Reduce Intraoperative Stroke Risk with Volume Flow Measurements

- Identify Inadvertent Vessel Compromise
- Confirm Flow Preservation
- Quantify Flow Augmentation
Charbel Flowprobes® Provide On-the-Spot Quantitative Cerebrovascular Measurements

Intraoperative measurements with the bayonet-style Charbel Flowprobe® take the guesswork out of blood flow during aneurysm clipping, extracranial to intracranial (EC-IC) bypass surgeries, arteriovenous malformations (AVMs), dural fistula obliteration, and tumor resection surgeries.

During aneurysm clipping surgery, flow measurements help surgeons achieve optimal clip placement to obliterate the aneurysm without compromising flow in parent vessels and distal branches that might cause an intraoperative stroke. Measurements either confirm the surgeon’s clinical assessment of flow preservation, or expose the need for immediate correction of flow deficits. Moreover, during temporary clippings, flow measurements offer an assessment of collateral flow reserve and predict the safety of the temporary clipping.

During EC-IC bypass surgery to preserve or augment distal cerebral perfusion, intraoperative flow measurements help the surgeon choose the most appropriate bypass and predict its future patency.

Intraoperative flow measurements provide invaluable quantitative flow information to augment the surgeon’s clinical armamentarium. No other technology produces flow data so quickly, accurately, and non-intrusively during cerebrovascular surgery as do Transonic® intraoperative Flowmeters.

“Flow is a vital parameter during cerebrovascular surgery; including flow in my surgical approach gives me a high degree of control over surgical outcome. When I close the patient, I know the patient will recover without ischemia surprises. This translates into peace of mind for the patient and me, and saves money for the hospital.”

F Charbel, MD, FACS

“… Intraoperative Flow may now constitute the most reliable tool for increasing safety in aneurysm surgery.”

A Pasqualin, 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.”

N Nakayama, MD

“One of the major risks associated with aneurysm surgery is the potential for inadvertent occlusion or compromise of the vascular branches from which the aneurysm arises, which can result in stroke.” “Use of the ultrasonic flow probe provides real-time immediate feedback concerning vessel patency … Intraoperative flow measurement is a valuable adjunct for enhancing the safety of aneurysm surgery.”

S Amin-Hajani, MD, FACS

TRANSIT-TIME ULTRASOUND TECHNOLOGY MEASURES VOLUME FLOW, NOT VELOCITY

Two transducers pass ultrasonic signals, alternately intersecting the vessel in upstream and downstream directions. The difference between the two transit times yields a measure of volume flow.

Transonic Systems Inc. is a global manufacturer of innovative biomedical measurement equipment. Founded in 1983, Transonic sells “gold standard” transit-time ultrasound flowmeters and monitors for surgical, hemodialysis, pediatric critical care, perfusion, interventional radiology and research applications. In addition, Transonic provides pressure and pressure volume systems, laser Doppler flowmeters and telemetry systems.

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Flow-assisted Surgical Techniques and Notes*
Aneurysm Clipping Surgery Protocol

Drawn from the clinical expertise of FT Charbel, MD, S Amin-Hanjani MD, Univ. of IL at Chicago

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Introduction1-4
During aneurysm clipping surgery, a cerebrovascular surgeon may elect to use a non-constrictive Charbel Micro-Flowprobe® to measure blood flow in major cerebral vessels. Flow measurements help the surgeon achieve optimal clip placement to obliterate the aneurysm without compromising flow in parent vessels and distal branches that might cause an intraoperative stroke.

Measurements Steps1-4

1. Identify Vessels at Risk
   • Expose and identify parent vessels and distal outflow vessels of the aneurysm.

2. Select Flowprobe Size
   • Measure the vessel diameter of the target vessels with a gauge before opening the Probe package. Select Probe size(s) so that the vessel(s) will fill between 75% - 100% of the window of the Probe(s).

3. Apply Flowprobe
   • Examine the vessel to determine the optimal position for applying the Probe. Select a site wide enough to accommodate the Probe’s acoustic reflector without compromising perforating arteries coming off the vessel. Apply the Flowprobe so that the entire vessel lies within the Probe window and aligns with the Probe body. Bend the Flowprobe’s flexible neck as needed to position the Probe on the vessel. As the Flowprobe is being applied to the vessel, listen to FlowSound®. The higher the pitch, the greater the flow.

