3 (division into three trunks) on the left (blue arrow) and type 2 on the right.
**Fig. 6:** Axial 5 mm section thickness MIP shows the course of the left DIAP, blue arrows. A- DIEA immediately after its origin between the posterior layer of the rectus sheath and the rectus muscle; B - Intramuscular segment; C- Subfascial segment; D- Subcutaneous segment.
Fig. 7: 3D superficial volume rendering reformation, pointing out cutaneous location of emerging fascial point of the lagers perforators vessels in relation to M1 (umbilicus). M2, M3, M4 and M5 represent perforators vessels.
Conclusion

CT angiography provides valuable information before surgery about the arterial anatomy of the inferior abdominal wall. It enables accurate identification of the most suitable dominant perforator vessel and helps the reconstructive breast surgeon avoid potential complications and also makes the procedure faster.

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 important diagnostic tool in the planning of DIEAP flaps.

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References


