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Leading article

Postoperative monitoring of microsurgical free-tissue transfers for head and neck reconstruction: a systematic review of current techniques—Part II. Invasive techniques

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Abstract

A systematic review of the literature relating to methods of monitoring viability of microvascular free-tissue transfers in the head and neck region was conducted. The aim of this review is to identify the best method of monitoring that would allow timely salvage of potentially failing free flaps. An analysis and description of the various studied techniques is also given. In this second part, invasive modalities are covered.
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Introduction

Free-tissue transfer is an accepted part of the armamentarium of reconstructive surgeons with quoted success rates greater than 95%.[1–3]

The success of free-tissue transfer is dependent on the continuous arterial inflow and venous outflow through patent microvascular anastomoses until neovascularization is established by peripheral ingrowth of vessels. How long this takes has never been defined, but experimentally at least 8 days must elapse before the vascular pedicle of a free flap can be safely divided.[4]

If the compromised circulation of a free flap cannot be re-established within 8–12 h, salvage of such free-tissue transfer may be impossible because of the "no-reflow" phenomenon.[5]

It is therefore essential that detection of vascular compromise is made as early as possible to maximise the chance of salvage.

The second part of this review covers the existing literature relating to invasive modes of postoperative monitoring of free-tissue transfers used for head and neck reconstruction.

Invasive techniques

Implantable Doppler monitoring (using high-frequency pulsed ultrasound)

Unlike a conventional low-frequency ultrasonic Doppler probe, which consists of two separate crystals, one for transmitting and one for receiving, the high-frequency pulsed ultrasonic Doppler consists of a single piezoelectric crystal, which functions as a receiver in the time interval between emitting alternate pulses of ultrasound.

Swartz et al. used a small amount of silicone to secure a 1.0-mm Doppler probe to a cuff of Gore-Tex, wrapped the cuff around the flap vessel, and secured the Gore-Tex in place by suturing it to itself. They demonstrated in a series of animal

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experiments that a probe implanted in this way will provide real-time monitoring of flap blood flow.[6] A probe implanted around a flap artery will detect the cessation of arterial flow immediately; however, an arterial Doppler signal will persist for several hours after venous thrombosis.

A probe implanted around the outflow vein of a flap will detect cessation of venous flow almost immediately; furthermore, interruption of arterial flow will cause a near-immediate loss of the venous Doppler signal.

Swartz subsequently reported a series of 133 patients over a 4-year period who had free-tissue transfers monitored by the implantable 20-mHz ultrasonic Doppler device: 30 arterial and 103 venous. The arterial monitors detected vascular thromboses in four of six patients, with three flaps salvaged. Venous Doppler monitors detected 16 of 16 thromboses, with 12 flaps salvaged. Six patients had probe/machine malfunctions during their postoperative course and were monitored by clinical means thereafter without thrombosis. He concluded that the 20-mHz ultrasonic Doppler device is an effective monitor of blood flow in microvascular anastomoses.[7] When the monitor is placed on the vein, a greater degree of sensitivity is demonstrated, particularly to venous obstruction, compared with probes monitoring arterial flow.

Another more recent study provided retrospective data on 260 anastomoses monitored using implantable Doppler in a single institution. A 20-MHz implantable Doppler probe was used to assess 118 arterial and 142 venous microanastamoses, in both buried and non-buried transfers, both intra- and postoperatively.[8] In this study the free flap success rate was 99%, the re-exploration rate was 8%, and the salvage rate was 83%.

The Cook venous Doppler monitoring system

The Cook venous Doppler monitoring system (Cook Vascular Inc., Philadelphia) has been developed commercially as a technique for monitoring venous flow in free-tissue transfers, based on the initial technique described by Swartz et al.

It consists of an implantable probe with a removable, 20-MHz ultrasonic Doppler crystal and a suturable cuff to secure it around the vessel adventitia of the venous pedicle, and a battery operated or line powered portable monitor.

The cuff consists of a small 8 mm × 5 mm thin silicone sheet which is wrapped around the vessel and the overlying ends either sutured or clipped. This probe's proximal end exits as a thin wire through the wound and is connected to an intermediate extension cable that is sutured to the patient through the use of specially designed retention tabs. The intermediate cable plugs into a transportable monitor at the patient bedside, which is battery or mains operated. The electrode slides free from the cuff when pulled externally at 5–10 days post-operatively depending on the length of monitoring required. The electrode is designed to separate from the cuff, when a tension of 50 g is applied. By 5 days the cuff is sufficiently adherent to the vessel and the vessel adherent to the surrounding tissue to allow safe traction and removal of the electrode.

The probe allows direct vessel monitoring of a microvascular anastomosis at a specific site along a designated vessel. Likewise, it is possible to listen to the signal in the donor vessels whilst selecting a vessel for anastomosis. It is also possible to use multiple probes if several venous anastomoses are carried out.

Mistry et al. reported a retrospective review of their first experience in the use of the Cook venous Doppler probe in four patients undergoing buried free-tissue transfers.[9]

In two patients a small skin monitor flap was also used to allow clinical correlation with implantable Doppler signals. They reported that all the study surgeons found the technical aspects of inserting and securing the probe to be simple. All flaps were viable at 1 week at the time of probe wire removal. This retrospective series presents level 4 evidence from a relatively small group of patients. As this was the author's first experience with this system, it provides limited evidence of feasibility and safety of the technique in a new setting.

Oliver et al. prospectively analysed their use of the Cook implantable venous Doppler probe for monitoring 24 free-tissue transfers over a 9-month period. They concluded that the system was reliable and clinically useful, but recommended it as an adjunct to conventional clinical monitoring.[10]

Contrast-enhanced Doppler

Current approaches to contrast-enhanced ultrasound imaging may be grouped into three classes.[11,12]

Harmonic imaging uses radio-frequency filtering on a single echo to separate non-linear microbubble echoes from the linear echoes from tissue.

Power Doppler imaging uses pulse-to-pulse decorrelation in agent echoes caused by microbubble disruption to distinguish between agent and tissue using Doppler frequency processing.

A third class of technique, termed pulse inversion Doppler, detects both non-linear scattering and agent decorrelation using Doppler frequency processing.

Microbubbles act as echo-enhancers by the same mechanism as that determining echo-scattering in all the other types of diagnostic ultrasound (US), namely that the backscatter echo intensity is proportional to the change in acoustic impedance between the blood and the gas making the bubbles.

Of note is the finding that the resonance frequency of microbubbles 1–7 μm in diameter lies within the 2–15 MHz range, i.e. the US frequency used for clinical diagnosis.

In the context of microvascular imaging, it is fundamental to know the difference between the current echo-enhancers and the ionic agents used for contrast radiography and magnetic resonance imaging (MRI), namely that the 1–7 μm microbubbles do not diffuse across the endothelium and thus there is no interstitial enhancement following their administration. Therefore they are purely blood pool markers, or markers of any other body space into which they have been

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