Flow-Assisted Surgical Technique F•A•S•T during Microvascular Reconstructive Surgery

Contents

Microvascular Surgery

"Transit time volume flow measurement provides objective data with real clinical value and has potential to both reduce microvascular complications and improve patient outcomes."[1]
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Evolution of Microsurgery

Microsurgery is irrevocably linked to the evolution of vascular surgery anastomosis techniques pioneered by surgeons in during the 20th century. However, microsurgery was made possible by the development the operating microscope and the development of finer instruments, needles and suture materials which allowed surgeons to perform delicate procedures which would have been impossible using the naked eye.

The introduction of the operating microscope in 1960 by Jules Jacobson, (University of Vermont, Burlington) was the single most important advance in improving outcomes in small vessel surgery.[2] With ever evolving tools and techniques, including the use of robotically-assisted microsurgery to scale down surgical movements, microsurgery has now evolved to a level of supermicrosurgery that is performed on vessels, including lymph vessels, that have diameters of less than 0.5mm.[3]

Microvascular Reconstructive Surgery

Microvascular free flap surgery has thus become a successful and reliable method of vascular reconstruction and is performed daily in large cancer treatment centers such as Memorial Sloan Kettering with more than 4,000 cases per year, and MD Anderson Center in Houston with over 3,700 cases per year. Used in a variety of procedures including breast reconstruction, flap closure during Mohs procedures to obliterate skin cancers and replantations, successful reconstructions depend on supplying adequate blood flow to the tissue to promote would healing and resistance to infection at the recipient site.[3]

Quantitative Measurement of Flap Flow

Microvascular surgeons have previously relied on clinical assessment for their surgical decisions. Now, flow measurements during microvascular procedures quantify unprecedented flows in the smallest vessels. The surgeon can objectively assess the quality of the donor vessel, reconstruction or replantation, and offer an opportunity to correct otherwise undetectable flow restrictions before closing the patient.

Transonic's series of microvascular handle Flowprobes can measure flow in vessels from 0.4 mm to 3.7 mm in diameter. The probes feature a short flexible neck and a L-style reflector so that the probe can be easily slipped around these delicate vessels. Larger Flowprobe sizes are also available.

Ultrasonic sensing windows of Microvascular Flowprobe (MU) Series with a tip of a 25g. needle.

Flow Protocol: Microvascular Surgery

Intraoperative Measurements during Reconstructive Surgery

Microvascular surgery places high demands on the microvascular surgeon. Not only must the surgical team have developed highly honed technical skills, but they must make critical on-the-spot decisions as surgery progresses to ensure an optimal outcome for the procedure, be it creation of free flaps, lymphovenous anastomoses (LVAs) or other repairs.

Vessel Compromise - Time Consuming

Although total flap loss rates are low (between 0.6 to 6%)[1], vascular compromise still leads to time-consuming flap re-exploration. Low venous pressure is susceptible to compression from improper positioning, pedicle tension, and/or hemodynamic compromise. An unrecognized venous thrombosis can progress to an arterial thrombosis and ultimately lead to flap failure. Arterial insufficiency is associated with the highest percentage (49.3%) of unsalvageable flaps.[1]

Tool to Confirm Clinical Impressions

Transit-time ultrasound volume flow measurements in microvessels provides the microvascular surgeon a tool to give him or her a quantitative measurement of flow in microvessels. No longer does the surgeon need to rely solely on clinical impressions to assess the quality of the surgery. This ground breaking, volume flow technology produces accurate, quantitative flow information that can be used to:

- Test Anastomotic Quality: Measuring anastomotic flow intraoperatively has been found to be a useful tool during and also during microsurgery training labs to test each participant's progress;
- Measure Arterial (Perforator) Inflow: Knowing perforator flows beforehand helps the surgeon select an optimal perforator for flap inflow;
- Quantify Venous Outflow: Flap outflow can be quantified by measuring venous outflow;
- Measure Lymph Flow: Being able to actually measure lymph flow and to know its direction can guide the selection of the best lymph vessel for use during creation of LVAs.[2]
- Document Results: Measuring flow provides documentation of surgical results for the patient's record.

Vessel Sizes for Microvascular Flowprobes

Probe Size (mm)	Vessel OD (mm)	Maximum Flow (ml/min)
0.7	0.4 - 0.7	50
1	0.7 - 1.2	100
1.5	1.0 - 1.5	200
2	1.5 - 2.7	500
3	2.5 - 3.7	1000

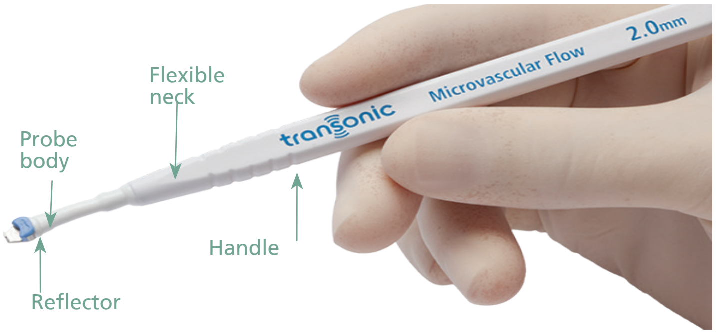

Fig. 1: 2 mm Microvascular Flowprobe showing handle and flexible probe neck for easy positioning of the Flowprobe around a vessel.