   Sterile saline or cerebrospinal fluid may be used to flood the Probe window and provide ultrasound coupling. Do not irrigate continuously because the Probe will also measure the flow of the saline. Check the Signal Quality Indicator on the Flowmeter for adequate acoustic contact. If acoustic contact falls below an acceptable minimum, the Flowmeter/monitor displays an acoustic error message.

4. Measure Baseline Flows
   • Measure baseline flows in all vessels at risk before clipping the aneurysm. Baseline flows should be measured following burst suppression, since these protective agents will decrease baseline flows. Record the baseline flow measurements and the patient’s blood pressure on the Flow Record.

5. Document Flows
   • Wait 10-15 seconds for mean readings to stabilize after applying the Probe. Document flows for the case record by recording them, printing or taking a snapshot of the phasic flows. If the meter displays a negative flow, press the INVERT button to change the polarity before printing the waveform.

6. Post-Clip Flows & Compare to Baseline
   • After an aneurysm has been clipped, remeasure flow in each of the vessels and compare the post-clip flows with baseline flows. Each measurement should be equal or greater than the respective baseline flow. Greater flows are expected in cases where the aneurysm has compromised flow well below the vessel’s expected flow level (chart on page 4). Temporary clipping can also produce hyperemia which can cause flows to be 20-30% higher than baseline.

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*Flow-Assisted Surgical Techniques (“F•A•S•T”) and Protocols are drawn from surgical experiences by transit-time flow measurement users and passed along by Transonic for educational purposes. They are not intended to be used as sole basis for diagnosis. Clinical interpretation of each patient’s individual case is required.
Flow-assisted Surgical Techniques and Notes*
Aneurysm Clipping Surgery Protocol cont.

Common sites for anterior circulation aneurysms include the carotid ophthalmic artery (OpthA), Internal Carotid Artery (ICA) bifurcation, Middle Cerebral Artery (MCA) bifurcation, M1 Segment MCA, Anterior Cerebral Communicating Artery (AComA), and Posterior Communicating Artery (PComA) artery. The most common sites for aneurysms in the posterior cerebral circulation include the basilar artery (BA), posterior inferior cerebellar artery (PICA) and superior cerebellar artery (SCA).

Flow Measurement Summary1-3
- Measure vessel and select a Flowprobe size so that the vessel will fill at least 75% of the Flowprobe’s lumen. Use sterile saline or cerebrospinal fluid to obtain good ultrasonic contact between the Flowprobe and the vessel.
- Bend the Flowprobe’s flexible segment to best position the probe around the vessel. Listen to FlowSound® to hear volume flow.
- When readings stabilize, flow data captured flow data by recording, taking a snapshot, or by pressing PRINT on the Flowmeter. If the Flowmeter’s LED flow reading is negative, press INVERT to reverse the polarity of the flow reading from negative to positive before printing out the waveform.

Measurement Review1
- Measure baseline flows before clipping aneurysm.
- Measure flow after temporary clipping of an aneurysm to check integrity of flow.
- Confirm flow restoration after permanent clipping by comparing post-clipping flows with baseline flows.

Identify Vessels at Risk
Select Proper Flowprobe Size
Measure Baseline Flows in all vessels at risk
Measure Post-clip Flows in all vessels at risk
Compare Post-clip Flows to Baseline Flow

Flow equal or more than baseline
Flow Preserved in vessels at risk
Flow less than baseline
Re-examine/adjust clip and remeasure flow.
Case Report: Flow Measurement during SCA Aneurysm Clipping Surgery

Vessel(s) at Risk Identified
A patient presented with headaches and diplopia. A cerebral angiogram confirmed a right cerebellar aneurysm. Meticulous dissection on the right side exposed an aneurysm between the superior cerebellar artery (SCA) and posterior cerebral artery (PCA).

Baseline Flow Measurements
The Charbel Micro-Flowprobe® was first placed on the SCA. Flow measured 6-18 cc/min. The Flowprobe was then placed on the PCA and flow measured 34-36 cc/min.

