Technical Note

Flap and Replant Monitoring

Introduction

Continuous monitoring of the circulation in flaps and replants is critical for microsurgical success. To prevent ischemia that can lead to partial or complete tissue loss, perfusion changes must be recognized and treated quickly. Throughout the course of a microsurgical procedure, clinical evaluation by an experienced microsurgeon is considered the gold standard for perfusion assessment. Although clinical observation is effective and requires no specialized equipment, it depends on the clinical acumen and experience of the evaluator and even with the most experienced observer, it is subjective, imprecise and can be misleading. A number of monitoring modalities are now used during microsurgery to augment this clinical impression. They should be objective, reliable, accurate, simple to operative, continuous and inexpensive. An overview of various monitoring modalities and their use during microsurgery follows.

Pre-operative Assessment

Computed Tomography Angiography

Computed tomography angiography (CTA or CT Angiography) is a technique used to visualize flow within arterial and venous vessels throughout the body. This ranges from arteries serving the brain to those bringing blood to the lungs, kidneys, arms and legs. CT combines the use of x-rays with computerized analysis of the images. Beams of x-rays are passed from a rotating device through the area of interest in the patient's body from several different angles to obtain projection images, which are then assembled by computer into a three-dimensional picture of the area being studied. CTA has proved invaluable for preoperative planning of microvascular procedures by accurately predicting vascular anatomy.

Intraoperative Assessment

Transit-Time Ultrasound Volume Flow

Although surgeons are constantly relying on their subjective clinical evaluations to assess the quality of their anastomoses, intraoperative transit-time ultrasound flowmetry now gives the reconstructive microvascular surgeon direct (real-time), quantitative measurements of pulsatile and average volume flow into and out of a pedicle. This on-the-spot measurement informs the surgeon about the quality of the anastomosis, resistance in the system and its functioning outflow. Measurements either confirm the surgeon's clinical impression or refute it prompting additional exploration. Used with an acoustic couplant, Transonic's non-constrictive Flowprobes do not constrict or require any direct contact with the vessel (Fig. 1).

Fig. 1: Transonic® non-constrictive perivascular volume flowprobes use wide beam illumination as two transducers pass ultrasonic signals back and forth, alternately intersecting the flow in upstream and downstream directions. By deriving an accurate measure of the "transit time" it takes for the ultrasound waves to travel from one transducer to the other and calcuating the difference between the integrated transit times, volume flow, not velocity is measured.

transonic
THE MEASURE OF BETTER RESULTS.

Flap and Replant Monitoring Cont.

Intraoperative Assessment cont.

Laser-assisted Indocyanine Green Dye (ICG) Video Angiography

ICG is used as a fluorescent marker to assess tissue and organ perfusion during reconstructive microvascular surgery. Administered intravenously, ICG binds tightly to plasma proteins and is removed from circulation by the liver via bile. The light needed for the excitation of the fluorescence is generated by a near infrared light source attached to a camera. A digital video camera allows the absorption of the ICG fluorescence to be recorded in real time, which means that perfusion can be assessed and documented. Laser-assisted indocyanine green dye fluorescent angiography provides real-time, objective information about organ perfusion and has been shown to be sensitive in predicting tissue necrosis. Although the dye has a short (3 to 4 minute) half-life, multiple visualizations require multiple injection of the dye. ICG as an indicator can only assess vessels directly visible to the surgeon through the operating microscope field. Therefore, obscure vessels or hidden perforators are not readily identified.

Post-operative Assessment

Microvascular Doppler Sonography

Microvascular Doppler uses a pen-tip sensor applied against the wall of a vessel exposed during surgery or to the skin post-surgery to hear how fast the blood is moving. The technology is operator dependent and measures velocity, not volume flow. As shown in Fig. 2, it is difficult to differentiate the degree of stenosis between robust and poor flow in a non-occlusive vessel compromise. Grade I stenosis exhibits the same flow velocity as Grade V. The velocities in a Grade II stenosis are similar to the velocities in Grade IV. Doppler measurements are qualitative, not quantitative and all flaps and replanted parts do not have have Doppler signals that can be obtained, limiting the Doppler sonography use to a subset of patients.

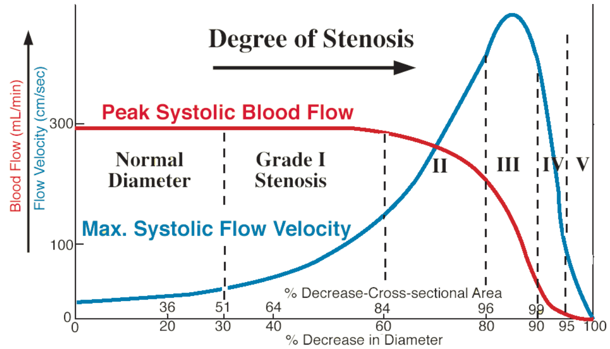

Fig. 2: Graph demonstrates that volume flow will decrease during a Grade II & III stenosis (75% occlusion), as flow velocity is spiking before dropping during a Graft IV stenosis (90% occlusion). (Adapted from Spencer P, Reid, JM, "Quantification of Carotid Stenosis with Continuous-Wave (C-W) Doppler Ultrasound," Stroke 1979; 10(3) 326-330.)

Pulse Oximetry

Pulse oximetry continuously monitors both oxygen saturation and pulse by detecting differences between wavelengths of light absorbed by reduced and oxygenated hemoglobin. The device also records the pulsations of the vascular bed. This system, is used widely in hospitals, is reliable, simple to apply, and does not require a sophisticated observer. If a pulse is absent as in an arterial occlusion, or oxygen saturation is decreased as in venous occlusion, an alarm sounds. The monitored tissue, however, must be of the correct shape to allow placement of the probe, which was designed to be placed on digits. It cannot be used in flaps and the probe itself obstructs the clinical assessment of replanted parts.

