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Preoperative CT angiography reduces surgery time in perforator flap reconstruction☆

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Summary The use of perforator flaps in breast reconstructions has increased considerably in the past decade. A disadvantage of the perforator flap is difficult dissection, which results in a longer procedure. During spring 2006, we introduced CT angiography (CTA) as part of the diagnostic work-up in perforator flap reconstructions to visualise each perforator more accurately. The main objectives were to reduce surgery time and the number of complications. A chart review was conducted 1 year after CTA introduction to investigate if these objectives were met.

Materials and methods: Patients with a deep inferior epigastric perforator (DIEP) flap who underwent preoperative analysis through CTA were retrospectively evaluated. The population ≤1 year before CTA introduction were the control group. The two groups were compared with respect to surgery time and complications (including flap failure).

Results: One hundred and thirty-eight DIEP breast reconstructions were done; 70 underwent preoperative CTA analysis, and 68 had preoperative Doppler investigation. Surgery time in the CTA group was significantly lower ($P < 0.001$) than in the control group, 264 min (SD ± 62) versus 354 min (SD ± 83), respectively. There was a tendency for fewer complications in the CTA group compared with the control group. All flaps were successful in the CTA group.

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In the control group, one flap failed and partial necrosis occurred in three flaps. The differences were not statistically significant.
Conclusions: Preoperative CTA in the assessment of vascular anatomy during perforator flap reconstruction was safe and reliable. It helped reduce surgery time, and may prevent the number of postoperative complications.

The use of perforator flaps for breast reconstruction has increased considerably during the past decade. They offer less postoperative pain, low morbidity, and preservation of muscles at the donor site compared with conventional musculocutaneous flaps. The variety of donor sites allows most patients to be suitable for this procedure.[1] The disadvantage of perforator flaps is that they are more difficult to harvest, which results in a longer procedure.[2] Some surgeons fear that without the protective muscle bulk, the pedicle will kink or be compressed.[3]

Complications during perforator flap reconstruction can be reduced by preoperative assessment of vascular anatomy. The commonest method is unidirectional Doppler sonography.[1,4] It is an accessible and inexpensive tool that can be used to investigate the location and flow of perforators, but is highly sensitive. It locates not only the perforators suitable for anastomosis, but also the very small perforators that are not. False-positive results for unidirectional Doppler sonography can be $\leq$50%. The number of false-negative perforators detected with unidirectional Doppler sonography is lower (e.g. 11% for the deep inferior epigastric perforator flap).[5,6] Unidirectional Doppler sonography is therefore not ideal for accurate preoperative assessment of vascular anatomy.

CT angiography (CTA) has been used in our centre for the planning of perforator flaps for breast reconstructions since spring 2006. The aim of its introduction was to better map the perforators to reduce the dissection time of the flap, and to reduce the number of complications. A chart review was conducted to investigate if this aim was successful.

Patients and methods

Study design

One year after the introduction of CTA before free microvascular tissue transfer in our clinic, a chart review was conducted of all patients who had free microvascular breast reconstruction. The patients who had breast reconstruction with a deep inferior epigastric perforator (DIEP) flap and who also had a CTA in their diagnostic work-up were further analysed. Patients who underwent the same reconstruction in the year before the introduction of CTA were the control group. The study was done from a prospectively maintained database, but was retrospective.

Setting

The section of microsurgery of Uppsala University Hospital, Sweden, consists of three plastic surgeons, one surgical fellow, and one resident on surgical rotation. The number of DIEP flaps done since 2000 is about 60—80 per year.

Data

Age, indication for surgery, date of surgery, ASA-classification, nicotine use, administration of radiotherapy, defect location, flap type, surgeon, surgery time, anastomosis type, type of anastomotic material used, receiving vessels, ischaemia time, vessel-suturing time, complications, need for revision, revision indication, and surgical outcome of all patients were noted.

The two groups mentioned above were compared with respect to surgery time, complications, and flap failure. In the comparison of surgery time, only patients who underwent delayed unilateral reconstruction were selected and compared. Selection was made to prevent a mismatch in surgery time because of different types of reconstruction (e.g. unilateral versus bilateral).

