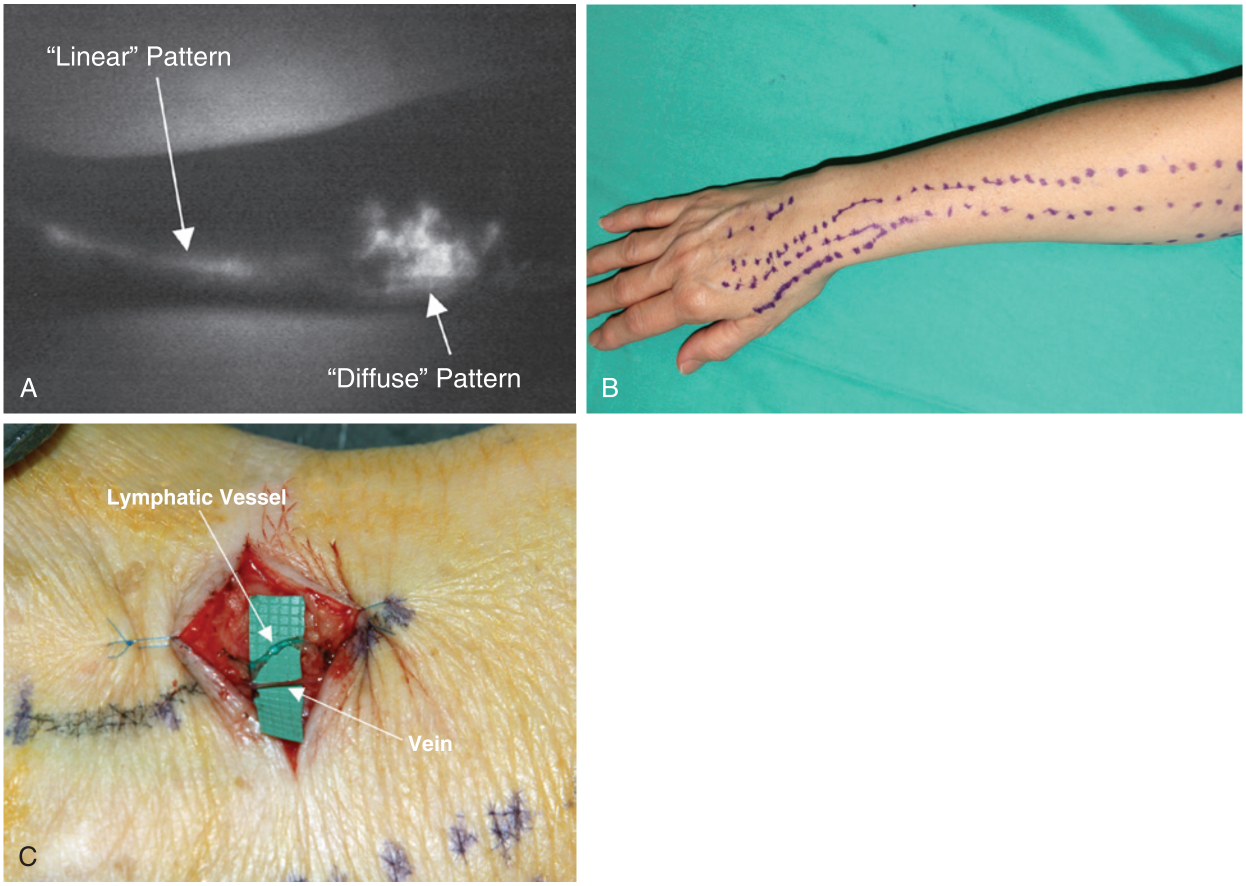

Figure 4.9 (A) ICG lymphography of the right upper extremity. (B) A linear pattern is seen distally to the left, indicating a patent lymphatic channel, but eventually becoming non-patent proximally, toward the right. The course of the lymphatics are traced with a skin marker. (C) During surgery, an incision is made over the skin marking and a lymphatic (filled with methylene blue dye) is readily visualized next to an adjacent vein, which are usually easily found subcutaneously. Veins can occasionally be seen causing voids along lymphatics visualized by ICG lymphography as they cross superficial to the lymphatic vessel (not shown).

be aided by injection with methylene blue into the same subcutaneous sites as the ICG injection.

