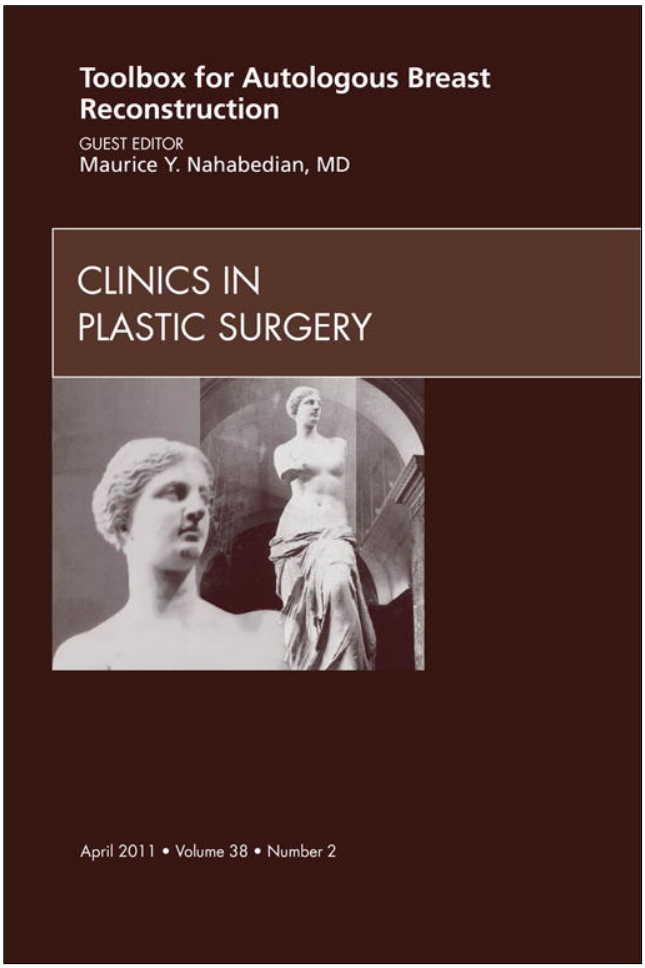

Maximizing the Use of the Handheld Doppler in Autologous Breast Reconstruction

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KEYWORDS

- Handheld Doppler • Autologous breast reconstruction
- Acoustic Doppler • Perforator flap breast reconstruction
- Flap monitoring

Over the past several decades, a variety of technological advancements have provided plastic surgeons with "tools" that have facilitated the ability to perform autologous reconstruction. The first tool was the acoustic Doppler ultrasound that was applied during the early years of flap reconstruction. Although surgeons had a general knowledge of the primary blood supply to a flap, little was known about the secondary vascularity, namely the perforators and other small vessels. The acoustic Doppler enabled surgeons to better understand the vascular anatomy relevant to a reconstructive procedure. Early studies were directed toward the donor sites to define perforator anatomy.[1,2] This information was useful for determining the cutaneous design and dimensions of a flap.

More recently, a number of technologically advanced devices have been introduced that have furthered our ability to define the vascular architecture. These include but are not limited to color duplex sonography, computerized tomographic angiography (CTA), magnetic resonance angiography (MRA), and fluorescent angiography.[2–8] Despite the benefits of these newer technologies, downsides related to cost, time, and interobserver variability have resulted in reluctance on the part of some surgeons to adopt these technologies. Instead, they have relied on classical techniques to define the vascular anatomy, such as the handheld acoustic Doppler. Although the acoustic Doppler does not provide the anatomic detail of these newer technologies, it still maintains a prominent role in soft tissue reconstruction and is very useful.

With the advent of perforator flap breast reconstruction, preoperative imaging and Doppler ultrasound technology has become increasingly important to better understand the vascular architecture. As a preoperative tool, the color duplex Doppler has been advocated.[9–11] Preoperative knowledge of the perforator anatomy can be important in the planning and design of flaps. The location and caliber of the perforators is variable for any given cutaneous surface. Benefits of Doppler sonography include real-time assessment, multiplanar capabilities, and evaluation of blood flow characteristics. The color duplex Doppler has been very effective in providing information regarding flow characteristics and directionality of flow.