Imaging

CTA was done using a Somatom Sensation 16 machine (Siemens, Forchheim, Germany). Patients were examined in the supine position. A catheter was placed in the antecubital vein of one arm, and a bolus injection of 80 ml contrast medium (Omnipaque 300 mg I/ml, GE Healthcare, Oslo, Norway) was administered through a power injector (Stellant Medrad, Indianola, USA) at 4 ml/s. The scanning delay was approximately 30 s. Bolus tracking was done with the region of interest (ROI) on the aorta, just above the aortic bifurcation. Scanning was initiated approximately 10 s after the ROI reached 100 Hounsfield units. Imaging was in a caudo-cranial direction from the femoral head to approximately 5 cm cranially of the umbilicus. Images were acquired during a single arterial phase with the following scan parameters: 0.5 s gantry rotation speed, 0.75 mm collimation, 10.5 feed/rotation (pitch $\leq$1), and image reconstruction of 1 mm with an increment of 0.6 mm.

Post-processing of images

Post-processing of three-dimensional images was done on a Siemens Leonardo Workstation (Siemens, Forchheim, Germany). Volume rendering technique (VRT) and multiplanar reformation (MPR) images were reproduced. Perforators could be identified simultaneously in axial, coronal, sagittal planes using a coordinate system with a MPR cursor. In a VRT coronal image of the scanned volume, a grid was placed with the umbilicus as zero point, and the best perforators could easily be marked. The suitability of each perforator was then analysed.

Surgical procedure

The surgery team comprised two surgeons and two nurses. One surgeon started with flap dissection, while the other surgeon dissected and prepared the receptor site. After dissecting the flap and preparing the receptor site, a pause of 15 min was often taken to see if the chosen perforator was appropriate. If the pedicle remained well perfused, it was harvested and anastomosed to the receiving vessels (often the internal mammary vessels). Anastomoses were made with sutures, clips or rings, depending on the diameter and quality of the vessels. Technical details of the anastomotic procedures have been previously described.[7] After re-establishment of blood flow in the flap, the defect at the donor site was closed, and the flap modified and sutured to match the contralateral breast.

Definitions

Surgery time was defined as the time between the first incision and wound closure. A complication was classified as haematoma, infection, superficial necrosis, seroma, anastomotic failure, or a combination of these. Surgical outcome was rated as success, partial necrosis (>10% tissue loss) or failure.

Data assessment

Data are represented as means ± standard deviation. Student *t*-test and chi-square tests were used to compare the groups. Significance was set at $P < 0.05$. Statistical analyses was done using a Statistical Package for the Social Sciences (SPSS 13.0, SPSS Benelux bv, Gorinchem, The Netherlands).

Results

Population

In the period reviewed, 138 DIEP breast reconstructions were done; 70 cases underwent preoperative CTA, and 68 underwent preoperative Doppler investigation.

In the CTA group, the mean age was 49.7 years (SD ± 9.3). The mean ASA-classification was 1.7 (4 patients were treated for hypertension, 3 used corticosteroids, 1 had cardiovascular problems, and 1 had diabetes mellitus). One patient smoked during admission for surgery, and 44.3% of patients received preoperative radiotherapy.

Reconstructions were done after mastectomy due to breast cancer (26% primary and 74% delayed). Forty-eight patients had unilateral reconstruction, 11 had bilateral reconstructions. The internal mammary vessels were used as receptor site in 87% of cases; the circumflex scapular or the thoracodorsal vessels were used in the rest. The cephalic vein was anastomosed to the superficial vein of the flap in 31% of cases. The anastomoses were end-to-end in all but two cases. Sutures were used in 47%, clips in 47%, and rings in 6% of anastomoses. Mean ischaemia time was 60.6 min (SD ± 25).

In the control group, the mean age was 49.9 years (SD ± 7.0).The mean ASA-classification was 1.7 (6 patients were treated for hypertension, none of the patients had cardiovascular problems, diabetes or had previously used corticosteroids). None of the patients smoked during admission for surgery, radiotherapy had been given in 63.2% of cases.

Reconstructions were carried out because of breast cancer in 94.1% of cases (20% primary and 80% delayed); two patients had reconstructions because of Poland's syndrome, and another two patients had extreme deformities after an infected prosthesis had been removed. Unilateral reconstruction was done in 50 cases; nine patients underwent bilateral reconstruction. The internal mammary vessels were used as receiving artery and vein in 74% of cases; the circumflex scapular vessels were used in the rest. The superficial vein of the flap was anastomosed to the cephalic vein in 60% of cases. Anastomoses were end-to-end. Sutures were used in 50%, clips in 30%, and rings in 20% of anastomoses. The mean ischemia time was 61.9 min (SD ± 26).