Protocol: Flow-assisted Surgical Technique

Microsurgery Flowprobes® (Fig. 1) are designed to measure blood flow in micro-vessels with diameters from 0.4 to 3.7 mm. Microsurgical Flowprobes use ultrasonic transit-time principles to directly measure volume blood flow, not velocity. In reconstruction surgery, flow measurements help guide the surgical strategy by helping to identify the best vessels to use, and testing the patency of an anastomosis.

Measurements Steps

1. Identify Vessels to be measured
   Expose and identify arterial inflow and venous outflow vessels to be used in the reconstruction.

2. Select Flowprobe Size
   Measure the vessel diameter of the vessels to be measured with a gauge before opening the Flowprobe package. Select a Flowprobe size so that the vessel will fill between 75% - 100% of the Probe's ultrasonic sensing window.

3. Prepare Vessel for Flowprobe
   Determine the optimal position for applying the Probe by selecting a site wide enough to accommodate the Flowprobe's acoustic reflector. Clear approximately 1 cm of the vessel to be measured of extraneous tissue (i.e. fascia, fat) for an accurate measurement. Fat could interfere with acoustic transmission.

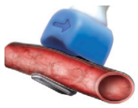

Fig. 2

4. Add Couplant to Flowprobe
   Fill the Flowprobe window with ultrasonic gel or submerge the Flowprobe head in saline in the surgical field.

5. Apply Flowprobe
   Apply the Flowprobe at right angles to the vessel (Fig. 2) taking care not to "twist" or "lift" the vessel with the Flowprobe. This will restrict or occlude blood flow creating inaccuracies at such small flow values. Apply the Flowprobe so that the entire vessel lies within the ultrasonic sensing window of the Probe.

6. Check Signal Strength
   Check the Flowprobe's ultrasonic signal strength on the Signal Quality Indicator on the Flowmeter or AureFlo®. If acoustic contact falls below an acceptable value, an acoustic error message will be displayed.

7. Multi-stage Flow Measurements
   a. Measure Flows *In Situ*
      Measure baseline flows after flap elevation and isolation on its pedicle; After flap dissection was completed, but prior to flap transfer, In Situ flow and PI were measured and recorded for the artery and vein for the flap
   b. Measure Flows Immediately Following Anastomosis Construction and Reperfusion
   c. Final Flow Measurement
      Measure flows 30 minutes following anastomosis and reperfusion.

5. Document Multi-stage Flows for the Case Record
   Document flow values from the multi-stage flow assessments by pressing the PRINT button on the Flowmeter or making a recording and taking a snapshot on the AureFlo. If the Flowmeter displays a negative flow, press the INVERT button to change the polarity before printing the waveform.

When to Zero Flow?

Surgeons frequently ask if they need to zero flow on the Flowmeter before measuring flow in small vessels?

The answer depends in what equipment they are using to measure flow.

AureFlo® System
If the AureFlo is being used, as recommended, to measure flows in micro-vessels, there is NO need to zero flow. The AureFlo automatically zeroes flow before a measurement is taken. The surgeon can view a 0.00 mL/min on the AureFlo monitor prior to measuring.

Optima Flowmeter Used As a Stand-alone
If the Optima Flowmeter is being used as a stand-alone, the Flowmeter should be zeroed before measuring by occluding the vessel to be measured, noting the flow on the Flowmeter and subtracting that number from the measured flow to arrive at true flow..

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(F•A•S•T) during Reconstructive Surgery

Multi-stage Flow Measurement Protocol

Select Proper Flowprobe Size

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Measure Baseline Flows
on arterial inflow and venous outflow vessels

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Determine surgical strategy
for flap reconstruction

Measure flows immediately after
anastomosis and reperfusion

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Record flow values of arterial
inflows and venous outflows

↓ **Flow equal or more than baseline**

Evaluate surgical strategy
vis á vis flow values

Measure flows 30 minutes
after anastomosis and reperfusion

↓

Compare to other flows and determine
surgical strategy

REFERENCE
Selber JC, Garvey PB, Clemens MW, Chang EI, Zhang H, Hanasono MM,"A Prospective Study of Transit Time Flow Volume (TTFV) Measurement for Intraoperative Evaluation and Optimization of Free Flaps," Plast Reconstr Surg. 2013; 131(2): 270-81. (Transonic Reference # 9762AHM)

Annotated Microsurgical References

1 Smith RM, Kang V, Al-Khudari S, "Vessel selection and free flap monitoring in head and neck microvascular reconstruction," World Journal of Otorhinolaryngology 2015 Feb; 5(1): 5-13. (Transonic Reference # 10250AHR) *"Surgical complications are not uncommon during microvascular free flap reconstructions. They prolong the procedure and can lead to the need for time-consuming surgical re-explorations."*

