Flow-Assisted Surgical Technique (F•A•S•T) during Peripheral Vascular Surgery

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To Measure Is To Know!

During surgery blood flow (or the lack thereof) impacts surgical success and long-term patient health. In order to assure the quality of surgery, and improve surgical outcomes, blood flow should be measured.

Surgeons Weigh In:

“As a surgeon you are continually striving to do the best possible operation tailored to the specific findings of a particular patient. You are trying to do the best with what you’ve got. Consequently, during surgery you are constantly re-assessing its progress to try to give the patient the best long-term result.

Any technology that you can use to provide an intraoperative assessment can be invaluable. Transonic Flow-QC intraoperative blood flow measurement is such a measurement. The measurements may either confirm what appears to be an acceptable surgical result, or it can alert you that there may be potential problems at a time when it can be more easily addressed. The assessment may dictate an immediate major revision or a change in the postoperative treatment such as the addition of long-term anticoagulation.

Transonic Flow-QC provides a measurable improvement in the quality of care you can extend to your patients. With Transonic Flow-QC you can: improve patient outcomes; reduce or delay the need for future interventions and document surgical results.”

T. Wolvos, MD, FACS

“The primary aim of intraoperative volume flow measurement is to obtain information on the immediate result of the reconstruction where a technical failure may jeopardize an otherwise successful operation.”


“Intraoperative assessment of graft patency is essential for detection of potentially reversible technical problems prior to leaving the operating room.”


“During banding of AVGs, it is very difficult to reduce access flow without causing a thrombosis. Therefore, one must measure flow to quantify the reduction.”

From presentation, “Banding (How I do it),” I. Davidson, MD, CIDA, 2011

“Flow reduction using intraoperative access flow monitoring is an effective and durable technique allowing for the correction of distal ischemia and cardiac insufficiency in patients with a high-flow autogenous access.”


“Accurate flow measurements can be of great assistance during vascular reconstructive surgery. The primary aim with these intraoperative measurements is to obtain information on the immediate result of the reconstruction, where a technical failure may jeopardize an otherwise successful operation.”


“Not a day goes by when this flowmeter doesn’t solve a problem for me.”

BP Mindich, MD

“Transit-time flow measurements are useful for surgical management during cerebrovascular surgery. The technique was simple to use and provided sensitive, stable, reliable results.”

To Measure Is To Know cont.

“Why Measure Flow?” has many responses. One of the most powerful is, “If one makes the effort of sewing an anastomosis, one should also take the time to measure its flow.”

Flow Measurement Provides An Objective Functional Assessment of Surgical Success
In surgeries where restoration of flow is primary, flow must be measured. While the Technical Quality of Surgery can be readily observed at the end of surgery when the patient recovers from anesthesia, the Surgical Functional Success is often more difficult to determine. It requires intraoperative measurement of physiological measurements. Are all the grafts operational? Is organ flow adequate? Do these corroborate a surgeon’s clinical assessment? What is the patient’s long-term prognosis based on intraoperative clinical assessments, and what treatment regimen do these suggest?

Informs Surgical Decisions
Adequate pressure but a lower-than-expected flow often indicates a technical error such as a stitch that picks up the back wall of a vessel. Flow measurement can save the day for the surgeon and the patient in such instances.

Heightened Need for Flow in More Challenging Procedures
As surgical complexity increases, so has the need for intraoperative flow measurement for assessment and documentation. In procedures such as endoscopic surgery, the surgeon cannot palpate the vessel to get a qualitative assessment of technical adequacy of the surgical repair. As more and more patients are stented, a surgeon is now called upon to restore flow in the presence of failed surgical implants. Moreover, in surgeries such as partial liver transplant, flow and ratios between flows are critical to surgical success.

Provides Peace of Mind
Especially in cases where there is risk for severe functional complications such as intraoperative stroke, measurement and correction of factors that would result in such complications, provides a level of peace of mind to the surgeon.

Continuous Quality Improvement (CQI)
A basic tenet of any quality program is that you have to measure what you want to improve. If blood flow affects surgical success, it must be measured.

Measurements Guide Post-op Care
Intraoperative flow measurement of flow parameters may avoid the need for post-surgical tests, and provide information for further patient treatment during recovery and thereafter.

