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Is There a Need for Preoperative Imaging of the Internal Mammary Recipient Site for Autologous Breast Reconstruction?

Warren M. Rozen, MBBS, BMedSc, PGDipSurgAnat, PhD, Alberto Alonso-Burgos, MD, Alice C. A. Murray, MBBChir, and Iain S. Whitaker, BA, MA, Cantab MBBChir, PhD, FRCS

Abstract: Preoperative imaging of recipient-site vasculatur in autologous breast reconstruction may potentiate improved outcomes through the identification of individual variations in vascular architecture. There are a range of both normal and pathologic states which can substantially affect the internal mammary vessels in particular, and the identification of these preoperatively may significantly affect operative approach. There are a range of imaging modalities available, with ultrasound particularly useful, and computed tomography angiography (CTA) evolving as a useful option, albeit with radiation exposure. The benefits of CTA must be balanced against its risks, which include contrast nephrotoxicity and allergic reactions, and radiation exposure. The radiation risk with thoracic imaging is substantially higher than that for donor sites, such as the abdominal wall, with reasons including exposure of the contralateral breast to radiation (with a risk of contralateral breast cancer in this population 2 to 6 times higher than that of primary breast cancer, reaching a 20-year incidence of 15%), as well as proximity to the thyroid gland. Current evidence suggests that although many cases may not warrant such imaging because of risk, the benefits of preoperative CTA in selected patients may outweigh the risks of exposure, prompting an individualized approach.

Key Words: free flap, perforator flap, reconstructive surgery, anatomy, variation

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The selection of suitable recipient-site vessels in autologous breast reconstruction is a crucial surgical decision. With vascular architecture varying significantly between patients in both normal and pathologic states, the decision can affect flap survival and overall surgical outcomes. An understanding of such anatomy enhances the safety and technical ease of reconstruction, and with advances in preoperative imaging, consideration of imaging recipient vessels has become debatable.[1] The most frequently used recipient vessels are the thoracodorsal (TD) and internal mammary (IM) vessels. IM vessels are preferred due to their accessibility, straightforward dissection, and freedom of flap positioning.[2,3] In addition, they are relatively spared after irradiation and axillary surgery compared with TD vessels,[1] are usually preserved in spite of mastectomies,[4] and preserve a useful option in the TD vessels for pedicled reconstruction should the free flap fail. Many studies have demonstrated success using IM recipient vessels for deep inferior epigastric artery perforator flaps.[5]

Although the value of preoperative imaging as a tool in planning free-flap tissue transfer in breast reconstruction is well recognized, this has largely been for donor-site vasculature. For donor vasculature, ultrasound has been used to identify suitable perforator vessels in abdominal donor-site flaps,[6,7] and has been shown to be safe and inexpensive. Although some attempts at using ultrasound for recipient vasculature have been made, particularly for IM vessels and perforators preoperatively,[8] inaccuracies between imaging and operative findings limit its use.[9–13] Computed tomography angiography (CTA) is a widely used noninvasive imaging technique for mapping the vascular supply to body regions,[14] and can provide detailed knowledge of arterial and venous architecture, including vessel origin, calibre, course, length, and branching patterns. Highresolution images provide accurate and reproducible findings,[15] with CTA demonstrated to be superior to Doppler and duplex ultrasound at identifying the course of the deep inferior epigastric artery, its branching pattern, and in visualizing its perforators.[16] For imaging the internal mammary artery (IMA), it has not been widely explored. Magnetic resonance angiography has also been used for preoperative imaging, and carries the benefit of reduced radiation dose, high sensitivity, and positive predictive value,[17] but produces relatively inferior images with regard to spatial resolution, less reproducible findings, and all this at an increased cost.[18]

The question as to whether there is a need to image recipient vasculature in breast reconstruction surgery thus emerges, answered only by an analysis of the relative incidences of anatomic variations, and by exploring the imaging modalities available in this role. Side effects from such imaging are also an important consideration.

