Postoperative Free-Flap Monitoring Techniques

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Abstract

Keywords

- free flap
- postoperative monitoring
- microvascular reconstruction

Free tissue transfer is commonly employed in the reconstruction of large or complicated defects. Postoperative flap failure from microvascular compromise is an uncommon but major potential complication of this procedure. As such, many postoperative monitoring techniques devices have been developed. This paper provides an overview of the wide variety of options available for surgeons today.

Free flaps have become a mainstay for tissue reconstruction in many types of oncological surgery. Free flaps are versatile by virtue of their ability to provide a variety of tissue types, including skin, muscle, and bone, and to allow reconstruction of sizeable tissue deficits, which preclude the use of grafting or local flaps. The defining feature of a free flap is the transfer of tissue, as well as the supplying blood vessels, also termed the vascular pedicle, from one anatomical site to another. The technique requires the creation of microvascular anastomoses between donor and recipient vessels. The flap, therefore, is dependent on blood supply through the pedicle, at least until sufficient time has passed for neovascularization to occur. Sufficient neovascularization to allow free-flap survival independent of the vascular pedicle has been reported to occur within 7 to 10 days.^{1–3}

Given the early dependence of free flaps on blood supply through the anastomosed vascular pedicle, close monitoring for signs of vascular compromise has become a mainstay in the postoperative care of free flaps. Vascular compromise may occur as a result of venous thrombosis, arterial insufficiency, hematoma, or wound dehiscence; of these, venous compromise is the most common cause of flap failure.^{4–7} Rates of free-flap failure due to vascular compromise in the early postoperative period range from 2 to 5% in several large case series.^{8–10} With frequent monitoring, however, flap

salvage rates following early reoperation for vascular compromise range from 30 to more than 70%.^{5,11–13} The majority of vascular compromise occurs in the first 24 hours postoperatively, and salvage rates are higher with early compared with delayed reoperation.^{5,14,15}

Resultantly, frequent postoperative free-flap monitoring is a standard of care. Clinical monitoring by physical examination is the most commonly employed technique.^{16,17} However, a variety of invasive and noninvasive methods have been proposed for the routine postoperative monitoring of free flaps (► **Table 1**). Aside from clinical assessment, though, no single method has been universally adopted. Each of these methods differs in terms of their ease of use, invasiveness, sensitivity, and cost. What, then, makes an ideal flap monitoring system? According to Chao,

“The ideal monitoring method should be accurate, continuous, harmless to both the patient and the flap, inexpensive, instantaneous, non-invasive, objective, recordable, reliable, reproducible, sensitive, and simple to interpret.”¹⁸

The aim of this paper will be to review available free-flap monitoring techniques, specifically with regard to their relative efficacy, costs, and feasibility.

Table 1 Summary of invasive and noninvasive free flap monitoring techniques

Noninvasive	Invasive (includes anything requiring injection)
Clinical assessment (gold standard)	Implantable Doppler/venous coupler
Acoustic cutaneous Doppler	Oxygen tension monitoring
Color Doppler sonography	Tissue pH monitoring
Laser Doppler flowmetry	Microdialysis
Microlight-guided spectrophotometry	Technetium-99m sestamibi scintigraphy
Surface temperature monitoring	Contrast-enhanced Doppler
Tissue oximetry	Biochemical markers from free-flap blood (e.g., glucose, lactate)
	Fluorescence imaging
	Perfusion-weighted MRI

Abbreviation: MRI, magnetic resonance imaging.