PREOPERATIVE PLANNING WITH COMPUTED TOMOGRAPHY ANGIOGRAPHY

Computed tomography angiography (CTA), using multidetector row CT scanners, is another imaging modality that is used evaluate recipient, pedicle, and perforator blood vessels. Because of its less invasive nature, CTA has become more popular than digital subtraction angiography, which involves additional risks of arterial puncture, pseudoaneurysm, and bleeding. CTA not only provides high-resolution images of both the arterial and venous systems, but also allows for simultaneous visualization of the surrounding bony and soft tissue architecture. In addition to verifying the patency of major blood vessels in settings such as vascular disease, prior surgery, trauma, and congenital anomalies, CTA has been used in reconstructive surgery to map perforators in abdominally-based free flaps used for breast reconstruction, as well as in anterolateral thigh and fibula free flaps used for reconstruction in other parts of the body.

BREAST RECONSTRUCTION

The DIEP flap is often preferred to the free transverse rectus abdominis myocutaneous (TRAM) flap because of potentially lower donor site morbidity and equal reliability. However, these theoretic advantages are actually dependent on locating adequate perforators that do not require extensive interruption of the rectus abdominis muscle and its innervation to dissect. Visual evaluation of perforator anatomy can require substantial time-consuming dissection to determine which perforator or perforators are best suited to base the flap on.

CTA has been used as a method of localizing cutaneous perforators preoperatively for DIEP flap harvest by several investigators.[23–27] By doing so, the theoretic advantage is that the surgeon saves time by focusing only on the dominant perforator or perforators while ligating minor unessential perforators. It also allows the surgeon to pick the side of the abdomen with better perforators in unilateral breast reconstruction (Fig. 4.10). In some cases, the location of a favorable perforator preoperatively might cause the surgeon to reposition the planned skin incisions for the flap. CTA also has utility in preoperatively visualizing the branching pattern and course of the vascular pedicle to determine whether it

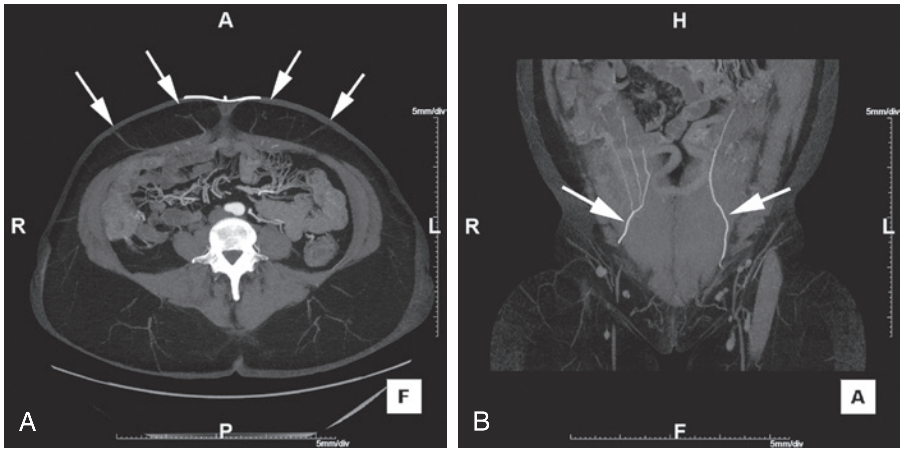

Figure 4.10 A computed tomography (CT) angiogram of the abdomen used for preoperative planning prior to deep inferior epigastric perforator flap harvest. (A) Arrows demonstrate subcutaneous perforators arising from the deep inferior epigastric arteries in the axial view. (B) Arrows point to the deep inferior epigastric arteries, which are seen branching in this section, in the anterior-posterior view.

is amenable to straightforward dissection without substantial destruction of the rectus abdominis muscle. In cases where the branching pattern requires the surgeon to sacrifice a large amount of muscle to capture the desired perforator(s), plans for a DIEP flap are abandoned and a muscle-sparing TRAM flap is harvested instead. The disadvantages of CTA include modest radiation exposure, cost, and risk for allergic reactions to intravenous contrast.