Avoid Re-Operations
Re-ops are costly, particularly when they are not reimbursed by the patient’s insurer. Whenever intraoperative flow measurement alerts the surgeon to a flow-limiting problem that can be corrected during surgery, re-operation is avoided and money is inevitably saved.

Intraoperative Training Tool for Surgical Residents
The use of intraoperative quality measurement devices such as flowmeters to confirm the quality of a surgical anastomosis has become an invaluable learning tool for residents and surgeons alike and has been integrated into numerous surgical training courses.

Helps Develop Standards of Care
New surgical protocols are developed using measurements, including blood flow measurements, and interpretation of all available physiological parameters.

Proven Patient Care
Exemplary patient care is the axiom. Hospitals must, therefore, stay on the forefront of medical innovation and quality assurance to attract the savvy patient who demands and deserves the best.

Provides Strong Evidence
In our litigious society, juries have become more inclined to grants large awards to patients. Surgical success, documented by intraoperative blood flow measurements, provides strong court evidence for the hospital or doctor in such instances.

Flow Measurements Complement Pressure
While an abnormal blood pressure may be tolerated by the body for prolonged periods, an abnormal blood flow can damage organs on short notice. Pressure divided by flow equals organ impedance, an important parameter for:
(a) Detection of technical error in an anastomosis;
(b) Selection of regimens for post-op patient treatment.

To Measure Is To Know!

* * * * * * *
Peripheral Vascular Surgery

“Accurate flow measurements can be of great assistance during vascular reconstructive surgery. The primary aim with these intraoperative measurements is to obtain information on the immediate result of the reconstruction, where a technical failure may jeopardise an otherwise success operation.”
Anders Lundell, MD, PhD

Validation: Ultrasonic Transit-Time Measurement Technology

Swedish vascular surgeon Dr. Anders Lundell was an early flow measurement pioneer. His 1992 publication “Intraoperative Flow Measurements in Vascular Reconstruction” reported his validation of transit-time ultrasound flow measurements in reconstructive surgeries. During the same fertile period, vascular surgeon Dr. Ian Gordon, at the University of California at Irvine, measured flow during carotid endarterectomy procedures and contributed his medical protocols to the growing base of Transonic vascular surgery applications.

Peripheral Bypass Surgery

Creating a lower extremity bypass is often a last ditch effort to salvage a limb from amputation. Quantitative on-the-spot intraoperative flow measurements provide valuable functional information for the vascular surgeon who doesn’t want to rely on guesswork to know the outflow of a limb saving bypass. To that end, vascular surgeons depend on the value of intraoperative flow measurements to help them with construction of lower limb bypasses. They report:
- Intraoperative flow measurement of distal runoff is a valid predictor of outcome of infrainguinal bypass surgery. Flow is easy to measure and is a better predictor of outcome than angiography. Decisions about grafting should rely on flow measurements if there is any doubt about patency or limb salvage, particularly if a PTFE graft is going to be used.
- Intraoperative graft volume flow is a predictor of bypass occlusion after infrainguinal bypass.

Vascular Handle Flowprobes Developed

To accommodate the increasing need for easy-to-use Flowprobes in a variety of sizes for general vascular surgery, Transonic has designed vascular handle Flowprobes for vessel lumens from 4 mm to 14 mm in size. These handle probes feature a short flexible neck for applications where the artery, vein or graft is readily accessible. The probe head can be quickly slipped around the vessel and maintain optimal vessel alignment during flow measurement. To prevent the dislodging of plaque during carotid endarterectomy procedures, probe heads with L-shaped reflectors so that the sensing head slips on and off the vessel without temporarily bending the vessel were added to the vascular flowprobe line.

In this section we will present surgical protocols for vascular and microvascular surgeries: carotid endarterectomy, peripheral bypass and microvascular reconstruction.