Flap and Replant Monitoring Cont.

Post-operative Assessment cont.

Transcutaneous Tissue Oximetry

Transcutaneous oximetry is a non-invasive measure of the amount of oxygen in certain body tissues. Wound healing depends on adequate tissue perfusion, the test is useful in determining post-op tissue perfusion after reconstructive microvascular surgery. A number of sites can be selected for transcutaneous oxygen measurements. A control site is chosen along with other sites around the edge of a wound. During the test, a special sensor with an adhesive ring that ensures that no oxygen from the surrounding air leaks into the sensor membrane, is placed on the skin. The temperature in the ring is slightly raised to allow oxygen to pass through a gas permeable membrane to a cathode that triggers an electrochemical reaction resulting in an electrical current. The amount of current indicates the amount of oxygen reaching the skin.

Transcutaneous oximetry was first developed for use in neonatal intensive care units to obtain data about oxygen levels in ill newborns who cannot withstand repeated blood drawings. It is particularly useful for diabetics, whose blood vessels are sometimes hard to compress, making blood pressure readings unreliable.

Implantable Doppler

An implantable Doppler probe, placed on the draining vein of the free flap, monitors venous flow post-operatively. Flow loss may represent venous or arterial clotting in the microcirculation of the flap. This modality has been found to be highly reliable with several attractive qualities. A 1998 study by Kind, Buntic and Buncke et. al. reported that the implantable Doppler probe was able to salvage 100% of flaps that were failing due to clotting at an anastomotic site. Drawbacks include possible tethering of the probe wire causing venous kinking, disruption of the anastomosis due to the force required to remove the device, difficulty/inability to use in small veins and the qualitative nature of interpreting the signal.

Quantitative Fluorometry

Quantitative fluorometry is used to monitor replanted parts and tissue transfers with cutaneous components or skin islands. The readings are obtained by nurses. Baseline skin readings are obtained from the monitored tissue and a control area. Repeated readings are obtained 10 and 60 minutes after injection of 0.5 to 1.0 mg/kg of fluorescein intravenously. Absence of a rise in fluorescence at 10 minutes indicates arterial occlusion. Absence of a fall in fluorescence at 60 minutes indicates venous obstruction. Determinations are made every 2 hours in the early postoperative period. Fluorometry often detects vascular complications before physical examination.

Arteriography

Arteriography can demonstrate the patency of vascular anastomoses, but is limited as a postoperative monitoring technique because its use in the very small microsurgical vessels is difficult and visualization is poor. It is invasive, requires a large team and exposes the patient to contrast dyes.

Flap and Replant Monitoring Cont.

Post-operative Assessment cont.

Near Infra Red Spectroscopy

Like pulse oximetry, near infra red spectroscopy detects the reflected spectra of oxygenated and deoxygenated hemoglobin in the microcirculation of the skin. The skin is illuminated by the photometer's fiberoptic light and the reflected light is analyzed by a photodiode. Oxygenated hemoglobin has two peaks in its extinction spectra. With deoxygenation, the peaks decrease in amplitude and begin to merge. A microprocessor calculates oxygen saturation based on the difference in the distance between the peaks. In practice the device numbers widely vary and are difficult to correlate clinically. The probe and fiber optic attachment are quite stiff and obstruct replanted parts if used continuously.

Temperature Monitoring

Cutaneous temperature monitoring measures skin temperature as an indicator of perfusion of the monitored tissue and has been used in many experimental and clinical settings. With adequate perfusion, the monitored tissue surface temperature should be constant and within a few degrees of a well perfused control area. Changes in core temperature and in ambient temperature and heat retention by dressings cause spurious readings, negating the value of the technique.

Laser Doppler

Laser Doppler measures capillary tissue perfusion by calculating changes in the wave length of laser light reflected off moving red cells in dermal capillaries to surface probes affixed to the skin. It cannot distinguish between arterial and venous occlusion. Tissue compression caused by adhesive strips or loss of probe contact on moist or bloody surfaces is problematic as is the use of laser light. False-positive readings are frequent. Use on replanted parts is limited by the small size of the parts relative to the probe and requirement for the probe to be fixed to the parts, obstructing the clinical assessment of the part.

REFERENCES:

Selber JC et al, "A Prospective Study of Transit Time Flow Volume (TTFV) Measurement for Intraoperative Evaluation and Optimization of Free Flaps," Plastic and Reconstructive Surgery, Advance Online Article DOI: 10.1097/PRS.0b013b3182789c91
http://www.answers.com/topic/transcutaneous-oxygen-measurements#ixzz2J04wRDB6
http://www.microsurgeon.org/monitoring

AMERICAS
Transonic Systems Inc.
34 Dutch Mill Rd
Ithaca, NY 14850
U.S.A.
Tel: +1 607-257-5300
Fax: +1 607-257-7256
support@transonic.com

EUROPE
Transonic Europe B.V.
Business Park Stein 205
6181 MB Elsloo
The Netherlands
Tel: +31 43-407-7200
Fax: +31 43-407-7201
europe@transonic.com

ASIA/PACIFIC
Transonic Asia Inc.
6F-3 No 5 Hangsiang Rd
Dayuan, Taoyuan County
33747 Taiwan, R.O.C.
Tel: +886 3399-5806
Fax: +886 3399-5805
support@transonicasia.com

JAPAN
Transonic Japan Inc.
KS Bldg 201, 735-4 Kita-Akitsu
Tokorozawa Saitama
359-0038 Japan
Tel: +81 04-2946-8541
Fax: +81 04-2946-8542
japan@transonic.come