Initial clip placement compromises SCA flow

Flow Integrity Checked after Aneurysm clipping
SCA flow dropped to 2-4 cc/min.
PCA flow was recorded as 55-60 cc/min.

Clip repositioned: SCA flow restored to baseline

The SCA was found to be partially incorporated in the clip. Clip repositioned and SCA and PCA flows returned almost to baseline levels.
## TECHNICAL RECOMMENDATIONS: ANEURYSM SURGERY COURTESY of FT Charbel MD, FACS

<table>
<thead>
<tr>
<th>Aneurysm Site</th>
<th>Probe Placement</th>
<th>Size (mm)</th>
<th>Expected Flows (ml/min)</th>
<th>Tips</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carotid Ophthalmic A (OPth)</strong></td>
<td>M1</td>
<td>2.0</td>
<td>80-110 and/or</td>
<td>Usually large aneurysms with no proximal control. Flow must be preserved in the ICA and M1 and A1 outlet vessels.</td>
</tr>
<tr>
<td></td>
<td>A1</td>
<td>2.0</td>
<td>40-60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ICA</td>
<td>3.0</td>
<td>120-170</td>
<td></td>
</tr>
<tr>
<td><strong>Posterior Communicating A (PCom)</strong></td>
<td>M1</td>
<td>2.0</td>
<td>80-110 and/or</td>
<td>Usually large aneurysms with no proximal control. Flow must be preserved in the ICA and M1 and A1 outlet vessels.</td>
</tr>
<tr>
<td></td>
<td>A1</td>
<td>2.0</td>
<td>40-60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ICA</td>
<td>3.0</td>
<td>120-170</td>
<td></td>
</tr>
<tr>
<td><strong>Anterior Choroidal A (ACh)</strong></td>
<td>M1</td>
<td>2.0</td>
<td>80-110 and/or</td>
<td>Flow in the anterior choroidal is particularly important. The 1.5 mm probe is good for this vessel.</td>
</tr>
<tr>
<td></td>
<td>A1</td>
<td>2.0</td>
<td>40-60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ICA</td>
<td>3.0</td>
<td>120-170</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AChA</td>
<td>1.5</td>
<td>20-60</td>
<td></td>
</tr>
<tr>
<td><strong>Carotid Bifurcation (ICA)</strong></td>
<td>M1</td>
<td>2.0</td>
<td>80-110 and/or</td>
<td>The technical challenge is to preserve flow in the M1 and A1 outlet vessels. Flow in the ICA (3 mm) can be checked also.</td>
</tr>
<tr>
<td></td>
<td>A1</td>
<td>2.0</td>
<td>40-60</td>
<td></td>
</tr>
<tr>
<td><strong>Anterior Communicating A (ACom)</strong></td>
<td>A1 (ipsilateral)</td>
<td>2.0</td>
<td>40-60</td>
<td>High risk. The technical challenge is to preserve flow in the A2 outlet vessels. No change in both A2s indicates flow is fully preserved. One A1 usually predominates and feeds both vessels.</td>
</tr>
<tr>
<td></td>
<td>A1 (contralateral)</td>
<td>2.0</td>
<td>40-60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A2 (both)</td>
<td>1.5</td>
<td>40-50</td>
<td></td>
</tr>
<tr>
<td><strong>Middle Cerebral A (MCA)</strong></td>
<td>M2 (outlet)</td>
<td>2.0</td>
<td>50-80</td>
<td>This is a straightforward, relatively low stress case for the surgeon. One of the easiest places to apply the probe.</td>
</tr>
<tr>
<td><strong>Post. Inferior Cerebellar A (PICA)</strong></td>
<td>VA</td>
<td>3.0</td>
<td>100-200 and/or</td>
<td>Check flow in proximal or distal VA and PICA.</td>
</tr>
<tr>
<td></td>
<td>PICA</td>
<td>2.0</td>
<td>10-15</td>
<td></td>
</tr>
<tr>
<td><strong>Superior Cerebellar A (SCA)</strong></td>
<td>SCA (ipsilateral)</td>
<td>1.5</td>
<td>18-20 and/or</td>
<td>Check flow in ipsilateral SCA and PCA (Posterior Cerebral Artery).</td>
</tr>
<tr>
<td></td>
<td>PCA</td>
<td>2.0</td>
<td>26-30</td>
<td></td>
</tr>
<tr>
<td><strong>Basilar Tip A (BA)</strong></td>
<td>P2 (ipsilateral)</td>
<td>2.0</td>
<td>26-30 and/or</td>
<td>The perforators will still need to be inspected.</td>
</tr>
<tr>
<td></td>
<td>SCA</td>
<td>1.5</td>
<td>18-20</td>
<td></td>
</tr>
</tbody>
</table>

