Abdominal wall vascularisation mapping in microsurgeons preoperative planning: a retrospective study on 174 CT angiographies. DIEA, SIEA and SICA prevalence, caliber and branching pattern

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Authors: T. Stocca, M. Bertolotto, M. Belgrano, F. Pozzi Mucelli, Y. Zimolo, M. A. Cova; Trieste/IT
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Purpose

In our hospital breast reconstruction using autologous tissue taken from abdominal wall fat is a cornerstone in treatment of breast cancer.

This choice allows good breast reconstruction which look and feels most natural for the patient and also with better results on the long time.

In perforator flap surgery doppler sonography is the most commonly used modality for preoperative localization of individual vessels; however, it offers a limited amount of informations. The specificity of this investigation is generally low. Therefore MDCT is a reliable method for precise identification of the position, course and caliber of the dominant abdominal wall perforators which is extremely valuable.

The microsurgeons must have a precise understanding of the surgical vascular anatomy of the patient. By deciding preoperatively which perforators are most suitable, the surgeons can proceed directly to the chosen perforator with much more confidence and ligate other perforators safely and quickly.

Time saved in the operating room should be overbalanced with the extra cost of the CT scanning. Moreover this preoperative investigation reduces the rate of fat necrosis and partial flap loss because it allows the surgeon to choose the best vascularized region of abdominal tissue supplied by the dominant perforator. Any remarkable anatomic or vascular conditions are revealed, including those could be contraindications for surgery. (Fig.1 on page 6)

Instead any favourable vascular condition can be report to the surgical equipe as an helpful option for the preoperative planning. (Fig.2 on page 6) (Video 1 on page 16)

In the lasts 5 years, the cooperation with ours microsurgical team improve our experience in pre-operative planning with CT-angiographies especially in planning protocol for Deep Inferior Epigastric Perforators (DIEP) flaps that is the first choice for autologus breast reconstruction.

Deep Inferior Epigastric Artery is a constant vessel that ascend along the posterior surface of the rectus abdominis muscle. DIEA provides musculocutaneous perforators that supply abdominal fat and skin through the rectus sheath. In our experience there are 5±2 (Average) perforators arising from the deep inferior epigastric artery with a mean caliber of 1mm.

Unfortunately course, branching pattern, caliber and perforators of this artery presents high variability and accurate preoperative reconstructions are essentials for microsurgeons.
In the last 2 years we started to focus our attention on another important, but unconstant artery: the **Superficial Inferior Epigastric Artery (SIEA)** which is another step to further reduce donor site morbidity in autologous breast reconstruction.  

If this vessel is present, its isolation is easier than of DIEA perforators, since it runs over the rectus abdominis muscle, so never requires muscle dissection, and this is the reason for which it produces minimal donor site morbidity.

Unfortunately SIEA is an unconstant artery so its prevalence and morphology is very variable and is still being defined in clinical, imaging and cadaveric studies.

If present, SIEA is a very thin vessel that arises from the front of the common femoral artery and originates 1-3cm below the inguinal ligament as either an independent trunk, or together with the superficial circumflex iliac artery (SCIA).  

After its origin this vessel perforates the deep fascia of the femoral triangle and ascends in the subcutaneous tissue with a medial course over the semilunaris linea.

The **Superficial Circumflex Iliac Artery (SCIA)** branches off the lateral side of the common femoral artery, 3-5cm below the inguinal ligament as its own trunk or as a common trunk with the SIEA artery.

The SCIA perforates the deep fascia and ascend in the subcutaneous tissue like SIEA does, but its course is more lateral and turn straight to the anterior superior iliac spine. The territory of the SCIA span the hip flexion crease below the inguinal ligament to the anterior superior iliac spine. However exactly like the SIEA, the superficial Circumflex Iliac Artery is subject to variability in the presence, length and caliber.

When present this vessel can mime the presence of a SIEA artery.

It is important to discern SIEA to SCIA artery because the second one can’t be used for breast autologous reconstruction but it’s been used for head and neck facial augmentation, upper extremity skin defect reconstructions and lower extremity skin coverage.

