

Computerized Tomographic and Magnetic Resonance Angiography for Perforator-Based Free Flaps: Technical Considerations

Justin S. Lee, MD^a, Ketan M. Patel, MD^b, Zhitong Zou, MD^c,
Martin R. Prince, MD, PhD^c, Emil I. Cohen, MD^{a,*}

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- Magnetic resonance angiography
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The advent of multidetector computed tomography (MDCT), with an ever-increasing number of detectors and faster gantry rotations, has revolutionized diagnostic radiology, allowing for rapid imaging at an increased resolution.¹ Coupling MDCT technology with improvements to intravenous contrast has made it possible to perform precise imaging during the arterial phase of contrast infusion increasing resolution of smaller vessels.² Computed tomographic angiography (CTA) is now routinely used in vascular, abdominal, and transplant surgery for its ability to provide accurate vascular anatomic detail. In most settings it has supplanted conventional invasive catheter angiography as the diagnostic imaging modality of choice for imaging blood vessels. CTA is a noninvasive method for preoperative planning, such as determining tumor resectability, arterial anatomy before organ donation, and

extent of peripheral vascular disease.^{3–5} As advanced CTA has become mainstream, it is not surprising that new and novel applications have been developed in other specialties, including reconstructive surgery.

Over the last several decades, the use of perforator-based free flaps has gained appeal because of the reduction in donor-site morbidity common with conventional musculocutaneous flaps.^{6,7} Successful perforator-based free flaps rely on selection of the appropriate dominant vessel supplying the vascular territory of the flap. Generally, anatomic variability increases in distal branches beyond the parent vessel. In addition, anatomic variability tends to increase as vessel size decreases. Improvements to surgical technique, allowing for the harvest of smaller, distal vascular segments has made knowledge of the native vascular anatomy critical during surgical

^a Division of Vascular and Interventional Radiology, Department of Radiology, Georgetown University Hospital, 3800 Reservoir Road NW, Washington, DC 20007, USA

^b Department of Plastic Surgery, Johns Hopkins University, Georgetown University Hospital, Washington, DC, USA

^c Department of Radiology, Weill Cornell Imaging at New York Presbyterian Hospital, Weill Cornell and Columbia University, 416 East 55th Street, New York, NY 10022, USA

* Corresponding author.

E-mail address: Emil.I.Cohen@gunet.georgetown.edu

dissection. Anatomic course and perforator diameter are important determining factors for flap perfusion.⁸ Furthermore, understanding the perforator distribution and blood supply of a flap can impact the operative time and perfusion of the flap, ultimately affecting the outcome.⁹

Doppler ultrasound is used extensively for free-flap operative planning. Duplex sonography adds the ability to assess the rate of flow in addition to the acoustic characteristics of a vessel.¹⁰ Unfortunately, ultrasound of any form is limited by its subjective nature, time required to perform a quality evaluation, and ultimately its reproducibility. Digital subtraction angiography was at one time considered the gold standard for the identification and mapping of vessels. However, it is an invasive procedure, which always has the risk of complications, such as vessel dissection and access-site hemorrhage. Evaluation of small, perforator-sized vessels requires selective angiography, which increases the risk of vessel injury and still fails to accurately depict the course of the vessel of interest in the surrounding soft tissue.¹¹

Magnetic resonance angiography (MRA) and CTA have the advantages of being noninvasive methods of imaging vascular anatomy with high spatial resolution and soft-tissue detail that is easily reproducible. MRA has the advantage of not using ionizing radiation, which is a consideration, particularly when dealing with younger patient populations. These two imaging modalities are discussed further as tools for preoperative evaluation in perforator-based flap reconstruction.

Alonso-Burgos and colleagues¹² published one of the first reports using CTA for reconstructive surgery in which 6 patients were evaluated using CT for deep inferior epigastric perforator (DIEP) tissue flap planning. A 4-detector row MDCT scanner was used with 150 mL of iodixanol contrast medium. The investigators obtained a slice thickness of 1.25 mm and reformatted images into multiplanar reformats, maximum intensity projections (MIP), and 3-dimensional (3-D) volume-rendered images. Arterial perforators were identified and evaluated for vessel diameter, fascial penetration pattern, intramuscular course, origin from the deep inferior epigastric artery, and other anatomic variations. In all 6 patients, accurate main perforators were identified on CTA with no additional vessels found at the time of the surgery. In addition, CTA provided important adjunctive preoperative information, such as muscular diastasis, abdominal wall hernia, and fatty infiltration of potential flaps. This early experience with an early 4-detector row scanner showed promising results for CTA as a noninvasive means for presurgical planning.

The same year Masia and colleagues¹³ published a retrospective review of 66 DIEP flap reconstructions in which CTA was used for preoperative planning. The investigators found an average time saved of 1 hour and 40 minutes in cases with preoperative CTA. There were 2 cases with partial necrosis and 1 total failure in the group without prior CTA and only 1 partial necrosis case in the CTA group. The investigators thought that CTA offered a high sensitivity, specificity, and 100% positive predictive value. Furthermore, they were able to highlight the value of CTA as a tool to reduce operative time by identifying the most suitable perforator allowing safe ligation of other smaller vessels.

In 2008, Rozen and colleagues¹⁴ published a series of articles using CTA for DIEP and superficial inferior epigastric artery (SIEA) flaps (**Table 1**). The first report included 75 patients using a 64-detector row scanner the images reconstructed as 1-mm slices. Of the 75 patients, they specifically describe seven cases in which CTA actually changed the operative plan due to the anatomy, particularly patients with prior abdominal wall surgical history. Later, a second study performed by the same group evaluated 104 reconstructions to determine if there were outcome differences after preoperative CTA.¹⁵ The investigators concluded that preoperative CTA was associated with a statistically significant decrease in flap complications, donor-site morbidity and operative stress for the surgeon. In a similar study, Smit and colleagues¹⁶ also demonstrated a trend toward the reduction in surgical time. Their study compared 70 patients who were evaluated preoperatively with CTA and 68 by preoperative Doppler ultrasound. There was a statistically significant decrease in surgical time and no flap complications in the CTA group.

Despite CTA strengths in arterial imaging, limitations do exist. A comparison study of Doppler to CTA for DIEP flap planning in 2010 evaluated 45 patients preoperatively examined with both Doppler and CTA. In this series, the dominant perforator used for the flap was found in 44 patients with Doppler and 41 patients with CTA.¹⁷ Additionally, among CTA patients, there was a disagreement in perforator size described on the CTA compared with what was found during surgery. Overestimation on the CTA was attributed to a summation of the perforating artery and adjacent vein during measurement, likely secondary to volume averaging. The investigators did find that CTA provided a better analysis of the intramuscular course of the vessels as well as assessment of superficial venous communication, and that overall CTA provided a global picture to the surgeon.

MRA has continued to improve on its ability to visualize vessels distinctly within adjacent soft

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