### References:
3. AU-QRG-Optima-EN Rev E
Flow-assisted Surgical Techniques and Notes*

STA-MCA Bypass for Moyamoya Protocol

*Flow-Assisted Surgical Techniques ("F•A•S•T") and Protocols are drawn from surgical experiences by transit-time flow measurement users and passed along by Transonic for educational purposes. They are not intended to be used as sole basis for diagnosis. Clinical interpretation of each patient’s individual case is required.

Introduction1,3

One strategy a surgeon may elect to use to alleviate the symptoms of Moyamoya syndrome is the surgical creation of an arterial extracranial to intracranial (EC-IC) bypass from the superficial temporal artery (STA) to the M4 middle cerebral artery branch. The bypass is designed to augment flow in the intracranial territories. During surgery, the Charbel Micro-Flowprobe® is used to measure direct volume blood flow in the STA bypass and small target M4/MCA vessels. Intraoperative blood flow measurements confirm the quality of the anastomosis and assure that the target area is receiving sufficient blood from the bypass. Measurements also prompt revision if a technical error is suspected.

Flow Measurement Steps1,2

Measure mean arterial pressure (MAP), end-tidal CO₂ and temperature. Record values on an EC-IC Bypass Flow Record.

Pre-anastomosis: Intracranial Recipient Artery

1. Measure the diameter of the intracranial recipient artery (M4/MCA) and choose an appropriately sized Charbel Micro-Flowprobe® to measure recipient vessel flow.

<table>
<thead>
<tr>
<th>Probe Size</th>
<th>Vessel Range, Outer Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 mm</td>
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</tr>
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<td>3 mm</td>
<td>2.3 - 3.4 mm</td>
</tr>
</tbody>
</table>

2. Measure recipient vessel (M4/MCA) flow.
3. Record flow and flow direction on EC-IC Bypass Record.

Extracranial Donor Artery1,2

4. Dissect the extracranial STA artery free. Skeletonize a segment for application of the Flowprobe.
5. Measure the diameter of the STA and choose the appropriately sized Flowprobe to measure STA baseline flow.

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<td>3 mm</td>
<td>2.3 - 3.4 mm</td>
</tr>
</tbody>
</table>

Post-anastomotic Flow Measurements

6. After construction of the STA-MCA bypass, measure post–anastomotic flows in the intracranial and extracranial arteries sequentially in the following order:

1) distal M4/MCA (Fig. 3);
2) proximal M4/MCA;
3) distal STA;
4) proximal STA.

7. If post-bypass flow in the recipient artery (sum of absolute values of distal and proximal M4/MCA flow) is not significantly above the pre-bypass flow, re-examine the anastomosis and the bypass for kinks or twists and redo, if necessary. Apply a vasodilator (papaverine) when there has been some vasospasm due to manipulation of the vessel and/ or flow measurements seem to be low or absent.

8. Record flow rates and flow directions, MAP, end-tidal CO₂, and occlusion time on the EC-IC Bypass Record.

References:

Flow-assisted Surgical Techniques and Notes*
STA-MCA Bypass for Moyamoya Protocol cont.

Flow Measurement during EC-IC Bypass
Revascularization for Moyamoya Syndrome\textsuperscript{1-4}

- Measure size of recipient intracranial artery (M4/MCA) and choose appropriate size Flowprobe.
- Measure baseline flow of recipient intracranial artery (M4/MCA) at anastomotic site. Record flow.
- Measure size of donor artery (STA) at distal end and choose appropriate size Flowprobe.
- Cut donor STA
- Optional: measure/record free (cut) flow in donor STA.
- Construct EC-IC bypass by anastomosing STA to M4/MCA.
- Measure post-bypass flows proximal and distal to the anastomosis in the recipient vessel and donor STA. Record all flow rates.

