Acoustic Doppler Sonography, Color Duplex Ultrasound, and Laser Doppler Flowmetry as Tools for Successful Autologous Breast Reconstruction

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• Laser Doppler flowmetry • Breast reconstruction

Predictable and reproducible success in the transfer of autogenous tissues from any donor site for breast reconstruction must begin in the preoperative planning stage. Milton challenged the dictums of his time in recognizing that the sine qua non for best ensuring viability of any flap depended on its "circulation."[1] The precise identification of direct or indirect perforators[2] nurturing the assortment of available cutaneous flaps for breast reconstruction for just this reason has assumed paramount importance, as proper flap design must ensure inclusion of that perforator. A giant step taken in that direction was by Taylor and colleagues,[3] who first used the still ubiquitous acoustic Doppler probe to identify "dominant" skin perforators, and then planned safe flaps of "unusual dimensions and directions," along an axis connecting those perforators. The Doppler effect so evoked remains tacitly understood from basic principles of physics. Named after the Austrian physicist Christian Doppler, who actually identified the concept in 1842, this phenomenon is the change in frequency of a wave for an observer moving relative to the source of the wave.[4] This key principle has become ingrained in plastic surgery routines, and has since been expanded to include other evolving technologies such as color duplex ultrasound and laser Doppler flowmetry.

ACOUSTIC DOPPLER SONOGRAPHY

The typical acoustic Doppler probe is virtually universally available in every operating room and at every nursing station (**Fig. 1**). This compact device is highly portable, simple to use, and usually easy to interpret.

Acoustic Doppler sonography emits sound waves that reflect on a moving object relative to a fixed observer, and has a distinct phase shift according to the Doppler effect.[5] In flaps, the red blood cells are basically the only moving objects that scatter the incident source. The frequency of the latter will be shifted by an amount proportional to the number and velocity of the moving red blood cells in the specific target region, which predominantly represents intravascular blood flow. This results in the familiar and characteristic audible pitch that we differentiate between arteries and veins.[6]

To increase the specificity for locating a skin perforator, which is necessary to ensure flap boundaries will be designed to include that perforator, Mun and Jeon[7] have suggested a "perforator compression test." Because perforators are thinner walled and more superficial than their source vessel, and their course is approximately perpendicular to the skin surface, "true" perforators will

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Fig. 1. Handheld acoustic Doppler ultrasound devices. Left, 5-MHz vascular probe (Medasonics, Newark, CA) used daily in our office practice; right, Ultrasonic Doppler Flow Detector with 8.9-MHz probe (Model 811-B, Parks Medical Electronics, Inc, Aloha, OR) native to our operating rooms and hospital floors.

be more easily compressed by an external force applied perpendicular to the skin surface. Thus, after finding a potential perforator with the audible Doppler probe, increased downward pressure will reduce and almost obliterate the original sound. Gradual release of the pressure will result in increasing loudness. Deeper or source vessels should have little change in sound intensity during such maneuvers.

As with any modality, there are limitations with acoustic Doppler sonography. The sensitivity may actually be too high (false positives), as often diminutive vessels inadequate to sustain a cutaneous flap can be found.[6] The specificity may be too low (false negatives), as vessels can be overlooked or missed because of background noise from larger vessels in the vicinity.[5] This latter characteristic also diminishes the capability of this device to allow accurate and consistent postoperative monitoring.

From a pragmatic standpoint, acoustic Doppler sonography has a short learning curve and will always be used by many, because it is readily available, as the sole technique for preoperative perforator identification,[8] or to corroborate the conclusions gleaned from other diagnostic modalities (**Fig. 2**). Because the probe can be sterilized, this is still the most practical means for intraoperative verification of perforators, as well as assessment of the location of recipient vessels.

COLOR DUPLEX ULTRASOUND

If a color spectrum is added to the moving component of conventional high-resolution, B-mode, gray-scale ultrasound, this combination of techniques is color duplex imaging.[9,10] The actual color observed on the monitor depends on the direction of flow in relation to the transducer used to perform the study. This can arbitrarily be assigned the color red or blue, with red usually chosen for the arteries and blue for the veins to simplify data interpretation, once each vessel type is identified correctly using the audible format included with most commercial machines.

Higher frequency transducers now permit scanning to superficial depths just below the skin level, with sensitivity to detect vessels with a diameter as small as 0.2 mm.[10,11] This so-called "power Doppler imaging"[11] is particularly relevant for investigations of perforators within the microcirculation, and was first used in plastic surgery for mapping of transverse rectus abdominis musculocutaneous (TRAM) flap perforators, usually then marked by coordinates centered about the umbilicus before breast reconstruction.[12,13] Fasciocutaneous perforators to deep inferior epigastric artery perforator (DIEAP) flaps, as well as other potential donor sites, have also been similarly localized.[6,9,14]

Depending on the orientation of the color duplex imaging transducer, the vessel orifice can be calibrated and peak systolic flow velocity determined from concomitant pulse-volume recordings; the take-off of perforators from the source vessel identified (**Fig. 3**); and the perforator intramuscular, subfascial, or epifascial course documented.[9,10,15]

Sensitivity in identifying perforators with color duplex imaging is high, but specificity is low, as only a small region can be examined at any time.[14,16] This equipment has limited availability, and usually a technician must be present to obtain consistent observations. Postoperative monitoring of buried DIEAP free flaps[15,17,18] has been reported, but the apparatus is just too awkward for routine continuous bedside or intraoperative monitoring (**Fig. 4**).