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Utilisation of contrast-enhanced magnetic resonance angiography in the assessment of deep inferior epigastric artery perforator flap for breast reconstruction surgery

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AIM: To identify and characterise the ideal-sized (defined as at least 2.7 mm based on the experience of plastic surgeons at Hull Royal Infirmary) perforators using magnetic resonance angiography (MRA). The study also evaluated a presumption that perforators on the left are generally larger than on the right.

MATERIALS AND METHODS: Fifty consecutive patients who had undergone MRA prior to deep inferior epigastric perforator (DIEP) reconstruction were included. MRA acquisition sequences, MRA images, radiologist reports, and surgical entry database were reviewed retrospectively. Intraoperative findings were compared. The diameter and characteristics of the perforators fulfilling the criteria of being "ideal-sized", at least 2.7 mm were collected. Wilcoxon's test was used to compare the size of the left and right perforators.

RESULTS: Ninety-three ideal-sized perforators were identified (diameter of 2.8–4.2 mm). Fifty-one of these were located on the left, and 42 on the right. The left perforators were indeed larger than the right (Wilcoxon's test, $p=0.017$). Most of the perforators were found in the superior region and medial rows. Additionally, lateral row perforators were observed to have a shorter intramuscular course.

CONCLUSION: Contrast-enhanced MRA is a useful preoperative imaging technique to locate ideal DIEPs for breast reconstruction. Perforators on the left were found to be larger than the right, and more ideal-sized perforators were located on the left.

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Introduction

Deep inferior epigastric perforator (DIEP) flap is a muscle-sparing technique for autologous tissue reconstruction post-mastectomy, where the skin and subcutaneous fat overlying the muscle are harvested. This technique is increasingly used and found to have lower morbidity and similar or even superior cosmetic outcome compared to the

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more traditional transverse rectus abdominis muscle (TRAM) flap technique, where the flap consists of the skin, fat, muscle, and its blood supply.[1] The vascular anatomy of the DIEP flap is highly variable, contributing to longer operative time for harvesting and elevating the best flap. The use of imaging for preoperative planning has been shown to reduce surgical time, and therefore, the anaesthetic requirement.[2] MRA is a valuable imaging technique offering excellent contrast resolution which is superior to computed tomography (CT).[3] There is no ionising radiation involved, which is particularly important in patients with genetic mutations who are more sensitive to the effects of radiation than the general population.[4]

At Hull Royal Infirmary, MRA is performed routinely prior to breast reconstruction surgery. If there is a contraindication to magnetic resonance imaging (MRI), CT angiography would be the examination of choice. The definition of ideal-sized perforator is variable in the available literature. Nevertheless, it is known that the larger the calibre of a perforator, the better the outcome of the reconstruction surgery.[5]

The aim of the present study was to identify the distribution and anatomical characteristics of "ideal-sized" perforators, defined locally by the surgeons as perforators of at least 2.7 mm in diameter on MRA based on surgical experience and is not evidence-based. It also evaluates a presumption that perforators on the left are generally larger than those on the right based on anecdotal evidence.

Materials and methods

Institutional clinical project committee approval was obtained. The collection and use of clinical data were retrospective in nature and adhered to the guidelines and principles in relation to ethics and confidentiality. Therefore, informed consent was not explicitly sought.

Fifty consecutive patients with breast cancer who had preoperative MRA and underwent breast reconstruction surgery using DIEP flaps from May 2016 to March 2018 were included. There were no exclusion criteria. The preoperative MRA images, radiologist reports, and breast reconstruction surgical entry database were reviewed retrospectively. The perforators were evaluated by the same consultant radiologist.

The "ideal-sized perforator" is defined as a perforator diameter of at least 2.7 mm on MRA (where it crosses the anterior surface of the rectus muscle, at or below the level of umbilicus). The diameter of the perforator artery fulfilling these criteria was measured. The number of ideal-sized perforators in each patient was collected. The perforator is characterised by its location in the left or right of the umbilicus; medial or lateral row by equally dividing between the midline of the abdomen and the lateral edge of the rectus sheath; superior, middle, or inferior regions by equally dividing the abdominal wall from the level of umbilicus to the level of symphysis pubis. Other documented features are the length of intramuscular course, and whether the locations of the perforators were symmetrical (equidistance from the midline, ±1 cm). The size of the left and right perforators was compared using Wilcoxon's test

as the data were not normally distributed. Fig 1 illustrates the course of the deep inferior epigastric arteries on coronal maximal intensity projection. Fig 2 demonstrates the transverse MRA with a 4 mm left perforator and a right perforator as they crossed the anterior surface of the rectus abdominis. Fig 3 shows the coronal view of a left perforator.