- **M4 flows did not increase**
  - Examine anastomosis; examine bypass for kinks etc. Analyze recipient bed.

- **M4 flows increased**
  - Good bypass.

- **M4 flows increased significantly**
  - Aggressive post-op management indicated to avoid complications.
Flow-assisted Surgical Techniques and Notes*
Arterial EC-IC Bypass Surgery Protocol

Drawn from the clinical expertise of FT Charbel, MD, FACS, S Amin-Hanjani, Univ. of IL at Chicago, Chicago, IL et al.1-24

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Introduction
An extracranial to intracranial (EC-IC) bypass is used during cerebrovascular surgery:
1) to augment flow for occlusive cerebrovascular disease (ie, Moyamoya)
2) to replace flow during aneurysm clipping surgery when an aneurysm is trapped and a parent vessel (ie, internal carotid) has to be occluded and sacrificed.

Flow Augmentation for Occlusive Cerebrovascular Disease1-5
In 2005, Drs. Fady Charbel and Sepideh Amin-Hanjani introduced the concept of a Cut Flow Index to evaluate the quality of an EC-IC bypass used to enhance flow during cerebral ischemia. Briefly, the free flow of the donor extracranial artery intended for use as a bypass is measured. Once the bypass is constructed, the bypass flow of the donor artery is measured. The ratio of bypass flow to free flow is the Cut Flow Index. A value greater than 0.5 indicates that the bypass should be viable.

Flow Replacement for during Aneurysm Clipping Surgery1,6
Dr. Amin-Hanjani developed a strategy to assess the adequacy of a STA-or an occipital artery bypass to replace flow when a aneurysm has to be trapped and a parent vessel sacrificed.

Flow Deficit Determined
Flow in the artery or territory distal to the aneurysm is measured and recorded. The vessel to be sacrificed is temporarily occluded and flow is again measured in the distal artery or territory. The difference between the two flows represents the amount of flow deficit that can be expected if the parent vessel is sacrificed. This is the flow that the bypass will have to replace.

Free Flow Determined
The “free” or “Cut Flow” of the intended bypass is then measured. This Cut Flow value is compared to Deficit Flow. If the Cut Flow value equals or exceeds the potential flow deficit, the EC-IC bypass is completed and the vessel can be sacrificed with reasonable assurance that the bypass flow will compensate for the flow deficit from the sacrificed parent vessel.

Example: STA to M3 Bypass (ICA Aneurysm Clipped, Trapped and ICA Sacrificed)1,6
1) M1 baseline flow measured 70 mL/min
2) M1 flow measured with ICA temporarily occluded 50 mL/min
3) Anticipated Flow Deficit Calculated 20 mL/min
   (if aneurysm trapped and parent vessel sacrificed)
4) STA Cut Flow measured 44 mL/min
   (STA bypass should be able to supply the flow deficit)
5) STA Bypass to M3 completed; aneurysm clipped and trapped
6) STA Bypass Graft Flow measured 24 mL/min
   (bypass flow can compensate for anticipated flow deficit)

Dr. Amin-Hanjani reported that this selective strategy allows the surgeon to:
1) Assess the adequacy of a bypass before completing its construction
2) Select the best match for a bypass
3) Evaluate the bypass immediately
Flow-assisted Surgical Techniques and Notes
Arterial EC-IC Bypass Surgery Protocol cont.