Short Handle Vascular/Endarterectomy/Microvascular Flowprobes: FMV-(vascular), FME-(endartectomy) and FMU-(microvascular) Flowprobe Series features short handle designed for spot flow checks. Available in a wide range of sizes from 0.75 mm to 14 mm.
Flow Protocol: Carotid Endarterectomy

Intraoperative Blood Flow Assessment during Carotid Endarterectomy (CEA)  By Ian Gordon MD

Surgical Approach

No special adjustment in surgical technique is necessary for measurement of blood flow during carotid surgery. The sites on the carotid arteries skeletonized by dissection for vascular clamp placement are identical to those employed for Flowprobe placement. A 10 mm Flowprobe (sometimes an 8 mm Flowprobe is used) is employed for the distal common carotid artery and 6 mm Flowprobes for the origin of the internal and external carotid arteries.

The Flowprobe on the external carotid is placed just distal to the origin of the superior thyroid artery. We perform the pre-endarterectomy flow measurements immediately after administration of systemic heparin. Measurement of all three arteries (Fig. 1) only requires a few minutes.

After the first measurement, vascular clamps are placed and the endarterectomy is performed. We shunt all our patients with a large Javid shunt and place a clamp-on sensor on the shunt to ensure that any interruption of shunt flow is detected.

After finishing the endarterectomy, removing all clamps, and establishing hemostasis, a repeat flow measurement is performed. Occasionally, a low flow or turbulent flow waveform is detected indicating the presence of a significant stenosis which requires immediate revision. As a consequence, we try not to reverse heparin with protamine until completion of the flow measurements.

**TYPICAL FLOWS OBSERVED** (Gordon 1995: n = 38)

<table>
<thead>
<tr>
<th>Conduit</th>
<th>Pre-Endarterectomy</th>
<th>Post-Endarterectomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common carotid a</td>
<td>287 ± 17 mL/min</td>
<td>329 ± 18 mL/min</td>
</tr>
<tr>
<td>External carotid a</td>
<td>126 ± 10 mL/min</td>
<td>104 ± 8 mL/min</td>
</tr>
<tr>
<td>Internal carotid a</td>
<td>135 ± 10 mL/min</td>
<td>178 ± 11 mL/min</td>
</tr>
</tbody>
</table>


**TYPICAL FLOWS OBSERVED** (Aleksic, 2009; n = 1000)

<table>
<thead>
<tr>
<th>Conduit</th>
<th>Pre-Endarterectomy</th>
<th>Post-Endarterectomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common carotid a</td>
<td>290 mL/min</td>
<td>336 mL/min (up 16%)</td>
</tr>
<tr>
<td>External carotid a</td>
<td>152 mL/min</td>
<td>150 mL/min (down 4%)</td>
</tr>
<tr>
<td>Internal carotid a</td>
<td>160 mL/min</td>
<td>240 mL/min (up 46%)</td>
</tr>
</tbody>
</table>


**FLOW MEASUREMENTS DURING CEA**

CEA blood flow measurement track changes in carotid flow distribution.
- A limited decrease in ECA flow after CEA accompanies an increase in ICA flow.
- Flow measurements also can test the adequacy of the carotid reconstruction with regard to normalized ICA flow.
- Flow measurements allow immediate detection of critically diminished ECA flow due to intraoperative stroke.


Intraoperative Blood Flow Assessment during Carotid Endarterectomy (CEA) cont.

**Carotid Flowprobes**

| Common carotid artery (CCA) | 8, 10 | -FTE, -FME, -FSB |
| External carotid artery (ECA) | 6 | -FTE, -FME, -FSB |
| Internal carotid artery (ICA) | 6 | -FTE, -FME, -FSB |

**Non-handle Flowprobes**

Non-handle Flowprobes (FSB-Series) feature an ultrasonic flowsensing window defined by a L-bracket with a sliding closure so that the Flowprobe can remain positioned around the vessel for extended measurements. FSB-Series Flowprobes are available in sizes from 2 mm to 14 mm.

**References**

Hosoda K et al, “Cerebral vaso-reactivity and internal carotid artery flow help to identify patients at risk for hyperperfusion after carotid endarterectomy,” Stroke 2001; 32(7): 1567-73. (6995AH)


Introduction: Lower Extremity Bypass

Lower extremity bypass surgery includes augmentation or restoration of flow in the lower extremities through either a femoro-popliteal bypass and abdominal (iliac artery) bypass (Figs. 1, 2). In these surgeries quantification of flow:

- Detects technical defects
  - Twisted vein grafts can be revised immediately
  - Patients do not leave surgery with poorly functioning grafts
  - Eliminates unnecessary revisions
- Confirms reconstruction success
  - The higher the intraoperative blood flow, the greater the patency intervals.
- Prognosticates bypass patency
  - The post-reconstruction measurement can be used as an indicator of patency.
  - Distal flows > 100 ml/min (fem-pop) indicates a successful reconstruction
  - Distal flows < 75 ml/min indicates a high risk of graft occlusion within the first six postoperative months
- Allow for more efficient management of a patient’s peripheral arterial disease.
  - Leads to time savings for the surgeon, OR, and patient (quicker than angiography).
  - Saves money for the surgeon and OR: Avoids non-reimbursable re-operations.