The handheld acoustic Doppler is commonly used in the setting of autologous reconstruction. Like the color duplex Doppler, it can be used preoperatively but has the advantage of being used intraoperatively and postoperatively. It can be used as a sole modality or it can be used in conjunction with or to confirm the findings of CTA or MRA. This article focuses on the preoperative, intraoperative, and postoperative use of the handheld Doppler for free tissue transfer with an emphasis on perforator flap breast reconstruction.

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DOPPLER PHYSICS

Human hearing can detect frequencies ranging from 20 Hz to 20 KHz. “Ultra”sound operates at frequencies higher (>20 KHz) than the audible range. Systems typically used in medicine have ranges far exceeding this, usually in the 1 to 20 MHz range. In the most basic state, ultrasound detection uses short pulses of high-frequency sound emitted into the body. Combinations of reflection, absorption, and scatter of sound waves to varying tissues are received to form the signal. With the addition of the Doppler effect to ultrasonography, the frequency of the reflected sound can be used to determine the direction of blood flow. Changes in signal intensity provide valuable information with regard to blood flow. Typically, the unidirectional Doppler ultrasound works by these principles.

DOPPLER: TRANSITIONING FROM PREOPERATIVE TO INTRAOPERATIVE TOOL

The handheld Doppler unit (**Fig. 1**) has proven to be one of the most versatile and widely used devices in autologous and especially microvascular breast reconstruction. Commonly used as a postoperative tool for free flap monitoring, preoperative and intraoperative efficacy have also been demonstrated.[12–15] Preoperatively, it is sometimes used to localize perforator location on the cutaneous surface of the flap. Intraoperatively, it can be used to assist with perforator selection by discriminating between the various signal intensities. In the setting of abdominal or gluteal flap breast reconstruction, knowledge of perforator density and caliber can aid in faster and more effective flap elevation. Although some surgeons prefer the use of CTA, confirmation of the CTA data is almost always performed using a Doppler device. In a prior study using CTA for gluteal flap planning, it was demonstrated that there were an average of 11 perforators in the superior gluteal artery territory with a mean diameter of 0.6 mm. This was very similar to the comparative findings of Doppler ultrasound, as there were 9 perforators with a mean diameter of 0.4 mm.[16] The location of the CTA-documented perforators was confirmed using Doppler.[17]

Fig. 1. A standard handheld Doppler unit found throughout nursing units and operating rooms.

The Doppler systems have played a prominent role in the planning and harvest of abdominal flaps. At the skin level, the handheld Doppler can predict the deeper location of abdominal perforators before any dissection. The periumbilical region consistently provides most usable abdominal perforators.[18] Giunta and colleagues[11] evaluated using the handheld Doppler in 46 patients before undergoing breast reconstruction. They found an average of 3.6 perforators in one-sided deep inferior epigastric perforator (DIEP) flap and 3.6 perforators in the superior gluteal artery perforator (SGAP) flap with preoperative Doppler assessment. Interestingly, when the preoperative Doppler skin signals were compared with intraoperative findings, a high false-positive rate of 47.6% and a false-negative rate of 11.0% were demonstrated. In addition, it was found that there was only minor discrepancy between the locations of the skin signal in relation to the deep location of each perforator (average of 0.8 cm vertically and 0.8 cm horizontally). This emphasizes the importance of possibly predicting the location of each perforator to approximately 1 square centimeter. The perforator compression test can potentially decrease a high false-positive rate. By applying external pressure with the Doppler probe, true perforator signals will vanish, leaving deeper source vessels as the remaining signal. This test can help to determine the origin of the Doppler signal.[19]

Clinical studies using Doppler ultrasound have been previously reported. Blondeel and colleagues[10] incorporated Doppler ultrasound in preoperative evaluation for patients who were to undergo DIEP and SGAP reconstruction. Approximately 4.5 perforators were indentified for each side of the abdominal flap and an average of 2.6

perforators for each SGAP flap. As related to the intraoperative findings, Blondeel and colleagues[10] reported a true positive rate of 80.6% and a positive predictive value of 91.9%. These studies highlight the sensitivity, sometimes oversensitivity, of the handheld Doppler at identifying cutaneous vessels. This is an important observation because many perforators are visualized during the elevation of an abdominal flap, many of which are small and will be sacrificed because of suboptimal location or caliber.