The surgeons routinely review the MRA images and radiologist reports preoperatively, and choose the most suitable perforators to base the flap on. The locations of the chosen perforators were marked on the patient's skin after the patients were anaesthetised for the surgery. The operative entry database was reviewed to determine if intraoperative findings of the location and relative size (based on the surgeons' judgements of the vessel size compared to other vessels of the same patient) of the perforators were consistent with the MRA findings.

MRA technique

The patients were imaged in the supine position with a 1.5 T GE Optima MRI scanner. Octopus coils overlying the abdominal wall were used to improve resolution of the anterior abdominal wall. The MRA field of view covered 2 cm above the umbilicus to the level of symphysis pubis, and anterior skin surface to approximately 3 cm posterior to the rectus abdominis muscle. Images were acquired during breath-holds for approximately 20 seconds for each series to counter movement artefact. Unenhanced transverse two-dimensional (2D) free induction echo stimulated acquisition (FIESTA) BH, and coronal LAVA-flex (three-dimensional [3D] fast spoiled gradient echo [FSPGR] T1-weighted) sequences were acquired. Gadolinium (Gadovist 0.5mmol/kg of body weight) contrast would then be administered intravenously, followed by bolus tracking and manually triggered acquisition of coronal LAVA-flex after gadolinium administration when contrast medium was seen in the iliac arteries. Subsequent first, second, and third delay coronal

Figure 1 Coronal maximal intensity projection (MIP) demonstrating the course of the inferior epigastric arteries (arrows).
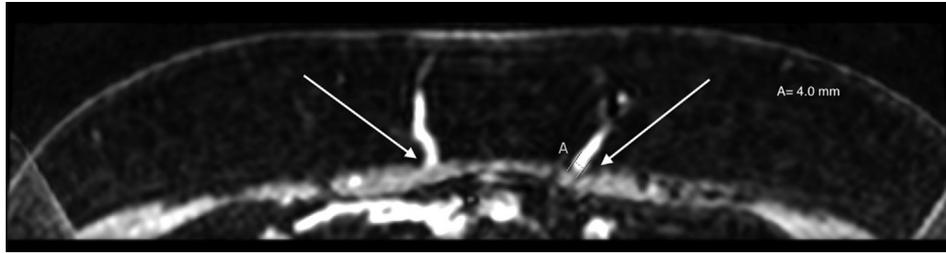
Figure 2 Transverse MRA with a left (4 mm in diameter) and a right DIEPs (arrows) as they crossed the anterior surface of the rectus abdominis.

LAVA-flex sequences were also obtained. Typical 3D LAVA-flex imaging parameters were: matrix of 320×192, repetition time (TR) of 6.4 ms, echo time (TE) of 4 ms, flip angle of $12°$, and section thickness of 2 mm reconstructed at 1 mm intervals using ZIP2 (twofold zero interpolation). Coronal images were reconstructed in the transverse and sagittal planes with section thickness and inter-section gap of 0.88. The acquired voxel size was $1.41\times1.88\times1$ mm^3 with reconstructed voxel size of $0.88\times0.88\times0.88$ mm^3.

Results

Fifty female patients had undergone DIEP flap breast reconstruction surgery from May 2016 to March 2018. The age of the patients at the time of surgery ranged from 34–68 years old. None of the patients had previous abdominal surgery. Thirty-six patients had unilateral breast reconstruction, and 14 had bilateral breast reconstructions. There were 42 operative entries with comments by the surgeons in terms of intraoperative findings in relation to MRA findings. The locations and relative sizes of perforators were noted to be consistent both intraoperatively and in MRA. A total of 93 ideal-sized perforators were identified at MRA, ranging from 2.8 to 4.2 mm. Fifty-one of these perforators were located on the left (2.8–4 mm), and 42

perforators on the right (2.8–4.2 mm). Table 1 demonstrates the number of patients with various numbers of ideal-sized perforators on each side of the abdomen. The majority of patients had one ideal-sized perforator on each side. Forty-eight percent of the patients had the same number of perforators on each side. Thirty-two percent of the patients had more perforators on the left.

Two out of the 50 patients in this study had perforators of <2.7 mm seen at MRA. Intraoperatively the perforators were found to be small, but were used for DIEP flaps. Although both patients did not experience delayed healing or wound breakdown, they developed areas of palpable fat necrosis that were managed conservatively.