Surgery time

The mean surgery time in the CTA group was 313 min (SD ± 107) compared with 395 min (SD ± 109) in the control group. Mean surgery time in the CTA group was significantly lower ($P < 0.001$).

The number of patients who had unilateral delayed reconstruction because of breast cancer was 41 in the CTA group, and 44 in the control group. The time needed for surgery was significantly lower ($P < 0.001$) in the CTA group. Mean surgery time in this group was 264 min (SD ± 62) compared with 354 min (SD ± 83) in the control group (Figure 1).

Complications

Fewer complications occurred in the CTA group than in the control group: 20.0% versus 25.0%. In the CTA group,

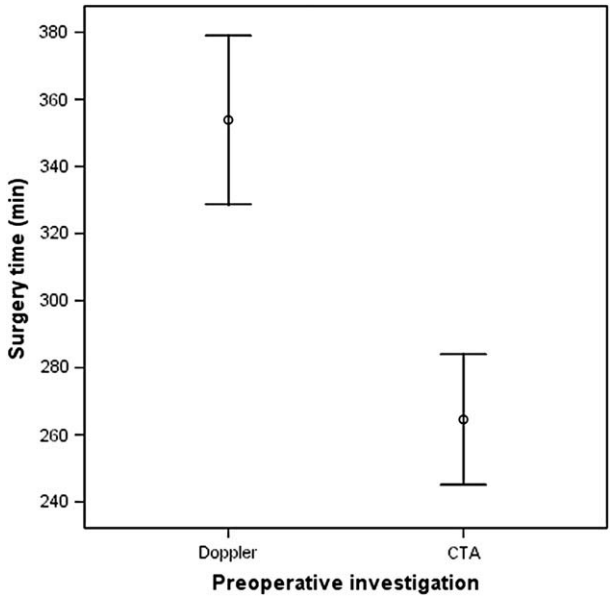

Figure 1 Mean surgery time per preoperative screening facility. Error bars represent the confidence interval of the mean (CI: 95%).