When a surgeon selects an arterial extracranial-intracranial (EC-IC) Bypass to preserve flow during aneurysm clipping or trapping surgery, Charbel Micro-Flowprobes assess the adequacy of flow(s) during and after construction of the bypass.1-5

**Extracranial Donor Artery**1-7
1. Choose an appropriate sized Extracranial Probe for the donor artery.

<table>
<thead>
<tr>
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</tr>
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<tr>
<td>3 mm</td>
<td>2.5 - 3.3 mm</td>
</tr>
<tr>
<td>4 mm</td>
<td>3.3 - 4.9 mm</td>
</tr>
<tr>
<td>6 mm</td>
<td>4.4 - 6.9 mm</td>
</tr>
</tbody>
</table>

2. Measure baseline flow in the donor artery. Record on the EC-IC Bypass Record.

3. Cut the donor extracranial artery and measure the artery’s “Free Flow” by allowing the cut distal end to bleed freely for 15-20 seconds. This free flow or “Cut Flow” is the amount of flow at zero resistance or the “carrying” capacity or maximum flow the artery can deliver. Record flow on the EC-IC Bypass Record.5

**Intracranial Recipient Artery**1-7
1. Choose an appropriate size Charbel Flowprobe for recipient artery.

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<td>3 mm</td>
<td>2.3 - 3.4 mm</td>
</tr>
</tbody>
</table>

2. Measure and record baseline flow in recipient intracranial artery distal to target anastomotic site.

3. Re-measure, record baseline flow in recipient intracranial artery distal to target anastomotic site with vessel to be sacrificed occluded.

4. Calculate anticipated flow deficit by subtracting flow with vessel occluded from baseline recipient arterial flow.

**Construct EC-IC Bypass**1-7
1. Anastomose the extracranial bypass to the recipient arterial vessel.
2. Measure post-bypass flow in the donor artery (Fig. 2). Record flow.
3. Calculate the Cut Flow Index (CFI) by dividing the Post-Bypass Flow by the Free or Cut Flow (Fig. 1).
   - If post-bypass flow exceeds 50% of (CFI > 0.5), the bypass can be considered successful.
   - If bypass flow is below 50% of free flow (CFI < 0.5), examine bypass for kinks, analyze recipient bed.
Flow-assisted Surgical Techniques and Notes
Arterial EC-IC Bypass Surgery Protocol cont.

EC-IC Bypass for Aneurysm Clipping and Trapping Surgery

**INTRACRANIAL**

- Select probe for recipient intracranial artery
- Measure & record baseline flow in recipient intracranial artery (territory) distal to target anastomosis site
- Occlude vessel to be sacrificed and measure and record baseline flow in distal recipient intracranial artery (territory)
- Calculate anticipated Flow Deficit

Flow Deficit = Baseline Flow minus flow with vessel occluded

**EXTRACRANIAL**

- Select probe for donor extracranial artery
- Measure in situ baseline flow in donor extracranial artery.
- Cut donor extracranial artery
- Measure & record free flow (Cut Flow) in donor artery

**Compare anticipated Flow Deficit with Cut Flow**

CFI = \[
\frac{\text{Cut "Free" Flow}}{\text{Baseline Flow minus flow with vessel occluded}}
\]

**Post Bypass Flow**

- CF > anticipated flow deficit
  - Proceed to construct bypass, trap aneurysm and sacrifice vessel
- CF < flow deficit
  - Consider another operative strategy

- Measure, record donor artery post-bypass flow
- Calculate Cut Flow Index (CFI)
  - CFI < 0.5
    - Examine bypass for kinks etc. Analyze recipient bed
  - CFI > 0.5
    - Patent Bypass

- Measure proximal, distal recipient artery post-bypass flows to document surgical success


Flow-assisted Surgical Techniques and Notes*
AVM Resection Protocol

Introduction1,3,4
During a microsurgical resection/obliteration of an arteriovenous malformation (AVM), a cerebrovascular surgeon may elect to use a Charbel Micro-Flowprobe® (Fig. 1) as a quantitative tool to directly measure volume blood flow in cerebral vessels in order to guide the surgical strategies.