NORMAL ANATOMIC VARIANTS

Knowledge of individual patient anatomy allows anticipation of intraoperative difficulties and consideration of all reconstructive options, with the surgeon who is then able to select the most favorable vasculature to achieve optimal results.

Recent anatomic studies of the IM vessels have shown greater relative anatomic consistency than was once thought. However, enough variation exists to complicate dissection and selection of suitable vessels. The IM vessels are commonly suitable at the third or fourth intercostal space, with veins above the fourth intercostal space largely adequate for microanastomosis.[8,18,19] However, the overall usability of the IM vessels has been reported to range from as low as 80%[19] to 98%.[20,21]

The IMA runs caudally from its origin at the subclavian artery, dorsal to the sternoclavicular joint and costal cartilage (CC), and ventral to the parietal pleura. From the third intercostal space, the artery runs between transversus thoracis and the outer intercostal muscle layers where it gives off branches at each intercostal space. Between the sixth and seventh CC, the IMA divides into superior epigastric and

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From The Taylor Laboratory, Jack Brockhoff Reconstructive Plastic Surgery Research Unit, Department of Anatomy and Cell Biology, The University of Melbourne, Victoria, Australia.
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Reprints: Warren Matthew Rozen, MBBS, BMedSc, PGDipSurgAnat, PhD, The Taylor Laboratory, Jack Brockhoff Reconstructive Plastic Surgery Research Unit, Department of Anatomy and Cell Biology, The University of Melbourne, Grattan St, Parkville 3050, Victoria, Australia. E-mail: warrenrozen@hotmail.com.

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musculophrenic arteries. The distance between the lateral sternal border and the IMA has been reported to be anywhere from 10 to 24 mm.[22,23] The depth of the IM vessels varies from 17 to 22 mm.[24] The diameter of the IMA at fourth rib ranges from 0.99 to 2.55 mm,[23] and is larger on the right side.[2]

Arnez et al described 4 different patterns of venous anatomy[25]: in 69% a single internal mammary vein (IMV) ran medial and parallel to the artery, then divided into a medial and lateral vein at the fourth intercostal space, whereas in 26% the IMV ran medial to the artery throughout its course. Overall, the IMV was shown to bifurcate at variable intercostal levels, becoming unsuitable for consistent venous anastomosis at or below fourth intercostal space, with the diameter of the IMV at the fourth rib ranging from 0.64 to 4.45 mm and then getting progressively smaller distally. Clark et al showed that at the level of third rib 40% of veins on the left and 70% on the right were ≥3 mm.[18] In these studies, the IMV bifurcates in 90% of cases by the third rib on the left side and in 40% on the right side, and the IMVs tend to bifurcate lower on the right side, which explains their larger calibre on the right than the left side.[18,25] The smallest recorded venous diameters are 0.5 mm and 1 mm of the lateral and medial branches, respectively.[18,25] In view of these anatomic variations, preoperative imaging may enable the surgeon to not only prepare for otherwise unexpected findings, but also to select the vessels and approach of choice. This may potentially reduce intraoperative dissection time and surgical error.[26] Gaining adequate access to the IMV can often require excision of a medial segment of the ipsilateral third CC, with the potential for anatomic variations discovered intraoperatively to enhance further exploration to find adequate vessels and resection of multiple rib segments, and thereby increasing recipient site morbidity.[21,27,28] Preoperative imaging can further reduce this risk.[28]

Some additional anatomic findings that may aid vessel selection include the assessment of donor and recipient vessel calibers, and thus assess for size mismatch, which has been known to result in conversion to alternative vasculature,[20] or subsequent flap complications.[2] Rarer anatomic variations that may preclude IM vessel use can include congenital arteriovenous fistulae between the IM vessels and pulmonary artery,[29] and collateralization from the IMA to the iliac artery in aortoiliac vascular disease.[30] Each of these can be demonstrated with preoperative imaging.