The aim of our retrospective study is to describe the different branching patterns and mean caliber of DIEA (Deep Inferior Epigastric Artery), a constant vessel used by microvascular surgeons in autologous breast reconstruction.
To assess the incidence and caliber of SIEA (Superficial Inferior Epigastric Artery) which can be used by surgeons as an alternative to DIEP flaps.

To evaluate the incidence of SICA (Superficial Iliac Circumflex Artery), a vessel which can mimic SIEA.

(Fig.9 on page 13) (Video 3 on page 14)

The Angio-CT scan volumes were originally acquired for several different vascular pathologies. In our retrospective study, full volumes were reloaded on the postprocessing console and analysed specifically looking for presence and anatomy of the DIEA, the SIEA and the SCIA.
Fig. 0: A 53 years old patient with the right DIEA vessel ligated by an old appendectomy surgical intervention. This condition must be reported to the microsurgeons equipe for correct pre-surgical planning.

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Fig. 0: A 47 years old patient with a very helpful vascular variant condition. In this case the left DIEA vessel pass through the rectus abdominal muscle ad continue its runs OVER the rectus abdominis muscle, so this great vessel don't requires muscle dissection.

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**Fig. 0:** This 3D-VR reconstruction shows the normal course of the DIEA artery under and into the rectus abdominis muscle. In this case is possible to recognise two Perforators vessels (DIEP) that ascend into the abdominal fat tissue. (Yellow arrows)

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Fig. 0: Vascular anatomy of the SIEA artery and vein.

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**Fig. 0:** A 47 year old patient with a large SIEA artery on the right abdominal wall useful for a SIEA free flap breast reconstruction.

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Fig. 0: Anatomy and course of the SCIA artery along the inguinal crease.

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**Fig. 0**: Vascula variations of SIEA and SCIA arteries.

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Fig. 0: Thick Oblique slice MIP reconstruction that shows the course of the Deep Circumflex Iliac Artery (DCIA) and the Superficial Circumflex Iliac Artery.

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Fig. 0: 3d-VR reconstruction of a 43 years old patient. Arrows shows the mains vessels of the abdominal wall. Deep Inferior Epigastric Artery (DIEA), Deep Inferior Epigastric Perforators (DIEP, Superficial Inferior Epigastric Artery (SIEA), Superficial Circumflex Iliac Artery (SCIA) and Deep Circumflex Iliac Artery (DCIA).

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**Fig. 3:** 3d-VR reconstruction of a 43 years old patient. Arrows shows the mains vessels of the abdominal wall. Deep Inferior Epigastric Artery (DIEA), Deep Inferior Epigastric Perforators (DIEP, Superficial Inferior Epigastric Artery (SIEA), Superficial Circumflex Iliac Artery (SCIA) and Deep Circumflex Iliac Artery (DCIA).

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**Fig. 2:** This 3D-VR reconstruction shows the normal course of the DIEA artery under and into the rectus abdominis muscle. In this case is possible to recognise two Perforators vessels (DIEP) that ascend into the abdominal fat tissue. (Yellow arrows)

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**Fig. 1:** A 47 years old patient with a very helpful vascular variant condition. In this case the left DIEA vessel pass through the rectus abdominal muscle and continue its runs OVER the rectus abdominis muscle, so this great vessel don’t require muscle dissection.

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Methods and Materials

Our experience is based on a 174 patients who underwent a CT-Angiographies for several different type of pathologies. The acquisitions were performed in a time period of two years from January 2007 and December 2008.

All the patients were female gender, median age of 72,3 years (range 35-100 years; SD +/- 14)

Full volume dataset: (0.5mm native stack images), were retrospectively reloaded from PACS system (Esaote DICOMed PACS; Esaote, Genova, Italy), to the advanced visualization console for analysis (Vitrea, version 3.1.1; Vital Images, Plymouth, MN, USA)

CTA studies were obtained with the use of a 64-decector CT scanner (Aquilion 64; Toshiba Medical, Tokyo, Japan). (Fig.10 on page 21)

Scan parameters were as follows; 0.4 sec gantry rotation speed, 0.5 mm slice thickness, 53 mm table movement per rotation, pitch 1.66. Tube voltage was 120 kV and z-axis dose modulation is enabled. Double scout: diaphragm to femoral diaphisis was performed.