Measurements Steps1,3

Pre-resection:
1. Identify Vessels to be measured
   Expose and identify afferent vessels and venous outflow vessels of an AVM.
2. Select Flowprobe Size
   Measure the vessel diameter of the vessels with a gauge before opening the Flowprobe package. Select a Flowprobe size so that the vessel will fill between 75% - 100% of the ultrasonic sensing window of the Flowprobe.
3. Apply Flowprobe
   Determine the optimal position for applying the Probe on the vessel by selecting a site wide enough to accommodate the Flowprobe's acoustic reflector without compromising perforating arteries coming off the vessel. Apply the Flowprobe so that the entire vessel lies within the ultrasonic sensing window of the Flowprobe and aligns with the Probe body (Fig. 2). Bend the Flowprobe's flexible neck segment as needed (Fig. 1). As the Flowprobe is being applied to the vessel, listen to FlowSound®. The higher the pitch, the greater the flow.
   Sterile saline or cerebrospinal fluid may be used to flood the Flowprobe's lumen and provide ultrasound coupling. Do not irrigate continuously because the Flowprobe will also measure saline flowing around the vessel. The Signal Quality Indicator on the Flowmeter or Monitor indicates acoustic contact. If acoustic contact fails below an acceptable value, an acoustic error message will be displayed.
4. Measure Baseline Flows before Resection
   Before AVM resection, and following burst suppression, measure baseline flows in all afferent, transit and venous vessels. Record the baseline flow measurements and the patient's blood pressure on a Flow Record.
5. Measure Flows during and Post Resection
   During resection, measure flows as needed in each of the vessels. In possible transit arteries measure at different sites along the vessel. A drop in flow between two points on the vessel might identify an additional feeder into the AVM. Compare flows with baseline flows to guide the surgical procedure. Measure flows post resection to ensure total obliteration of the AVM.
6. Document Flows
   Document flow phasic flow patterns for the case record by waiting 10-15 seconds after applying the Flowprobe for mean readings to stabilize. If a negative flow is displayed, press the INVERT button to change the polarity before printing the waveform.

References:

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Flow-assisted Surgical Techniques and Notes*
AVM Resection Protocol cont.

Flow-Guided AVM Resection

**Pre-dissection**

- **ICG-VA**
  - AVM Architecture
  - Measure flow on all exposed vessels, especially on vessels not shown by ICG-VA
  - Determine Baseline Flows
  - Determine surgical strategy for AVM dissection

**Measure flow as needed**

- Note flow direction of vessels entering AVM
- Note any drops in flow values along single vessels running close to AVM
- Compare to baseline flow data
- Note if vessel is arterial feeder or venous drainage
- Determine if vessel is transit artery
- Note hemodynamic changes in AVM

**Measure flow on venous drainage before section/closure**

- Flow value: > 1 mL/min
- Further AVM dissection to detect missed feeder(s)
- Compare to baseline flow data
- Dissect venous drainage
- AVM resection complete

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(Transonic Reference # 10288AH)
Cerebrovascular Flowprobes®
To Fit Your Needs

Available in Reusable 16-time Use or Pre-Sterilized Single-Use Flowprobes

Charbel Intracranial Micro-Flowprobe®

Charbel Intracranial Micro-Flowprobes® are designed for deep intracranial surgery (aneurysm clipping, AVM & tumor resections, EC-IC Bypass). Its long bayonet handle permits use under a surgical microscope and its flexible neck segment permits the probe to be optimally positioned around a vessel.

Charbel Extracranial Micro-Flowprobe®

Extracranial-Micro-Flowprobes (3 mm, 4 mm, 6 mm) feature a shorter bayonet handle and larger flowsensing body to be used during on extracranial vessels during EC-IC bypass surgery.
Transonic: The Cerebrovascular Flowprobe Innovator

Charbel Intracranial & Extracranial Micro-Flowprobes®

Charbel Intracranial Micro-Flowprobes® are available in 1.5, 2 and 3 mm sizes.


*"Flow is a vital parameter during cerebrovascular surgery; including flow in my surgical approach gives me a high degree of control over surgical outcome. When I close the patient, I know the patient will recover without ischemia surprises. This translates into peace of mind for the patient and me, and saves money for the hospital.

F Charbel, MD, FACS

*"Transit-time flow measurements are useful for surgical management during cerebrovascular surgery. The technique was simple to use and provided sensitive, stable, reliable results. The method revealed distal branch flow drop after aneurysm clipping, or residual flow during temporary clipping, and has the potential to predict post-operative complications in bypass or carotid endarterectomy surgeries.