Clinical Monitoring

In an era of advanced flap monitoring techniques, recent surveys of microvascular surgeons have revealed that clinical flap checks still remain the most commonly used postoperative monitoring technique.^{16,17} Clinical monitoring can consist of any combination of assessments of flap skin color, surface temperature, rate of bleeding with pinprick or scratch, capillary refill time, and acoustic cutaneous Doppler to detect intravascular arterial and venous blood flow. Given the importance of color in the clinical assessment of flaps, the light source used to inspect the flap is also important as different hues of light may change the appearance of the flap. For this reason, Van Genechten et al have used high color-rendering index, LED light sources.¹⁹ For buried flaps in which pedicle lies superficially, acoustic Doppler assessment may be a reliable means of assessing perfusion. The frequency of clinical monitoring in the early postoperative period varies between centers, but clinical flap checks are commonly done every 2 to 4 hours for the first 2 to 3 days postoperatively. Such high frequencies of monitoring prompt many surgeons to admit patients undergoing free-flap reconstruction to either an intensive care unit or intermediate-level-care/step-down ward for the initial postoperative days to facilitate high-level nursing availability.²⁰ In many centers, early postoperative clinical flap checks are performed by both residents and nurses. Clinical flap monitoring is noninvasive, with no associated risks or discomfort for the patient. The effectiveness of clinical monitoring is high: one meta-analysis found flap success rates with clinical assessment alone to range from 85 to 95%.²¹ Being the

most rudimentary form of flap monitoring, the cost of clinical assessment is the least of the flap monitoring techniques. The majority of components of the assessment (including skin color, temperature, capillary refill assessment) require no additional equipment, and the cost of needles for pinprick assessment and other equipment such as tongue depressors for the assessment of oral cavity flaps can be assumed to be negligible. The cost of handheld acoustic Doppler probes may be in the range of \$1,300; however, these probes are reusable, making the cost per patient also essentially negligible. Clinical flap assessment, therefore, remains an inexpensive, risk-free, and relatively efficient method of postoperative free-flap monitoring.

Color Duplex Ultrasonography

An alternative noninvasive method to free flap monitoring is the use of color duplex ultrasonography. This technique uses ultrasound technology to visualize flow through anastomosed vessels through a handheld probe and viewing monitor. Intravascular flow can be assessed audibly through a Doppler signal, similar to the handheld acoustic Doppler, or visually by assigning different colors to different flow velocities. Similar to handheld acoustic Doppler, color duplex ultrasonography is noninvasive and can be useful in the assessment of buried flaps. The technique is more resource intensive as a result of the required equipment, for which costs have been quoted as ranging from US\$30,000 to US\$225,000,²² and the requirement for an ultrasound technician, radiologist, and the microvascular surgeon to each be present to perform and interpret the examination. This relative resource-intensity limits serial use of the technique as a sole method of flap monitoring throughout the postoperative period, and as a result, it is most often used an adjunct to other monitoring techniques. Schön et al, Sekido et al, and Vakharia et al report the use of color duplex ultrasound as a confirmatory test in conjunction with clinical examination for a variety of free flaps including buried flaps. These case series found that color duplex was able to either confirm clinical suspicions of reduced intravascular flow, leading to prompt return to the operating room for flap salvage, or, alternatively, to demonstrate sustained flow in cases of suspected flap compromise, preventing reoperation or wound exploration for buried flaps.^{22–24} Khalid et al reported the use of the technique for the assessment of a series of flaps on postoperative days 1, 3, and 7. They found that alterations in intravascular flow were detectable by color duplex ultrasound as early as postoperative day 3; however, none of these flaps which were taken back to the operating room were salvageable.²⁵ These studies suggest that the inability of color ultrasonography to detect early vascular compromise may preclude its use as a sole free-flap monitoring technique, but rather that it may be successfully employed as an adjunct to other methods of flap monitoring to confirm suspected flap compromise.

Implantable Doppler

The use of an implantable Doppler probe as a method for free-flap monitoring was first described in 1988 by Swartz; the device is commonly referred to as a Cook–Swartz