2 Chen WF, Zhao H, "Transit-time ultrasound technology-assisted lymphatic super-microsurgery," J Plast Reconstr Aesthet Surg. 2015 Nov; 68(11): 1627-8. *"The TTUT measurements consistently correlated with the surgeon's observations in all 28 lymphatic vessels — healthy-appearing lymphatic vessels demonstrated flow values higher than those from unhealthy-appearing lymphatic vessels. ...Based on the above findings, we concluded that TTUT holds promise in 1) guiding the lymphatic vessel selection, 2) confirming anastomotic patency, and that 3) the absence of "wash out" may not unequivocally indicate anastomotic occlusion."*

3 Selber JC, Garvey PB, Clemens MW, Chang EI, Zhang H, Hanasono MM, "A Prospective Study of Transit Time Flow Volume (TTFV) Measurement for Intraoperative Evaluation and Optimization of Free Flaps," Plast Reconstr Surg. 2013; 131(2): 270-81. (Transonic Reference # 9762AHM) *"... TTFV (Transit-time Flow Volume) provides novel physiologic flap data and identifies flow anastomoses and higher-flow venae comitantes. These data have clinical value in microsurgery and hold the potential to reduce microvascular complications and improve outcomes."*

4 Visscher K, Boyd K, Ross DC, Amann J, Temple C, "Refining perforator selection for DIEP breast reconstruction using transit time flow volume measurements," J Reconstr Microsurg. 2010; 26(5): 285-90. (Transonic Reference # CV-9953AHM) *This study evaluated the correlation among computed tomographic angiography (CTA), intraoperative TTFV measurements, and hand-held Doppler signals in identifying perforators in ten consecutive free DIEP breast reconstructions. "Of the 54 perforators identified, TTFV showed arterial flow waveforms in 15 of 16 perforators identified by CTA and in 2 of the remaining 38 vessels. The sensitivity and specificity of TTFV in identifying arterial perforators were 94 and 95%, respectively. In contradistinction, hand-held Doppler was misleading in 70% of vessels. TTFV distinguishes arterial from venous waveforms in vessels that appear arterial by hand-held Doppler signals. CTA and TTFV are highly correlated, and the use of TTFV may prevent poor perfusion seen in some DIEP flaps."*

5 Herberhold S, Röttker J, Bartmann D, Solbach A, Keiner S, Welz A, Bootz F, Laffers W. "Evaluation and Optimization of Microvascular Arterial Anastomoses by Transit Time Flow Measurement," Laryngorhinootologie 2015 Dec 15. (Transonic Reference # 10035AHM) *This prospective study combined ultrasound imaging and transit time flow measurements to assess anastomotic quality of 15 radial forearm flaps. ..."Results: Mean blood flow immediately after opening the anastomosis and 15 min later were 3.9 and 3.4 ml/min respectively showing no statistically significant difference (p=0.96). ...Conclusion: Transit time flow measurement contributes to the improvement of anastomotic quality and therefore to the overall outcome of radial forearm flaps. The examined measurement method provides objective results and is useful for documentation purposes."*

6 Takanari K, Kamei Y, Toriyama K, Yagi S, Torii S, "Differences in blood flow volume and vascular resistance between free flaps: assessment in 58 cases," J Reconstr Microsurg. 2009 Jan;25(1):39-45. (Transonic Reference # 10313AH) *"We investigated blood flow in the flap by transit-time ultrasound flowmeter in 58 free-flap transfers. Flow volume was compared between flap tissues as vascular resistance in the flap was calculated. Fasciocutaneous and osteocutaneous flaps had relatively low blood flow volume, myocutaneous flaps had more, and intraperitoneal flaps had still higher blood flow volume. These differences were statistically significant. Vascular resistance significantly decreased in the same order of comparison. Our findings will help in selecting the most suitable flaps for reconstructive surgery."*

7 Lorenzetti F, Giordano S, Tukiainen E, "Intraoperative hemodynamic evaluation of the latissimus dorsi muscle flap: a prospective study," J Reconstr Microsurg. 2012; 28(4): 273-8. (Transonic Reference # 10035AHM) *Measurements of blood flow were performed intraoperatively in 27 patients using a 2- to 5-mm probe ultrasonic transit-time flowmeter around the dissected vessels. "Registrations were made in the thoracodorsal artery before and after harvesting the flap, after compressing and cutting the motor nerve, and after anastomosis. Mean blood flow of in situ harvested thoracodorsal artery as measured intraoperatively by transit-time flowmeter was 16.6 ± 11 mL/min and was significantly increased after raising the flap to 24.0 ± 22 mL/min (p <0.05); it was 25.6 ± 23 mL/min after compressing the motor nerve and was significantly increased after cutting the motor nerve to 32.5 ± 26 mL/min (p <0.05). A significant increase of blood flow to 28.1 ± 19 mL/min was also detected in the thoracodorsal artery after flap transplantation with end-to-side anastomosis (p <0.05)."*

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