Fig 4 illustrates the location of the ideal-sized perforators; most of these were located superiorly and in the medial rows. Twelve percent of the patients had a symmetrical location of the ideal-sized perforators from the midline. The lateral row perforators were found to have a shorter intramuscular course (Figs 5 and 6).

Due to the variable number of ideal-sized perforators on either side in each patient, a paired comparison is not possible. In cases where the perforators were not considered ideal-sized, the largest available perforators identified were included as a result (1.2–2.6 mm). This made up 65 pairs of perforators. The left perforators were statistically significantly larger than the right ($p=0.017$, Wilcoxon's test).

Discussion

The intraoperative findings were consistent with MRA. The present study demonstrated that the left DIEPs were statistically significantly larger than the right, and more perforators were identified in the left anterior abdominal wall. These findings are not described in any literature to

Figure 3 Coronal MRA of a left perforator (arrow). The dotted circle represents the umbilicus.

Table 1
Number of patients with various numbers of ideal-sized perforators on each side of the abdomen.

Number of ideal size perforators	No. of patients ($n=50$)
2 on the left, 2 on the right	1
2 on the left, 1 on the right	7
2 on the left, 0 on the right	3
1 on the left, 2 on the right	2
1 on the left, 1 on the right	21
1 on the left, 0 on the right	6
0 on the left, 1 on the right	8
0 on the left, 0 on the right	2

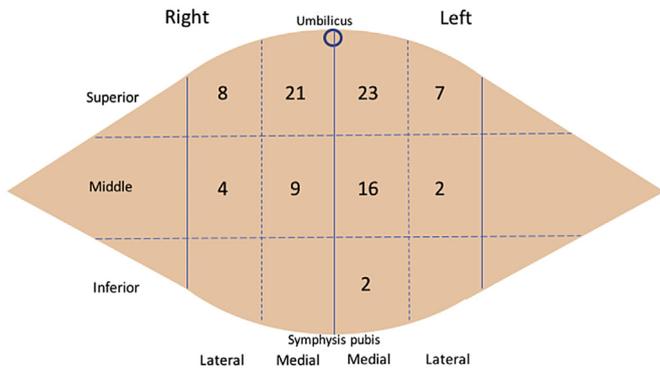A total of 93 ideal-sized perforators were identified in 50 patients.

Figure 4 Location of the ideal-size perforators in the anterior abdominal wall, from umbilicus to symphysis pubis.

date. More ideal-sized perforators were also found superiorly and in the medial rows. A similar finding was described in a cadaveric study, where most of the perforators >1 mm were located within 5 cm from the umbilicus.[6] A symmetrical location of the ideal-sized perforators was found in 12% of the patients.

The ideal size of the perforator for flap survival is variable in the available literature. Perforator of at least 0.9,[7] 1.5,[8,9] and 2.5 mm[10] had been described as ideal size in different sources for the DIEP flap. There may be interobserver variation, different imaging techniques or patient demographics accounting for this. Based on the experience of the surgeons at Hull Royal Infirmary, a perforator size of at least 2.7 mm is highly desirable. Considerations should also be given to other factors that determine the outcome of DIEP flap reconstruction, such as the venous drainage, position of the perforator in relation to the flap, flap weight, patient comorbidities, chest wall radiotherapy, and previous abdominal surgery.[11–13] In the absence of an ideal-sized perforator and presence of a suitable supra-umbilical perforator, the surgeons would consider harvesting it for breast reconstruction.
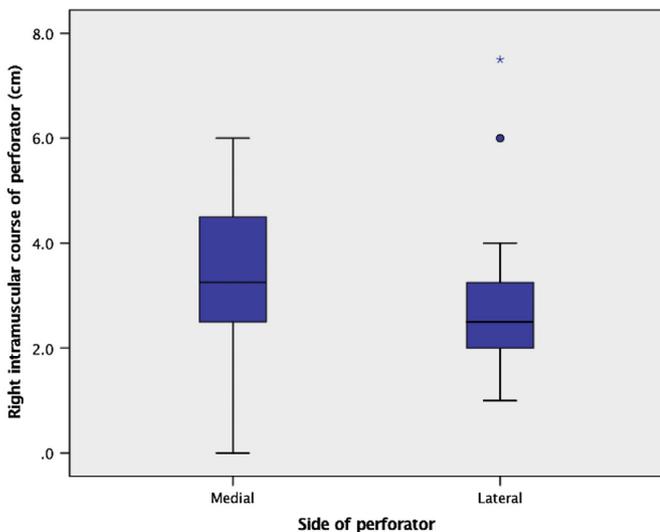