Patients were administered with 100 mL of high concentration (350 mg I/mL) nonionic iodinated contrast (Ultravist 370, 370 mg I /mL; Schering S.p.a., Milan, Italy), followed by a saline chase of 45 mL. The constrast medium and the saline were injected using a power injector (StellantTM CT Injection System; MEDRAD; Pavia, Italy) at a rate of 4,5mL/sec through a 18 gauge iv cannula inserted into the antecubital veins.

The scanning was triggered using a bolus tracking system (Sure StartTM; Toshiba Medical, Tokyo, Japan) with a ROI set on the aortic lumen at the level of L2-L3 vertebralbody. When 150 H.U. intensity was reached, and after a preset 12-16 sec delay the acquisition was performed.

Reconstruction protocol

For the volume dataset analisis we recostruct retrospectivelly

- Coronal Thick Slab MIP, 3D-MIP and Volume Rendering 3D recostructions:
Initially a thick slice 20 - 25 mm MIP Coronal slab was performed, positioned very anterior, to include the full course of the DIEA, originating from the iliac arteries up to the midabdomen. After that we apply automatic bone removal protocol to obtain very clear 3D-MIP and 3D VR reconstructions.

This was used to visualize presence of both DIEA arteries and as well to show the branching pattern. This reformat was not used directly to assess SIEA. (Fig. 11 on page 21 - Fig.12 on page 22)

• **Axial, Sagittal and Coronal Slab MIP**

The volume was reformatted at 6.5 mm MIP on the Axial, Sagittal and Coronal plane.

Specifically looking for presence of the SIEA and or the SCIA artery and to establish anatomy and measurements. Multiplanar 3D-reconstructions reference was commonly used to differentiate from various arteries present in the abdominal wall and to recognise the course of those arteries in the abdominal wall to discriminate between SIEA and SCIA.

(Fig. 13 on page 23 - Fig.14 on page 24)

• **Vessel probe - curved MPR**

Automated vessel MPR, was used to asses the caliber of DIEA and SIEA (When present).

MPR path was reviewed and manually corrected if necessary, adjusting the centerline.

(Fig.15 on page 25 - Fig.16 on page 26)

**Measurements**

Using the both multiplanar imaging and cMPR we assessed for:

• DIEA branching pattern, reported as; type I (single branch), type II (bifurcationg), or type III (more than two divisions), using the Taylor & Moon classification. (Fig.17 on page 27)

• Calibre of the DIEA arteries ; measured with automated cMPR

• Presence/Absence of the SIEA

• Calibre of the SIEA arteries (When present); measured with automated cMPR

• Presence/Absence of the SCIA
Images for this section:

**Fig. 0**: Ours CTA studies were obtained with the use of a 64-detector CT scanner (Aquilion 64; Toshiba Medical, Tokyo, Japan).

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Fig. 0: Thick Coronal slice MIP reconstruction that shows the course of the Deep Inferior Epigastric Arteries (DIEAs) and their branching patterns.

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Fig. 0: Four views multiplanar reformat. Deep Inferior Epigastric Perforators are indicated by yellows and purple arrows that shows their position on the abdominal surface.

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Fig. 0: Thick slap oblique reconstruction that shows the Superficial Inferior Epigastric Artery (SIEA) course and the Superficial Inferior Epigastric Vein (SIEV) course on the abdominal wall of a 43 yo patient.

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**Fig. 0:** Thick slap oblique reconstruction that shows the Deep Circumflex Iliac Artery (DCIA) course and the Superficial Circumflex Iliac Artery (SCIA) course on the abdominal wall of a 43 yo patient.

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**Fig. 0:** DIEA caliber measurement with Vassel Probe (TM) 3D-VR and MPR-MIP reconstruction.

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**Fig. 0:** Right large SIEA artery caliber measurement with Vassel Probe (TM) 3d-VR and MPR-MIP reconstruction.

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Fig. 0: Taylor and Moon DIEA branching pattern classification.

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Results

For automatic calculations the minimal calibre calculated from the console was considered, as vessel probeTM automated cMPR tool provides maximal diameter/area, minimal diameter/area.