N Nakayama, MD

Transonic Systems Inc. is a global manufacturer of innovative biomedical measurement equipment. Founded in 1983, Transonic sells "gold standard" transit-time ultrasound flowmeters and monitors for surgical, hemodialysis, pediatric critical care, perfusion, interventional radiology and research applications. In addition, Transonic provides pressure and pressure volume systems, laser Doppler flowmeters and telemetry systems.

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3. Charbel FT, Meglio G, Amin-Hanjani S, "Superficial temporal artery-to-middle cerebral artery bypass," Neurosurgery 2005; 56(1 Suppl): 186-90; discussion 186-90. (Transonic Reference # 2921AH); Careful attention to technique at every stage of the operation is crucial for successful EC-IC bypass. "Adherence to a stereotyped step-by-step approach to this operation, with recognition of the importance of every step, can result in consistent technical success."


5. Nakayama N, Kuroda S, Houkin K, Takikawa S, Abe H, "Intraoperative Measurement of Arterial Blood Flow Using a Transit-Time Flowmeter: Monitoring of Hemodynamic Changes During Cerebrovascular Surgery," Acta Neurochirurgica 2001; 143: 17-24. (Transonic Reference # 1831AH); Transit-time flow measurements are useful for surgical management during cerebrovascular surgery. The technique was simple to use and provided sensitive, stable, reliable results. The method revealed distal branch flow drop after aneurysm clipping, or residual flow during temporary clipping, and has the potential to predict post-operative complications in bypass or carotid endarterectomy surgeries.


7. Kirk HJ, Rao PJ, Seow K, Fuller J, Chandran N, Khurana VG, "Intraoperative Transit-time Flowmetry Reduces the Risk of Ischemic Neurological Deficits in Neurosurgery," Br J Neurosurg 2009; 23(1): 40-7. (Transonic Reference # 774AH); Transit-time ultrasound flowmetry provides immediate feedback regarding vessel patency and clip-related arterial compromise and local vasospasm. It was found to have a broad utility in intra-cranial surgery including AVMs, fistulae disconnections and tumor excisions. Transit-time ultrasound flowmetry was found to be was safe, rapidly performed, easy to interpret and generally reliable. Its use contributes significantly to the safety of patients.

8. Lee M, Guzman R, Bell-Stephens T, Steinberg GK, "Intraoperative Blood Flow Analysis of Direct Revascularization Procedures in Patients with Moyamoya Disease," J Cereb Blood Flow Metab 2011; 31(1): 262-74. (Transonic Reference: # 7969AH); This landmark moyamoya study is the largest single center study for direct revascularization for Moyamoya published. The authors conclude that surgery is the mainstay for treatment of moyamoya disease; direct revascularization surgery promotes clinical benefits more promptly, with low morbidity; revascularization results in a four-fivefold increase in blood flow through the anastomosis; STA diameter and flow is the main determinants of blood flow augmentation.

9. Nossek E, Chalif DJ, Dehdashti AR, "How I Do It: Occipital Artery to Posterior Inferior Cerebellar Artery Bypass," Acta Neurochir (Wien) 2014; 156(5): 971-5. (Transonic Reference # 1007AH); An occipital artery to posterior inferior cerebellar artery (OA-PICA) bypass option should remain as a treatment modality in the armamentarium of neurosurgeons. Check the flow in the distal PICA while the proximal PICA is clamped and compare to the baseline PICA flow.

10. Durand A, Penchet G, Thines L, "Intra-operative monitoring by imaging and electrophysiological techniques during giant intracranial aneurysm surgery," Neurochirurgie. 2016; 62(1): 14-9. (Transonic Reference # 117AH); "Precise measurement of flow with a flowmeter is also a valuable tool to certify that brain perfusion is preserved in the main distal arteries after occluding a GIA. Its use is also strongly recommended if a bypass procedure is added to the microsurgical treatment of a GIA in order to certify that the target flow is obtained in the bypass before occluding the parent artery carrying the aneurysm. The risk of secondary occlusion of superficial temporal artery to middle cerebral artery bypass could also be predicted by measuring the cut flow index peripheratively. It is defined as the ratio between the final bypass flow and the primary flow obtained at the sectioned end of the donor artery ("cut flow"). An index inferior to 0.5 seems to be a strong indicator of bypass dysfunction with a high risk of secondary thrombosis (50%)."