The use of IM perforators as recipient sites, first described in 1999,[31] can potentially provide a preferable option to the regional IM vessels. These perforators have been used successfully for deep inferior epigastric artery perforator, transverse rectus abdominis myocutaneous, and superficial inferior epigastric artery flaps. Unlike with the IM vessels themselves, there is no need for CC or pectoralis major excision/incision and the IMA is preserved as an arterial conduit for future coronary revascularization.[32] However, dissection of the perforators can be difficult and vessels may be unsuitable due to their calibre or damage from previous surgery and radiotherapy. Anatomic variants are common,[5,28,33] and their anatomy is not reproducible in all patients.[34] Ultimately this can result in failure to perform the anastomosis,[4,27] or prolonged surgery.[35] A variable percentage of patients have vessels adequate for microanastomosis, an incidence reported at 9% to 39%.[34,27] These patients are optimally identified preoperatively.[33]

IATROGENIC CHANGES

Adjunctive radiation treatment is an integral component of breast cancer management, and radiation effects can certainly become evident within the thoracic vasculature. This is clearly of importance in cases of delayed breast reconstruction, with risks associated with scar tissue, micro- and macroscopic vascular changes all discussed widely in the literature. Multiple structural and functional tissue changes occur after irradiation, the degree of which depends on the strength of radiation and manner in which the dose is delivered. Histopathological changes include subendothelial connective tissue proliferation, accumulation of fibrinoid substances, dense fibrosis of the adventitia, and obliteration of the vasa vasorum. Irradiation causes significant vascular narrowing which is pathologically indistinguishable from atherosclerosis.[36] Periarterial fibrosis, direct damage to arterial walls, and thickening of IMV wall are possible operative findings.[21]

After radiotherapy, the vessels in the axilla tend to be small with surrounding fibrosis,[27] making dissection of the TD vessels very difficult. However, reports describing the level of radiotherapy-related damage to the IM vessels are less consistent. Radiotherapy effects can result in the unusability of IM vessels due to scarring and fibrosis.[2] Although rare, complete IMA occlusion postmastectomy and radiotherapy,[37] and radiation-induced occlusion of the subclavian artery have been reported.[38] Previous radiotherapy is a documented reason for nonusage of the IMA in coronary artery bypass graft surgery,[39] and furthermore IMA graft patency is lower after mediastinal irradiation due to fibrosis and scarring.[40] Preoperative imaging can provide valuable detail on the level of stenosis and occlusion of the IMA, and can highlight those individual cases where irradiation has significantly altered vessel properties.

In breast cancer patients, previous surgery at both the donor and recipient site has the potential to significantly alter vascular anatomy. Local vascular morphology and larger source vessels have been shown to be markedly altered after surgery, with division of both major arterial or venous channels, as well as changes in local vessel calibres in response to surgical delay. These changes are not always predictable. Imaging of the recipient site can guide not only reconstructive surgeons in the delayed setting, but may also guide breast surgeons where care may be needed during resection, such as for preservation of the IM perforators. CTA in particular has been shown to successfully identify alterations in vessel morphology and vessel filling patterns which can aid preoperative planning.[41]

PATHOLOGIC CHANGES

Numerous case reports of pathologic vascular changes affecting the IMA have been described. Vasculitidies of medium and large-sized vessels can alter IM vessel patency significantly, from segmental occlusions of the IMA and collateralization around these areas in Buerger disease, to aneurysmal changes and total obstruction as sequelae of Kawasaki disease.[42,43] Subclavian stenosis can threaten the adequacy of the IMA as a conduit and potentially alter vessel dimensions. Potential causes of subclavian stenosis include following: thoracic outlet syndrome, chronic extra-arterial compression, radiation effects, antithrombin III deficiency, and/or thrombus of cardiac origin (eg, in atrial fibrillation). Wu et al published a case of subclavian thrombosis extending into the origin of the left IMA, thus compromising its blood flow.[44] Moussa et al showed that CTA was successfully used preoperatively to assess calibre, luminal diameter, and calcification of the left IMA in a patient with bilateral subclavian stenosis.[45] Arterial complications of thoracic outlet obstruction are common, these include chronic thrombosis of the subclavian artery, distal arterial microemboli, and subclavian aneurysm.