Patients undergo multidetector helical CT scans with 100–150 mL of contrast injected at a rate of 4–6 mL/s via a peripheral intravenous line. Axial CT data is used to create sagittal and coronal images, as well as a 3-dimensional image of the abdominal wall vasculature that can be rotated horizontally and vertically. The branching pattern of the deep inferior epigastric artery (DIEA) is determined as is its intramuscular course. Perforators are then examined as they arise from the DIEA and their position relative to the umbilicus is noted. Perforators as small as 0.3 mm can be visualized by CTA. The presence of the superficial inferior epigastric artery (SIEA) and associated veins are also noted to determine an SIEA flap is possible.

Rozen et al.[24] performed a study of 42 patients undergoing DIEP flap surgery in which they mapped all perforators >1 mm. CTA identified 280 major perforators in 42 patients with one false-positive and one false-negative, resulting in a sensitivity of 99.6% and positive predictive value of 99.6%. Casey et al.[25] performed a retrospective review of DIEP and SIEA breast reconstruction comparing operative times in 186 flaps performed with the assistance of handheld Doppler to 100 flaps performed subsequently with CTA. They found a statistically significant decrease in operative times in both unilateral and bilateral cases (370 vs 459 min, and 515 vs 657 min, respectively; both $p<0.01$). Smit et al.[26] performed a similar study and also found a shorter operative time associated with CTA compared to Doppler (264 vs 354 min, $p<0.001$). Tong et al.[27] reported a lower sensitivity of 79%, but also reported significantly shorter operative times and found that CTA changed the preoperative plan in 50% of cases by identifying the best perforator in unilateral cases or perforators with a long intramuscular course, causing them to select the contralateral side or utilize a muscle-sparing TRAM, rather than a DIEP flap for breast reconstruction.

USE IN DESIGNING OTHER FREE FLAPS

Garvey et al.[28] examined the accuracy of CTA in the detection of perforators for ALT free flaps. Among 16 flaps, CTA identified 40 out of 54 perforators identified intraoperatively, suggesting a sensitivity of 74%. The perforator location averaged 0.35 cm from the CTA-predicted position. The ability of CTA to predict perforator size was 67.5%. CTA was able to differentiate between septocutaneous and intramuscular perforators 77.5% of the time. As mentioned above, CTA is probably most useful in cases where the subcutaneous fat is ample, since the perforators can be visualized easily in the background of low-density fatty tissues. In individuals with thin thighs, ICG angiography or handheld Doppler may be more accurate and useful, at least in identifying perforator location.

In a separate study, Garvey et al.[29] examined the utility of CTA for examining cutaneous perforators in the fibula osteocutaneous free flap (Fig. 4.11). CTA identified 94.9% of cutaneous perforators found intraoperatively in a series of 40 patients. The perforators were located an average of 8.7 mm from their predicted locations. The slightly lower accuracy in predicting the spatial location of perforators may be because they are best seen between the lower leg muscles and not in the scant subcutaneous fat where they may take an oblique course toward the skin. The course of the perforators (intramuscular or septocutaneous) was discernable 93% of the time by CTA, however, the size could only be accurately predicted 66.7% of the time. In addition to being used for flap design, CTA may be of great benefit in verifying three-vessel flow to the lower extremity, particularly in patients with equivocal findings by history or physical exam, such as when the dorsalis pedis and posterior tibial arteries are not easily palpable (Fig. 4.12).

Ogata et al.[30] compared ICG angiography with the Photodynamic Eye to CTA. They found ICG angiography had an 84% positive predictive value and CTA 100% positive predictive value in a series of 50 patients undergoing a