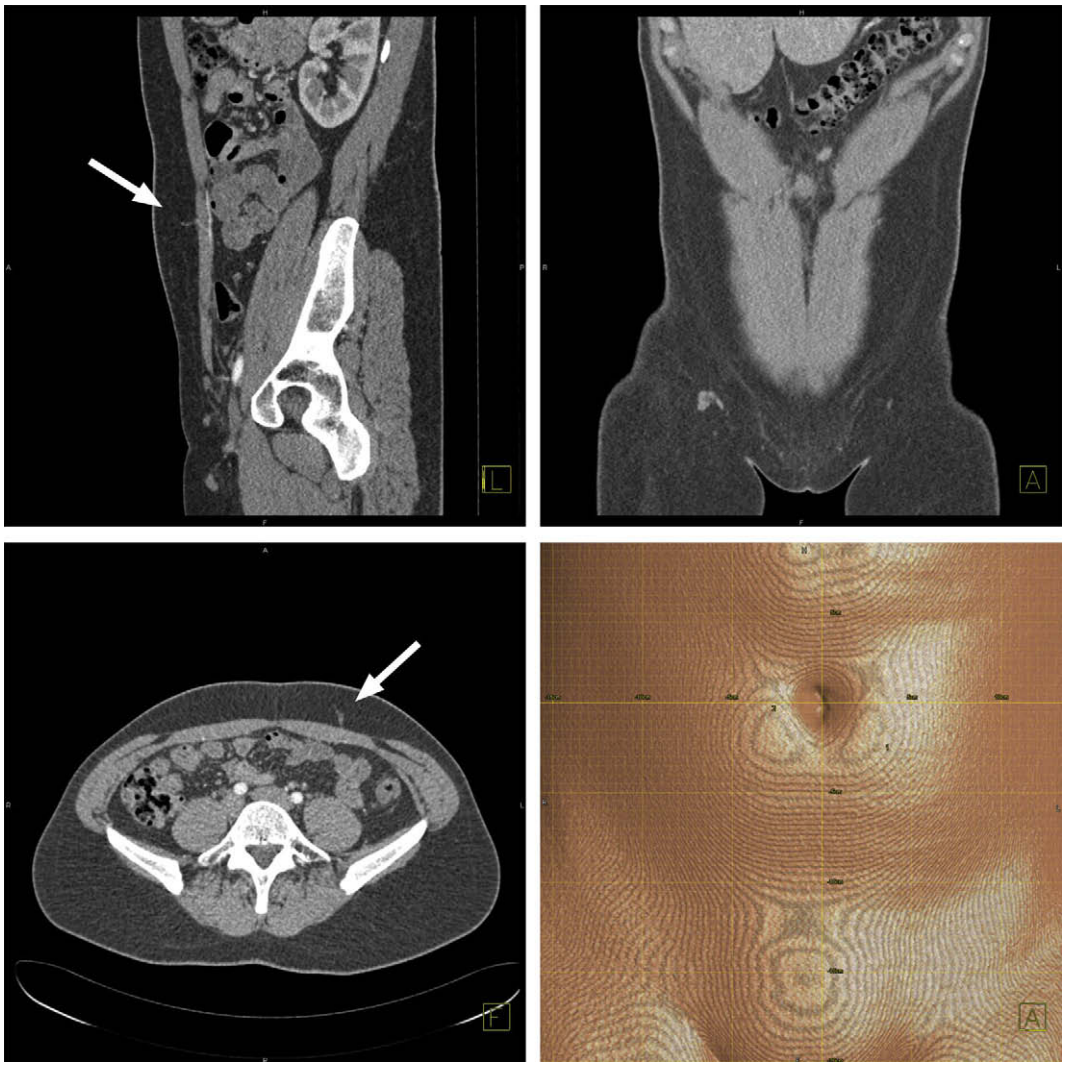

Figure 2 Reconstructions of CTA images in the sagittal, coronal and axial planes, and the VRT coronal image with a grid. The best perforator is marked with an arrow.

infection was observed six times, haematoma four times, and superficial necrosis and seroma both twice. Revision of the anastomoses was needed in two cases. In the control group, a haematoma occurred four times, whereas infection and superficial necrosis were both observed six times. Revision of the anastomosis was needed because of an arterial or venous occlusion in six cases. Differences between the two groups were not sufficiently large to reach statistical significance.

Flap failure

All flaps were successful in the CTA group. One flap failed, and partial necrosis occurred in three flaps in the control group.

Discussion

We observed that preoperative CTA of the donor site in microvascular perforator flap reconstruction diminishes surgery time. A tendency to less morbidity was noticed during follow-up, including fewer partial and complete flap failures. We could decrease the total cost of DIEP breast reconstruction by reducing surgery time. The costs of one CTA were approximately 350 pounds; the reduction in surgery time led to a mean saving of 1750 pounds per patient.

A limitation of this study was the selection criteria; the complete CTA group had surgery after the control group. Whether our results are due to the introduction of CTA or other factors (e.g. increased technical know-how) is unknown. Before the introduction of CTA, $>$380 DIEP breast reconstructions had been done in our clinic. During this period, no significant decrease in surgery time or the number of complications was observed. Taking this into account, it seems more credible that the current decrease in operating time can be attributed to CTA introduction.

CTA provides a three-dimensional view of the vascular anatomy of the perforator flap and its surroundings. It gives precise information about the location, size, position and course of perforators. With a positive predictive

