# Computed Tomographic Angiography: Clinical Applications

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The use of preoperative imaging for planning free flap operations has been enthusiastically received by most reconstructive surgeons, with advances in both operative techniques and imaging techniques highlighting the benefits of such imaging. Computed tomographic angiography (CTA) in particular, has emerged as a beneficial aid in the planning of perforator flaps, with proven efficacy in improving operative outcomes and allowing for accurate and appropriate preoperative decision making.[1–4] Its role has emerged for many perforator flap operations, and many centers have now published large series of data to show these outcomes. In addition to modifying flap planning, preoperative imaging has been explored as a means to planning the optimal mode of dissection and to minimize donor site morbidity. With further technological improvements in imaging techniques, these aims have become increasingly realized.

In its role for preoperative planning, CTA is able to detect perforators at any potential donor site, and with modern high-resolution scanners allows for detection of almost all vessels more than 0.3 mm in size.[2,3] This accuracy makes CTA the most accurate technology currently available for the preoperative mapping of perforators. In addition to this accuracy, CTA is able to evaluate more than 1 potential donor site simultaneously, allowing the surgeon flexibility in donor site selection as well as perforator selection within a single scan.

Perforator flap surgery is currently a mainstay in the management of breast reconstruction, with a range of donor sites commonly used for both partial and total breast reconstruction. Given the potential for overall improvements in both flap vascularity and survival, as well as donor site morbidity, a range of applications of CTA in the setting of autologous breast reconstruction have emerged. These applications include donor site selection, flap selection, and perforator selection for free tissue transfer, as well as flap and perforator selection for locoregional perforator flap options. Other applications for CTA that have become useful include the appraisal of recipient vessels for free tissue transfer and the screening for comorbidities, such as metastatic disease or

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incidental findings that may influence operative care. These and other useful techniques are explored in this article.

## TECHNIQUE

The process of scanning a patient to obtain images that can be used for preoperative planning is not complicated,[5] and a range of scanning protocols can be used to achieve equally good visualization of perforators. In general, the aim is to achieve arterial phase scans, which eliminate venous contamination, avoid confusion between different structures, and maximize arterial filling. We thus recommend triggering the scan from the origin of the pedicle, and scanning in the direction of blood flow through the perforating vessels. For example, for deep inferior epigastric artery perforator (DIEP) flaps, the scan is triggered from the external iliac/common femoral artery junction and the scan is performed in a caudocranial direction. This technique is modified for each donor site.

Analysis of CTA images can similarly be performed using a range of techniques, with the raw scan data through axial slices able to show all of the important information; however, visual appreciation of the vascular anatomy is best achieved with the use of software-generated three-dimensional (3D) reconstructions. These reconstructions are easy to interpret by surgeons and show the anatomic relationships of each vessel in a single 3D image. There are a variety of software applications that are able to generate suitable images for operative planning. Each generated image can be saved for reference during the operation, with only several images required for easy intraoperative reference. Rather than referral to a radiologist for all image analysis, we have found that many surgeons prefer to see or generate the 3D reconstructions themselves, because appreciation of the 3D course of a perforator on a saved image can be difficult.

## FREE FLAP DONOR SITES

Preoperative imaging of a donor site with CTA can achieve 2 global aims: first, to confirm that a proposed donor site is suitable in that role, and second, to select the most appropriate vasculature from that donor site as the basis of flap design. All potential donor sites for free flap breast reconstruction can be investigated with CTA to determine the exact nature of their vasculature. A variety of potential donor sites have been used for autologous breast reconstruction, with many of these still in widespread use; however, the anterior abdominal wall has remained the first choice because of the superior cosmesis of its donor site. Abdominal wall flaps used in this role include the free transverse rectus abdominis myocutaneous (TRAM) flap, muscle-sparing variants of the TRAM flap, the DIEP flap, and the superficial inferior epigastric artery (SIEA) flap. Although the abdominal wall is versatile and suitable in most cases, several other free flap donor sites are suitable as first-line or particularly where the abdominal wall is unsuitable (eg, if there is scarring). These sites include the superior and inferior gluteal artery perforator flaps (SGAPs and IGAPs, respectively) and the transverse upper gracilis (TUG) flap.

### *Anterior Abdominal Wall Flaps (TRAM, DIEP, and SIEA Flaps)*

Free flaps based on the lower anterior abdominal wall integument have progressed in techniques in a donor-site–sparing fashion, which has simultaneously increased surgical complexity and decision making. From inclusion of all deep inferior epigastric artery (DIEA) perforators in the TRAM flap, to the selection of the optimal perforators in the DIEP flap, preoperative imaging can substantially improve decision-making ability. For the SIEA flap, where anatomic variation is widespread and a suitable SIEA is present in only 10% of patients, preoperative planning is of utmost importance.[6,7] The abdominal wall vasculature is highly variable, potentially more than most other body regions. The DIEAs originate from the external iliac artery, and ascend within the rectus sheath on the deep surface of rectus abdominis, distributing musculocutaneous perforators to supply the overlying integument. Perforator variability is not only in location but also in size and course. The ability of this anatomy to cause operative havoc led to the use of the external Doppler prove for perforator mapping from the early days of such surgery. However, with low sensitivity and specificity in this role, the development of advanced perforator imaging technique arose in response to this uncertainty.

For perforator mapping in the anterior abdominal wall, CTA has become established as the gold standard, shown to be highly accurate in both cadaveric and clinical studies, with a sensitivity and specificity in such mapping approaching 100%.[2,8] It has been shown to accurately identify the DIEA (**Fig. 1**), all of its major branches, and its musculocutaneous perforating branches. In addition to the location and size of these vessels, a 3D appreciation of the course of the perforators can be shown (**Fig. 2**). The relative dominance of the superficial arterial system can also be determined (**Fig. 3**). The use of CTA to show this