Figure 5 Intramuscular course of the right perforators by comparing the medial and lateral rows.
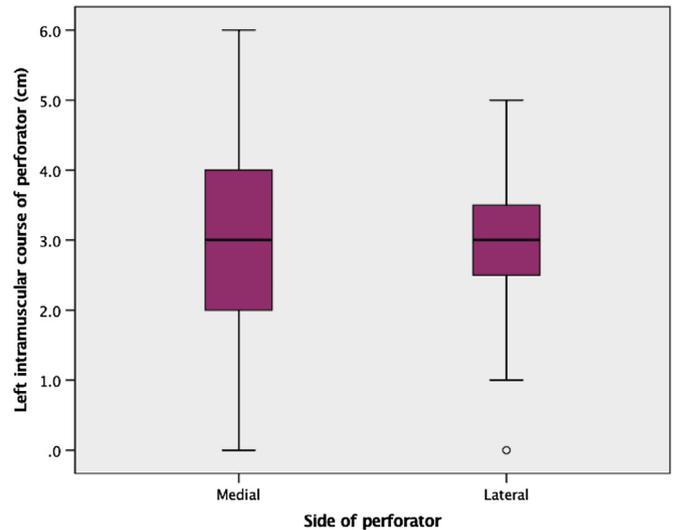

Figure 6 Intramuscular course of the left perforators by comparing the medial and lateral rows.

A perforator with a short intramuscular course is preferable as this leads to a decrease in the dissection time with a lower risk of injury to the perforator. The extent of damage to the rectus muscle from the surgical dissection is also minimised.[14] Although there were fewer lateral row perforators, these were observed to have a shorter intramuscular course than the medial row. This finding had been described in the existing literature.[15]

Unlike contrast-enhanced CT imaging, MRA does not subject the patients to ionising radiation exposure. This is particularly important in a subset of breast cancer patients with genetic mutations resulting in the impaired capability of DNA damage repair pathways such as BRCA 1, BRCA 2, PTEN (associated with Cowden syndrome), and TP53 (associated with Li–Fraumeni syndrome).[16] These patients have increased radiation sensitivity; therefore, ionising radiation should be minimised where possible.[17] MRA offers better contrast resolution than CT and is useful in the assessment of both arterial and venous vasculature.[18] Appreciation of the venous anatomy is of added value as there is a reported association between superficial inferior epigastric vein characteristics and the incidence of postoperative venous congestion.[19] There is a lower risk of renal function compromise and anaphylaxis compared to CT angiogram.[20] MRA is also more feasible than ultrasound Doppler in vascular mapping as it can produce anatomical images that the surgeon can review independently; however, MRA requires a longer time for adequate image acquisitions.[21] MRA is unsuitable for claustrophobic patients, patients with non-MRI compatible pacemakers or implanted metal devices.

MRA was performed with the patient in a supine position to minimise distortion to the anterior abdominal wall especially in obese patients. Breath-hold acquisitions were used to minimise movement artefact. With preoperative imaging, the traditional approach of raising the flap contralateral to the breast reconstruction site for logistic reasons has significantly decreased. Occasionally

angiography is not successfully obtained before the surgery. In this situation where the patient is arranged for unilateral DIEP flap reconstruction, the surgeons could preferentially raise the perforator flap from the left abdominal wall as there is a higher chance of identifying an ideal-size perforator based on the present findings.

This study can benefit from a larger sample size. The lack of standardised intraoperative measurement of the perforator size to compare with MRA findings was also identified as another limitation in the analysis. The study has not looked at intra- and inter-operator error in identification and sizing the perforators. This should be explored in the future study to objectively assess the accuracy of MRA using current departmental imaging techniques. Comparison may also be made with the available literature to determine if there is any difference in terms of MRA accuracy and imaging techniques. It would be interesting to explore the relationship between the size of the superior epigastric artery and DIEP.

In conclusion, contrast-enhanced MRA is a useful preoperative imaging technique to locate ideal DIEPs for breast reconstruction. This study presents a new observation that the left perforators are larger than the right, with more ideal-sized perforators located on the left. These perforators were also found mostly in the superior region and medial rows. Symmetry in the location of the ideal-sized perforators was demonstrated in 12% of cases. Additionally, lateral row perforators were observed to have a shorter intramuscular course.

Conflict of interest

The authors declare no conflict of interest.

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