Because the range of vascular disease varies from patient to patient, acceptable levels of flow at the conclusion of surgery have not yet been well documented. In all cases, we recommend the following standard flow measurement protocol.

1. At the beginning of bypass, once the site for the graft’s distal anastomosis has been exposed, measure the flow at this site (Position B, figures on next page). This is the flow that must be increased via the graft. Note the systemic pressure. Flow at this site, in first approximation, will vary proportional to systemic pressure.

2. After the proximal anastomosis of the graft has been constructed, apply a Flowprobe to the graft and take a short (10-15 sec) measurement of Free Flow through the graft with its distal end open. This is the free flow capacity of the graft. Flow augmentation provided by the graft will be only a fraction of the free flow due to the resistance of the distal vascular bed. This measurement also provides a quality measurement of the proximal anastomosis and will confirm that the valvulotomy in vein graft was adequate.

3. After the distal anastomosis is complete and the graft clamp is released, flow through the graft and current systemic pressure are again measured. The current graft flow (“Bypass Flow”) is a direct measure of the flow augmentation benefit provided by the bypass surgery.

\[
\text{Free Flow Index (FFI)} = \frac{\text{Bypass Flow}}{\text{Free Flow}}
\]

The Free Flow Index can be a valuable parameter in the study of long term benefit of the bypass surgery. A graft into tissue with low flow impedance such as an extracranial-intracranial (EC-IC) bypass has a target Free Flow Index of 0.5 or higher. In high-impedance sites of the lower limb with vascular disease, the Free Flow Index will be substantially lower, and could potentially serve as an indication of the severity of the vascular disease.

Reference

Flow Protocol: Lower Extremity Bypass

Intraoperative Blood Flow Assessment during Lower Extremity Bypass

Ian Gordon, MD, PhD, Professor, Dept. of Surgery, Univ. of CA, Irvine

After completing a lower extremity arterial bypass, flow is measured before wound closure. Generally, we measure flow immediately after finishing the last anastomosis of the bypass and do not reverse heparinization.

A 4 or 6 mm flowprobe is used for the saphenous vein, a 6 mm probe, for the popliteal artery, an 8 or 10 mm probe for the common femoral artery, and a 4 mm probe for tibial arteries.

Dacron grafts, which we very rarely use distal to the common femoral artery, permit direct measurement of flow by transit-time probes. Expanded PTFE grafts cannot be studied directly by a probe placed on the graft, as air trapped in the graft interstices interferes with ultrasound transmission, and an accurate measurement is not possible until this air is expelled.

Three methods, A, B, and C, are used to measure flow. Method A is suitable for saphenous vein or dacron grafts; and Methods B and C are useful for PTFE grafts. We frequently employ Method C to measure the distribution of flow beyond the distal anastomosis in retrograde and antegrade directions. Method B is employed whenever exposure of the distal vessel receiving the bypass is poor, and placement of the probe on both sides of the distal anastomosis is difficult.

A: Saphenous Vein/Dacron Bypass Grafts

PROXIMAL FLOW: To measure flow in a saphenous vein or dacron bypass graft, the Flowprobe is placed just distal to the proximal anastomosis (Fig. 1: A). Flow is documented and a representative flow waveform is generated. An artifact in the flow versus time waveform indicates the presence of a hemodynamically significant stenosis causing turbulence.

DISTAL FLOW: The distal anastomosis is similarly assessed for turbulence by placing the Flowprobe on the target vessel for the bypass just distal to the distal anastomosis (Fig. 1: B).

BYPASS FLOW: If there are no technical problems requiring graft revision, we perform our definitive flow measurement by positioning the Flowprobe on the bypass at any convenient position (Fig. 1: C) and measuring flow.