DISCUSSION

The unpredictable nature of normal anatomic and pathologic variants may limit operative success, increase recipient site morbidity, and ultimately affect flap survival and surgical outcomes. Preoperative imaging of the recipient site may demonstrate each of these possibilities, and may maximize the chances of operative success. There are many modalities that have been used in preoperative imaging, particularly for donor-site vasculature, and each of them may have a role in recipient vasculature likewise. Although we have used many such modalities, there are benefits and pitfalls with each, and certainly careful consideration of the optimal modality in this setting is paramount. Conventional ultrasound (Fig. 1) and particularly color duplex ultrasound (Fig. 2), can demonstrate unidirectional flow and vessel course. The resolution is certainly improved with the use of conventional catheter angiography (Fig. 3), however, there is a substantial morbidity with catheter placement and contrast load. CTA combines the resolution of angiography with the noninvasiveness of ultrasound (Fig. 4), and is particularly useful at demonstrating perforators of the IMA (Fig. 5), and smaller vessels.

The benefits of CTA must be balanced against its risks, which include contrast nephrotoxicity and allergic reactions, and radiation exposure.[46,47] The radiation risk with thoracic imaging is substantially higher than that for donor sites, such as the abdominal wall. There are several reasons for this. Of note, the risk of contralateral breast cancer is 2 to 6 times higher than that of primary breast cancer in the general population with a 10-year incidence of 10.5%

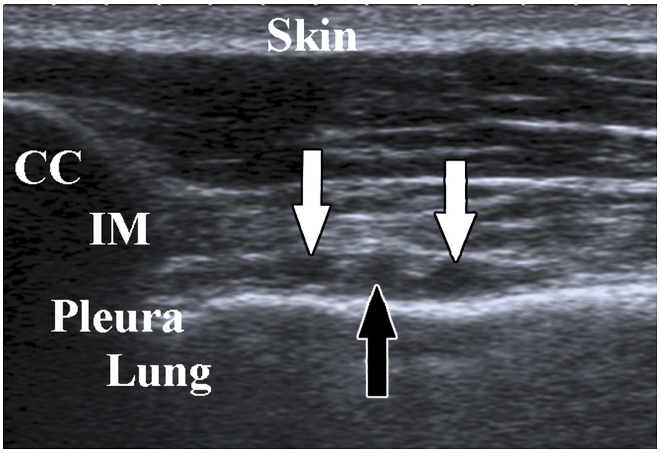

FIGURE 1. Conventional Doppler ultrasound of the IMA (black arrow) and veins (white arrows), coursing deep to the CC and intercostal musculature.

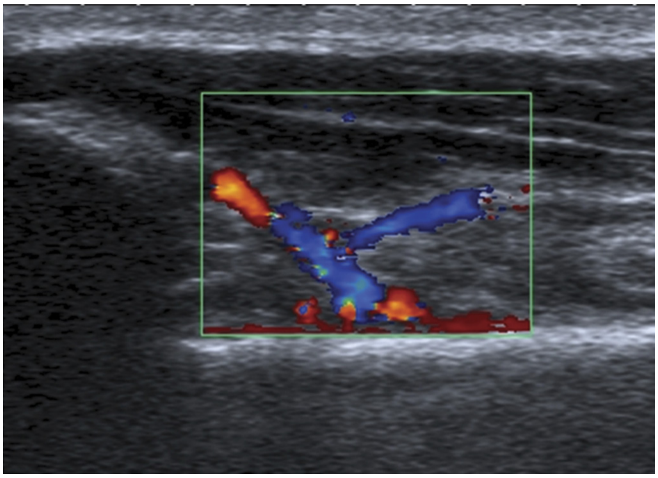

FIGURE 2. Color duplex ultrasound of the IM vessels, demonstrating their course through the intercostal and pectoralis major musculature.