Doppler.²⁶ The device consists of a piezoelectric crystal mounted on a silicon cuff that is wrapped around the anastomosed blood vessel—either artery, vein, or both—with wires extending to the surgical wound where they are connected to the equivalent of a cutaneous acoustic Doppler. By this means, the implantable Doppler provides continuous information about intravascular flow through the anastomosed vessel(s). Vascular compromise can therefore be detected instantaneously, allowing, in theory, a more prompt return to the operating room and better chances at flap salvage. The implantable Doppler is widely used, and several large case series as well as case-control studies have investigated free-flap outcomes with the use of the device. Schmulder et al evaluated a series of 259 free flaps which were monitored with the implantable Doppler and compared clinical outcomes to flaps monitored clinically. They found a significant difference in mean times to detection of flap compromise, success of operative reexploration for compromised flaps, and overall flap success rates when comparing the implantable Doppler to clinical monitoring. When their results were broken down by subspecialty area, though, they found that these results mainly held true for head and neck free flaps, with smaller differences in outcomes for free flaps in other specialties (e.g., breast, orthopedic oncology, trauma, etc.), which often no longer reached statistical significance.²⁷ Rozen et al also found nonsignificant increases in flap survival and salvage rates using the implantable Doppler compared with clinical examination in a series of 547 breast reconstruction free flaps.²⁸ A recent systematic review that pooled data from these as well as three other studies comparing the implantable Doppler to clinical monitoring—for head and neck, breast, and extremity reconstruction—found that overall, the implantable Doppler was associated with significantly greater flap salvage rates and overall flap success rates.²¹ However, this meta-analysis also reported an 8 to 17% false-positive rate associated with the use of the implantable Doppler. Other smaller case series have reported even higher false-positive rates due to probe malfunction or malpositioning, which resulted in unnecessary reoperation.^{29,30} In addition to the increased incidence of false-positive examinations, the implantable Doppler is more costly than clinical monitoring, with an estimated cost of US \$300 per implantable probe.³¹ Implantation of the device may be considered minimally invasive. The advantages in efficacy afforded by the implantable Doppler must therefore be weighed against the device's cost and potential for device failure, which can lead to unnecessary reoperation.

Other Options

While few have become commonly adopted practices, a wide variety of monitoring techniques (primarily targeted at the assessment of the microvasculature) have been described including fluorescent dye angiography, infrared analysis, and tissue oximetry.

Fluorescein angiography was first described in 1977 to evaluate the viability of arterialized flaps after harvest.³²

Newer trials have employed indocyanine green (ICG) dye instead of fluorescein, stating its low side-effect profile and lack of vascular extravasation (compared with fluorescein which does not remain strictly intravascular). In a 2013 pilot study, Betz et al demonstrated the feasibility of ICG angiography in concert with endoscopic infrared analysis of flaps.³³ While this group did not make any clinical decisions based on the ICG angiography data in this trial, several subsequent trials have reported some clinical benefit. A Chinese study found that a change in surgical management of patients undergoing intraoperative ICG angiography occurred in 5/14 patients (e.g., additional anastomosis, debridement of distal flaps),³⁴ whereas a second study found significantly lower rates of partial flap loss in select patients.³⁵

Smaller studies (with limited follow-up investigation) have also investigated continuous tissue perfusion monitoring that display photoplethysmograph waveforms on a bedside monitor,³⁶ technetium-99m sestamibi scintigraphy,³⁷ perfusion-weighted magnetic resonance imaging (MRI),³⁸ and serial measurement of the flap's capillary glucose and lactate levels.³⁹

While many of these potential options have relatively low cost and side-effect profiles, all of them require additional investigation (larger trials, randomized head-to-head comparisons, and cost analyses) to determine whether or not they truly provide any additional benefit over the traditional monitoring techniques discussed previously.

Conclusion

Close postoperative free-flap monitoring is vital, as early detection of vascular compromise is a critical first step in salvaging a failing flap. A wide variety of monitoring options exist, ranging from simple clinical observation with external acoustic Doppler examination to complex and expensive interventions.

Given the low failure rates of free flaps in the modern era, as well as the excellent reliability of clinical monitoring, it can be challenging to prove that these monitoring adjuncts result in significantly better patient outcomes. That said, clinical monitoring is often a subjective process, and there are benefits beyond flap survival. Objective methods of free-flap evaluation may help to reduce the need for frequent physician evaluation of the flap, which is of value not only in private institutions but also in university settings where resident work hours are constantly under scrutiny in recent times.

Clinical monitoring remains the gold standard method of postoperative free-flap evaluation. Other adjuncts can prove useful to the surgeon and allied health team, but no definite consensus exists regarding their proper use. As with many postoperative regimens, free-flap monitoring techniques are surgeon-dependent and can vary significantly from institution to institution.

Conflict of Interest
None declared.

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