The success and efficiency of perforator-based breast reconstruction relies on the surgeon's experience with choosing the correct perforator(s) and with the technical aspect of perforator dissection. The handheld Doppler can aid the surgeon in selecting the best perforator(s) to optimize flow and perfusion within a flap and minimize the incidence of fat or partial flap necrosis. The following sections will describe the technique of using the handheld Doppler in identifying and selecting reliable perforators.

HANDHELD DOPPLER IN PERFORATOR SELECTION

The sequence of events for Doppler use is important. With the patient on the operating room table and before making any incisions, the handheld Doppler can be used to identify or reconfirm the location of perforators. In the case of an abdominal perforator flap, the perforator locations are marked with ink based on the acoustic Doppler signals (**Figs. 2** and **3**). It is important to appreciate the signal intensity and ensure that it is biphasic. Prior studies have demonstrated that most suitable perforators are located in the periumbilical region.[1,2,8] The number of perforators identified at this stage is variable and will depend on the patient's body habitus and thickness of the adipocutaneous component of the abdominal wall. In general, however, approximately 3 to 4 perforators are marked.

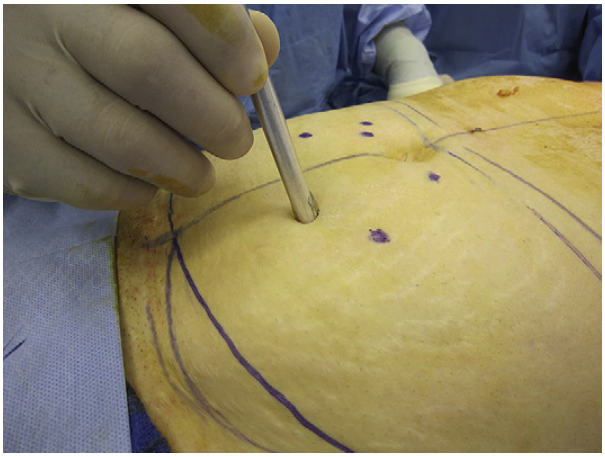

Fig. 3. Marking 3 to 4 strong intensity signals on each side is sufficient to begin the operation.

During abdominal flap elevation, dissection usually proceeds in a lateral to medial direction, preserving all relevant perforator bundles encountered (**Fig. 4**). However, in a bilateral reconstruction, proceeding from medial to lateral is also advised. Throughout the dissection, a variety of perforators will be observed, some of which are small (<1 mm) and others larger (>1 mm). Smaller perforators without a palpable pulse lateral to the linea semilunaris are cauterized or clipped. Once the medial and lateral borders of the rectus abdominis are identified, the perforators are preserved and circumferentially dissected when possible. Typically, the goal is to select a perforator with a diameter of at least 1.5 mm; however, in some situations, a dominant perforator may not be evident and this may change the operative plan.

Fig. 2. Marking the location of perforators before surgery. Markings are made starting at the umbilicus and then moving away.

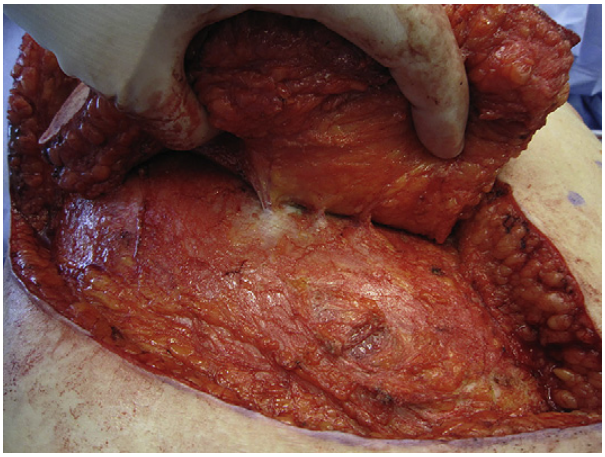

Fig. 4. After moving from lateral to medial, a series of perforator bundles are isolated.