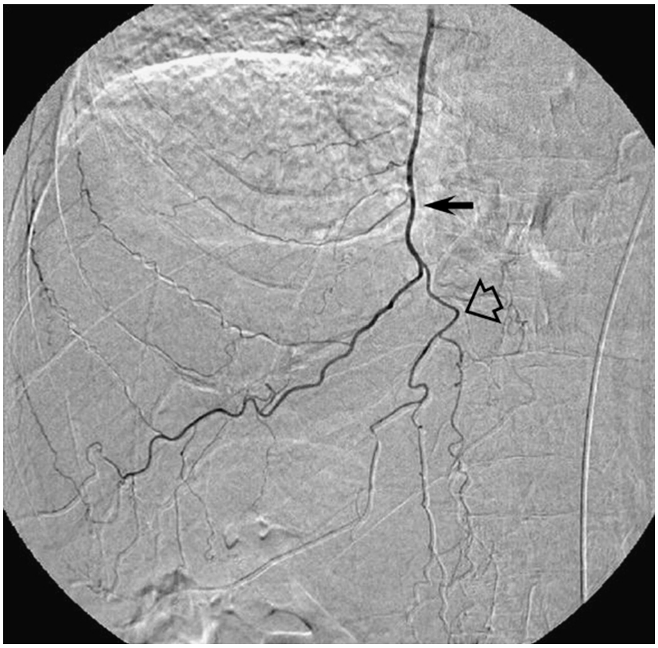

FIGURE 3. Conventional catheter angiography after selective catheterization of the IMA origin. The IMA (black arrow) and the deep superior epigastric artery trunk (white arrow) are demonstrated.

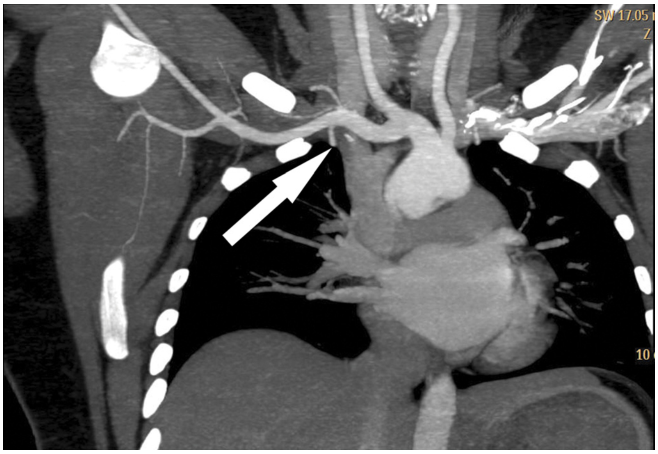

FIGURE 4. CTA of the thoracic vasculature, with volume rendered technique reconstruction, demonstrating the origin of the right IMA (arrow) from the right subclavian artery.

and 20-year incidence of 14.7%.[48] Radiation exposure through CTA imaging may further increase this risk, although this has not been definitively demonstrated. Proximity to the thyroid gland is also an important concern.

Despite the increasing technology available with which to plan free flap surgery, it should be noted that a radiologically ideal set of vessels may not be surgically suitable for anastomoses, with this truly only able to be determined with the vessels finally dissected out. Although there are clearly benefits to be gained with imaging, current evidence suggests that while many cases may not warrant such

FIGURE 5. CTA of the thoracic vasculature, with maximum intensity projection reconstruction, demonstrating the IMA (arrow) and course of a second intercostal space perforator through the pectoralis major and subcutaneous tissues.

imaging based on the risk profile of imaging, the benefits of preoperative CTA in selected patients may outweigh the risks. An individualized approach to such imaging is thus important, and an approach to such selection may be scope for future research.

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