The results were as follows:

- We identified 347 DIEA vassels (One patient has the right DIEA ligated during an appendicectomy surgical intervention)
- DIEA branching pattern showed: (Fig.17 on page 30)
  - Taylor & Moon Type I (One branch) n=211 vassels (61%)
  - Taylor & Moon Type II (Two branches) n=119 vassels (34.2%)
  - Taylor & Moon Type III (Three branches) n=17 vassels (4.8%)
- DIEA mean calibre was 3.1 mm, (range 1.8 - 5.3 mm; SD ± 0.5 mm)
- SIEA was present in 28% of patients (49/174). Bilateral in 9 cases (16%) and monolateral in 40 (84%). We recognise totally 56 SIEA vassels.
- SIEA mean calibre was 1.6 mm, (range 1.1 - 2.4 mm; SD ± 0.4 mm)
- SCIA was present 27% of patients (47/174). Bilateral in 19 cases (40%) and monolateral in 28 (60%)
**Fig. 0:** Taylor and Moon DIEA branching pattern classification.

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Conclusion

The vascularization of the inferior abdominal wall is very variable.

MDCT preoperative evaluation for DIEAP flap has multiple goals and is a useful tool that provides a reliable method for studying the inferior epigastric artery perforators of the lower abdomen. Compared with standard Doppler ultrasound probes and the color-Doppler system, MDCT offers the following advantages:

- High sensitivity and specificity

- Evaluation of the presence and the branching pattern of the DIEA artery below the rectus abdomini muscle.
  
  (Fig. 18 on page 33)

- Good three-dimensional evaluation of the quantity, quality, course and location of the DIEA perforators
  
  (Fig. 19 on page 33 - Fig. 20 on page 34)

- Easy interpretation and good reproducibility by the radiologist and plastic surgeons.

- Well tolerated by patients because the investigation lasts less than 15 minutes.

- Evaluation of the presence of the SIEA artery and can provide evaluation of its course through the abdominal wall fat.
  
  (Fig. 21 on page 35 - Fig. 22 on page 36 - Fig. 23 on page 37 - Fig. 24 on page 38 - Fig. 25 on page 39)

- Allows the radiologist to be able to discriminate between SIEA and SCIA.

The incidence of SIEA (28%) was below what reported in literature for anatomic studies, unilateral occurrence (40/49 cases) was common, which is also a rare occasion in cadaveric studies. The results seems to point that CT angiography (CTA) is able to visualize SIEA, but in some cases it can still go undetected.
As current intraoperative algorithms suggest not to use SIEA if smaller than 1.5 mm, and it is reasonable to assume that smaller arteries are prone to be undetected, CTA can be nevertheless useful to visualize SIEA eligible for flap harvesting.

Anyway comparison with literature in which SIEA was detected by means surgical explorations (without imaging), shows the incidence we reported is still lower, and therefore the protocol we used has still place for improvement.

Been able to recognise the presence of a SIEA artery is an important goal that must be reached by the radiologist involved in pre-operative studies and must be indicate to the microsurgeons team because of minimal donor site morbidity and complications.

SICA presence is unconstant but was present with the same incidence of the SIEA artery (27% Vs 28%). Radiologist should be able to recognise and discriminate between those two similar vessels that can or can't be used as a good option in the breast autologous reconstruction surgery.
Images for this section:

**Fig. 0:** 3D-VR MIP reconstruction of DIEA course and branching pattern in the abdominal wall fat tissue.

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**Fig. 0:** Thick Axial MIP reconstruction that show DIEA course and DIEP perforators origin on the anterior rectus abdominis muscle surface.

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**Fig. 0:** Four views multiplanar reformats. Deep Inferior Epigastric Perforators are indicated by yellows and purple arrows that shows their position on the abdominal surface.

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**Fig. 0:** Thick slab Axial Reconstruction that show Left SIEA artery.

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**Fig. 0:** Thick slab Coronal Reconstruction that show Left SIEA artery.

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Fig. 0: Thick slab Sagittal Reconstruction that show Left SIEA artery.

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Fig. 0: Four views multiplanar reformats. Left SIEA is shown (arrow) in different planes

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**Fig. 0:** Left SIEA artery caliber measurement with Vessel Probe (TM) 3d-VR and MPR-MIP reconstruction.

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References


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