We customarily measure flow, first with the graft temporarily clamped to confirm an accurate zero flow. Then graft flow \( F_{\text{graft}} \) is measured with the clamp released, and recorded.

RESISTANCE: To calculate resistance of graft flow in the distal run-off vessels, we measure the pressure drop across the graft. A 26 gauge needle, connected to a three-way stopcock, is connected by plastic extension tubing to a sterile pressure transducer (usually the anesthetist’s radial artery catheter transducer) and is introduced onto the surgical field. The bypass graft is punctured by the needle several centimeters distal to the proximal anastomosis (Fig. 2). Mean pressure is measured first, with the graft open \( P_{\text{open}} \), and then, with a clamp proximal to the needle, occluding the graft \( P_{\text{clamp}} \). The pressures are recorded. After completing the

measurements, the needle is withdrawn and the needle hole is closed with a 6-0 suture.

Flow resistance (R) is calculated as:

\[ R = \frac{F_{\text{graft}}}{(P_{\text{open}} - P_{\text{clamp}})} \]

**B. PTFE Femoropopliteal Bypass**

In a typical PTFE femoropopliteal bypass, the graft origin is from the common femoral artery. An 8 or 10 mm Flowprobe is placed on the common femoral artery just proximal to the bypass (Fig. 3, D). Flow in the common femoral artery is then measured with the graft open \( F_{\text{open}} \) or clamped \( F_{\text{clamp}} \). Net graft flow is equal to \( F_{\text{open}} - F_{\text{clamp}} \). Resistance is measured as above.

Method B is also used whenever placement of the Flowprobe on both sides of the distal anastomosis is difficult due to poor exposure of the distal vessel receiving the bypass.

**C. Antegrade & Retrograde Flow Distribution**

Method C is used to measure the distribution of flow beyond the distal anastomosis in retrograde and antegrade directions. A 4 or 6 mm probe is placed on the target vessel just distal to the distal anastomosis [position B].

**ANTEGRADE FLOW:** Antegrade flow is measured with the bypass graft open \( F_{\text{ao}} \) and clamped \( F_{\text{ac}} \).

**RETROGRADE FLOW:** To measure retrograde flow, the probe is placed on the target vessel [position E] just proximal to the distal anastomosis and flow is measured with the graft open \( F_{\text{ro}} \) and clamped \( F_{\text{rc}} \). Observe the direction of blood flow carefully observed and negative and positive signs correctly employed to accurately measure flow. Net graft flow is calculated as \( F_{\text{ao}} - F_{\text{ac}} + F_{\text{ro}} - F_{\text{rc}} \). Resistance is measured as in Method A.

Note: Pulse is a manifestation of pressure, not flow, so an occluded graft may still have a distinct pulse.

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**Note:** Dacron grafts, rarely used distal to the femoral artery, allow direct measurement of flow by transit-time Flowprobes. Expanded PTFE grafts cannot be studied immediately by a Flowprobe placed on the graft, as air trapped in the graft interstices interferes with ultrasound transmission, and an accurate measurement is not possible until this gas is expelled.

FLOWPROBES FOR LOWER EXTREMITY BYPASS

<table>
<thead>
<tr>
<th>BYPASS</th>
<th>SIZE</th>
<th>PROBE SERIES</th>
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<tbody>
<tr>
<td>Profunda femoris</td>
<td>8</td>
<td>-FMV, -FTV, -FSB</td>
</tr>
<tr>
<td>Common femoral</td>
<td>8, 10</td>
<td>-FMV, -FTV, -FSB</td>
</tr>
<tr>
<td>Popliteal</td>
<td>4, 6</td>
<td>-FMV, -FTV, -FSB</td>
</tr>
<tr>
<td>Tibial</td>
<td>3, 4</td>
<td>-FMV, -FTV, -FSB</td>
</tr>
</tbody>
</table>

Fig. 6: 3 mm - 14 mm Vascular Handle Flowprobes (-FMV-Series)

References

CAROTID ENDARTERECTOMY

LOWER EXTREMITY BYPASS
2. Transonic Medical Note #M1, Lower Extremity Bypass, Ian Gordon, MD, PhD