Fig. 5. A Doppler signal is obtained for each perforator and the intensity of each is compared.

The decisions as to whether a perforator flap or muscle-sparing flap will be performed are made at this juncture. The acoustic Doppler is especially useful at this time and can assist in making these decisions (**Fig. 5**). As the dissection proceeds along the anterior rectus sheath and larger dominant perforators are not visualized, an island of small perforators is created. Typically, the dimensions of this island range from 2 to 3 cm in width and 3 to 5 cm in length. The Doppler is used to confirm flow along the periphery of the fascial island. Typically, 3 to 5 small perforators are included. This island is usually within the middle third of the rectus abdominis muscle and thus an MS-2 free transverse rectus abdominus myocutaneous (TRAM) flap procedure is performed. Occasionally, the fascial island is along the medial or lateral segments of the muscle and an MS-1 free TRAM flap procedure is performed.

The method by which the probe is applied to the perforator(s) is important. It is directed perpendicular to each perforator being assessed. The probe is advanced along the length of the perforator, paying close attention to the signal quality. The presence of a biphasic arterial and monophasic venous signal are critical. Occasionally, a signal will be obtained that is monophasic or biphasic only. Selecting a perforator that is only venous or only arterial is obviously not advised when the goal is to perform a perforator flap.

Another important aspect of Doppler-related perforator selection is that perforators of different calibers will have different signal intensities. Some perforators will have a very robust signal and appear to be ideal, whereas others may have weak signal intensity. Generally speaking, larger perforators will be more robust, although small perforators can at times have very strong signal strength. It is important to assess signal strength and caliber when making decisions about perforator selection.

SEQUENTIAL CLAMPING TECHNIQUE

In situations where several usable perforators are isolated, the Doppler can be very useful in deciding which to select. The technique of selective occlusion of the perforator in conjunction with Doppler signals and flap characteristics has demonstrated benefit. After isolating usable perforators, vascular clamps can be placed on the perforators, leaving an isolated perforator to test for adequate flap perfusion (**Fig. 6**). The Doppler is applied to the remaining perforator to assess signal strength. It is also applied to the cutaneous surface to ensure that the location is appropriate. It is recommended to observe the flap for a few minutes to ensure that there are no color changes on the cutaneous surface. Color changes are interpreted as hyperemia, venous insufficiency, or arterial insufficiency. If arterial or venous insufficiency is evident, alternative perforators are selected. However, this may also be a sign that more than one perforator is necessary or that a muscle-sparing free TRAM flap may be indicated. Other factors that are important when making these decisions include the dimensions of the flap, the thickness of the flap, and the location of the

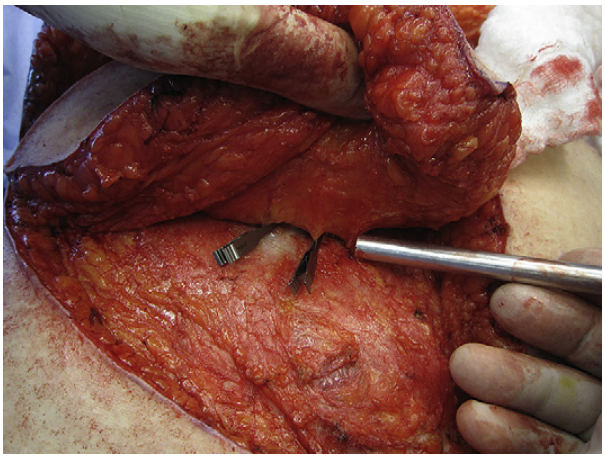

Fig. 6. All but one of the perforators are clamped with vascular clamps allowing the surgeon to determine if the perforator will support the entire flap. This test is coupled with evaluation of the skin paddle to determine if perfusion is adequate.

perforator relative to the flap dimensions. Once the flap has been harvested and the primary vascular pedicle has been defined, it is useful to use the acoustic Doppler along the length of the inferior epigastric and perforator vessels to ensure good flow based on the signal intensity and quality.