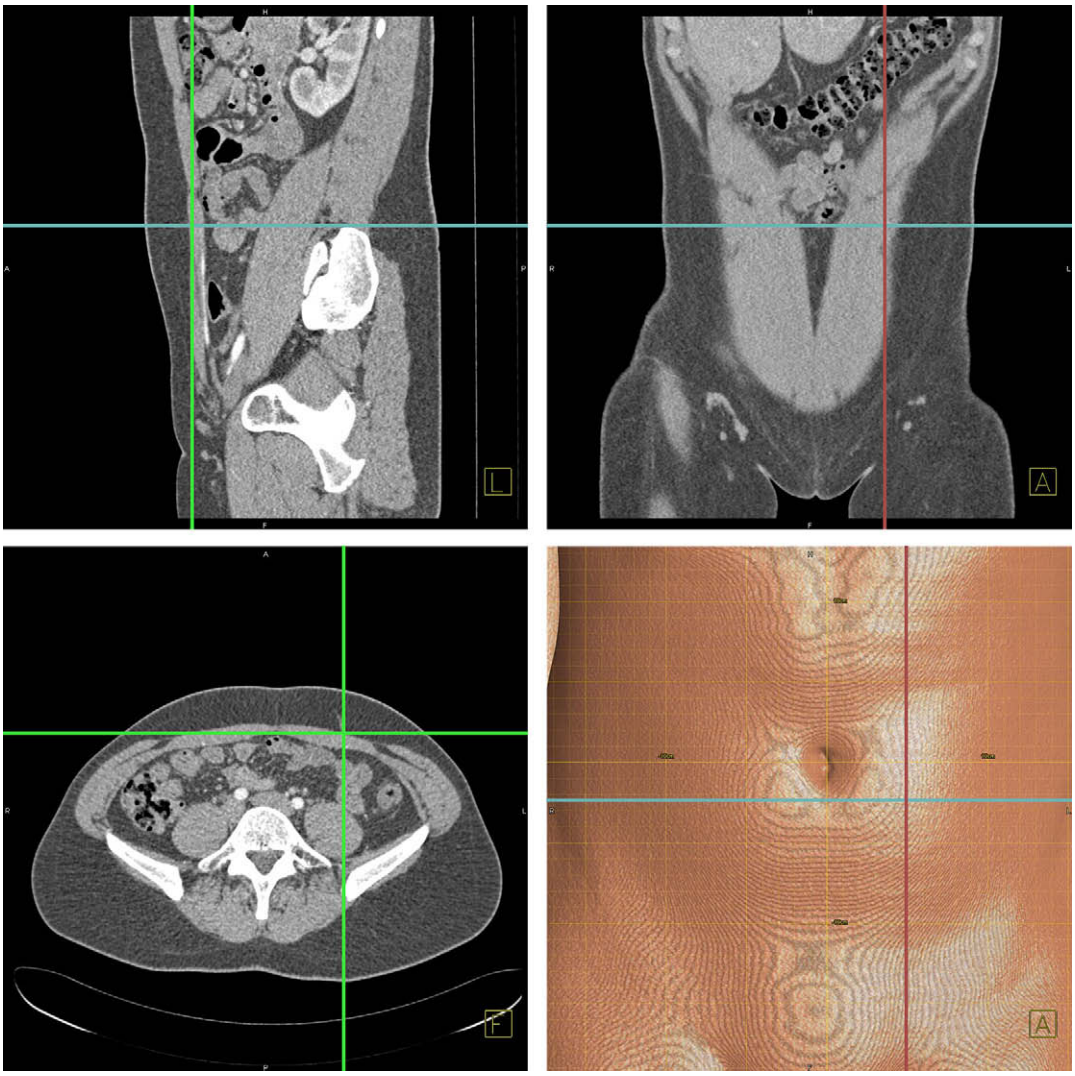

Figure 3 MPR cursor. Thick coloured lines mark the location of the perforator in the sagittal, coronal and axial planes, and the VRT coronal image with a grid and cursor.

value of 100%, CTA proved to be a reliable method to assess the perforator vessels before surgery.[8,9] CTA helped to determine if a patient was suitable for a DIEP flap. It also helped flap design, and the planning of incisions; the surgeon could determine how long the dissection would be.

Colour duplex ultrasound offers precise information on the number of perforators and their diameter with a positive predictive value of 100%.[6] Compared with CTA, colour duplex ultrasound offers more information about flow velocity inside the vessel, the condition and the thickness of the layer of subcutaneous fat, and the anatomical characteristics and status of the underlying skeletal muscles and fasciae. This gives the surgeon a detailed 'roadmap' that can be used in flap design for.[6] The disadvantage of colour duplex ultrasound is that it is a time-consuming technique for hospital staff and patients. The investigation takes $\leq$45—60 min, and can be carried out only by highly skilled personnel who also have knowledge of perforator flap surgery. The information obtained is less reproducible because of real-time dynamics.[6,10]

CTA is easier to interpret than colour duplex ultrasound. It took our radiologists an average of 15 min to post-process images. Post-processing included sagittal, axial and coronal slices, as well as three-dimensional reconstruction (Figures 2—4).

The disadvantages of CTA are radiation exposure and the more invasive character of the examination. Radiation exposure was minimised by scanning only the donor site. Intravenous contrast material did not cause adverse reactions, but patients with known contrast allergy or impairment of renal function must be excluded.

CTA is used experimentally in complicated microsurgical fibula transfers.[11] Our study shows that CTA can also play an important part in microvascular perforator flap reconstructions. It provides high-resolution images and three-dimensional reconstruction of the vasculature. The ability to selectively add and subtract soft tissue and bones from images provides useful landmarks and important information about the zone of perfusion.

CTA in the assessment of perforator flaps was proved to be safe and reliable. It can help reduce surgery time. There

Figure 4 Three-dimensional reconstruction of the perforator arising from the abdominal muscle. The perforator is indicated by the triangle. The arrow indicates the umbilicus.

are also indications that it positively influences the survival rate of flaps, but larger series are needed to confirm this.

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