In addition to the utility of the handheld Doppler for the planning and execution of abdominally based flaps, it has been very useful for gluteal perforator flaps. Gluteal flaps differ from abdominal flaps in many ways but most notably in the perforator characteristics. Gluteal perforators are usually smaller and shorter than their abdominal counterparts. Thus, preoperative localization is critical to optimize one's success.

With the patient in the prone position, the handheld Doppler is used to identify the location of the perforators in the buttocks. This is an important preoperative maneuver because the delineation of the flap will depend on perforator location. In contrast to abdominal flaps, where it is desirable to have the perforator centrally located, with gluteal flaps, it is desirable to select a perforator that is peripherally located. The reasons for this relate to short length of the perforator and the technical advantage this confers when positioning the flap on the chest wall in preparation for the microvascular anastomosis. Although perforators are located on the medial and lateral buttock, the selection of a lateral perforator is preferred to provide slightly more perforator length. During the elevation of the flap, the Doppler is used much like previously described. Because of the tremendous branching patterns associated with the gluteal vessels, the combination of sequential clamping of branch points and Doppler ultrasound can facilitate selecting a perforator that will provide optimal length and caliber.

TIPS FOR POSTOPERATIVE MONITORING

Bedside clinical monitoring following flap reconstruction has proven successful for most reconstructive surgeons. False-positive take-back rates following standard monitoring are low. Despite this, newer, more innovative monitoring tools using microdialysis,[20] laser Doppler,[21] near-infrared spectroscopy,[22,23] and possibly glucose monitoring[24] have been developed to improve outcomes following flap reconstruction. Most of these newer technologies are expensive and there is a learning curve associated with use, leading most surgeons to rely on the handheld Doppler and clinical examination for postoperative monitoring.

When used for monitoring flaps postoperatively, it is important for all ancillary staff to appreciate the arterial and venous signal. Common practice is to delineate the precise location of this signal in the operating room and mark it with a superficial suture. It is important to realize that following a microvascular anastomosis it usually requires 45 to 60 minutes for the flap to equilibrate in terms of perfusion. Thus, a strong Doppler signal may not be evident initially on the cutaneous surface. Figus and colleagues[25] found statistically significant increases in flow within 1 hour after transfer. When on the monitoring unit, the nursing staff members are able to use this landmark for frequent flap evaluations. It is important to combine the ultrasound findings with clinical examination evaluating flap color, capillary refill, temperature, and turgor. In addition, venous augmentation maneuvers can be used to ensure adequate flap drainage. This is easily appreciated using the handheld Doppler by pressing on the flap at a point remote from the Doppler signal.

Implantable acoustic Doppler devices have gained popularity in free-flap reconstruction, especially head and neck reconstruction where buried free flaps are common.[26,27] In the setting of microvascular breast reconstruction, an implantable Doppler has been used by placing a fiberlike Doppler probe along the vascular anastomosis. This is a useful adjunct, especially in the patient following nipple-sparing mastectomy where there may be no cutaneous portion of the flap to visually monitor. These probes can be heard continuously or intermittently based on the degree of suspicion. Once the critical period of flap monitoring is complete, the probe is pulled out or cut at the level of the skin.

SUMMARY

The handheld Doppler has been classically used in all aspects of flap reconstruction. Although studies have shown that the Doppler may not provide the same anatomic detail as the other newer modalities such as CTA and MRA, the handheld Doppler remains a very useful and important tool for autologous reconstruction. In the preoperative setting, color duplex Doppler sonography is useful for identifying perforator location and caliber. Intraoperatively, the handheld Doppler is useful for assessing flow characteristics of the various perforators and to assist in selecting the most dominant or ideal perforator for a desired cutaneous territory. In the postoperative setting, the handheld Doppler is an excellent adjunct to the clinical examination and can reliably evaluate flap perfusion following reconstruction. When used thoughtfully and diligently, the handheld Doppler can be all that is

needed to accurately and safely perform breast reconstruction.

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