Reduce Allograft Risk with Intraoperative Flow Measurements

- Identify Impaired Blood Flow before Closure
- Assess Flow Quickly and Quantitively
- Document Restored Flow
Intraoperative Measurements Inform during Transplantation Surgery

Lifesaving transplant surgeries challenge a transplant surgical team to perform at their highest level. During these high stake surgeries, intraoperative blood flow measurements provide quick, quantitative assessments of blood flow that may either confirm a clinical impression or alert the team to potential problems while they still can be more easily addressed.

Orthotopic liver transplantation, in particular, presents a unique opportunity for intraoperative flow measurements. Measurements are incorporated into the protocol for the multicenter Adult-to-Adult Living Donor Liver Transplantation (A2ALL) study. Since simple visualization of a pink-to-red reperfused liver doesn’t ensure that both the hepatic artery and portal vein are each functioning, simultaneous hepatic/portal measurements provide an essential quality assurance.

In addition to checking the quality of anastomoses in liver, renal, pancreatic, lung and heart transplant surgeries, intraoperative measurements also identify potential kinking of conduits, particularly veins, and are useful in identifying donor-to-recipient mismatches. No other flow technology produces flow data as quickly, accurately and non-intrusively during transplant surgery as Transonic® intraoperative flow measurements.

“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.

“Transplant surgeons to evaluate flows in the hepatic artery and portal vein in the setting of living donor liver transplantation. This formal process allowed us the evaluate the impact of flows on eventual graft function and correlate with risk factors for graft failure.”

Emond, J, MD, Chief of Transplantation, Columbia Presbyterian Medical Center, Co-chair, A2ALL Study.

“The routine use of intraoperative flow measurements of the hepatic artery may be a useful adjunct in identifying the hepatic artery reconstruction, which is at risk of subsequent hepatic arterial thrombosis (HAT).”


“Impaired hepatic arterial blood flow after reperfusion along with primary non-functioning organ (PNF) are significant predictors of increased graft injury and is associated with diminished long-term graft survival. ...Intraoperative transit time ultrasound flow measurements of the hepatic artery may allow identification of organ transplants at risk for poor outcomes. ...Hepatic arterial flow < 100 ml/min presents a significant risk on organ survival.”


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.
Vascular Flowprobes for TX Surgery

Transonic® Flowprobes work with HT300-Series Flowmeters to measure volume flow in blood vessels and grafts from 0.5 to 36.0 mm. The measurement of flow in vessels during transplant procedures can guide surgical decisions. The ability to correct otherwise undetectable flow restrictions provides the surgeon with an opportunity to improve the outcome for the patient.

**FLOWPROBES: TRANSPLANT SURGERY**

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Probe Size (mm)</th>
<th>Probe Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIVER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>hepatic artery</td>
<td>4, 6</td>
<td>FMV</td>
</tr>
<tr>
<td>portal vein</td>
<td>10, 12, 14</td>
<td>FMV, -AU</td>
</tr>
<tr>
<td>KIDNEY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ascending aorta</td>
<td>4, 6</td>
<td>FMV, -FSB</td>
</tr>
<tr>
<td>pulmonary artery</td>
<td>10</td>
<td>FMV, -FSB</td>
</tr>
<tr>
<td>PANCREAS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>common iliac artery</td>
<td>8</td>
<td>FMV, -FSB</td>
</tr>
</tbody>
</table>

Fig. 1: 4 and 6 mm Vascular Flowprobes recommended for measuring hepatic arterial flow. Picture shows Flowprobe handle with size of Probe in mm, the Probe's flexible neck for optimal positioning of the Probe around the vessel, the Probe body that houses the ultrasonic transducers, and the Probe reflector. Vessel is positioned within the Probe sensing window that is defined by the Probe body and its stationary reflector.

Fig. 2: 8 mm, 10 mm, 12 mm and 14 mm Vascular Flowprobes recommended for measuring portal venous flow.
COnfidence Flowprobes for TX Surgery

Four-transducer COnfidence Flowprobes® provide highly accurate measurements in vessels with turbulent flows such as the ascending aorta or portal vein. Available in 15 sizes from 8 mm to 36 mm, the Flowprobe’s slim, ergonomic profile is designed for measurements in great vessels in adults, pediatrics, and even neonates where a small Probe footprint is desirable. COnfidence Flowprobes® may be left in place for extended measurements and then easily removed via a ring attached to the pliable liner that cushions and protects the vessel.

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Intraoperative Blood Flow Measurement during Adult Orthotopic Liver Transplantation

Introduction
Abnormal hepatic hemodynamics and physiology in the transplanted liver pose continuing challenges for the surgeon. A practical method for measuring two of these hemodynamic parameters, portal venous and hepatic arterial flows, is by intraoperative flow measurements. Transit-time ultrasound technology is well suited to measure these flows. Flowprobes are easily applied and do not have to be applied tightly to vessels; they simply encompass the vessel.

Surgical Approach
Measurement of portal venous and hepatic arterial flows can be easily done at the completion of orthotopic liver transplantation using Transonic Flowprobes. Following completion of the vascular anastomoses, the new liver is reperfused, and hemostasis achieved. Prior to biliary reconstruction, the Flowprobes are placed on the reconstructed portal vein and hepatic artery.

The Probes are chosen to comfortably encompass - but not constrict - the vessels, and are placed such that extraneous tissue is excluded. The field is then immersed in saline which serves as a good acoustic contact with the vessels. Readings stabilize rapidly, usually within 1-2 minutes, and in stable patients fluctuate less than ± 10% when left in situ for 10-15 minutes. If there is wider fluctuation, this usually indicates improper positioning of the Flowprobes with poor alignment or extraneous tissue, and can normally be corrected by repositioning. Arterial flow readings are meaningful over a brief snapshot period. Venous flow exhibits a far slower rhythm, dictated by events such as gastric motility. A one-to-five minute observation period is often adequate.

Discussion
Combined portal venous and hepatic artery flow are usually 15 - 25% of cardiac output. Of clinical importance is hepatic artery patency and flow, as survival of the graft depends on this. Flowprobes provide a volumetric measure of hepatic artery flow, and when this is low can be used to determine if there is a fixed anatomic limitation to flow or a physiologic limitation. For example, in a patient with a cardiac output of 10 L/min, portal flow of 2000 ml/min and hepatic artery flow of 75 ml/min, reduction of portal flow to 1000 ml/min resulted in a hepatic artery flow increase to 125 ml/min. Thus, the low basal hepatic artery flow resulted from a high physiologic resistance rather than a fixed, potentially surgically correctable low inflow. This kind of data can be collected on the flowmeter’s strip chart recorder for a permanent record.

The information obtained with these transit-time ultrasound Flowprobes is often at variance with “clinical impression.” A transplant with obstructed hepatic artery may show a strong pressure pulse on the artery, and a healthy organ color due to its venous perfusion. Accurate information on volumetric flow at the time of operation can either be reassuring, or may indicate an unexpected problem which can be fixed at this time.
In a procedure such as liver transplant, where the stakes are high, this technology can be a useful adjunct in operative decision. Subsequent studies have identified the following intraoperative flow indices related to poor outcomes:

- Poor outcome is associated with graft hyperfusion. Recipient portal venous flow in the recipient should be lowered when graft to recipient body weight ratio (GRBWR) < 0.8 is accompanied by portal inflow of > 250 mL/min/100g graft weight.\(^3\)
- Hepatic arterial flow < 100 mL/min presents a significant risk on organ survival.\(^4\)
- Hepatic artery flows of less than 200 mL/min following orthotopic liver transplantation increase the risk of subsequent hepatic artery thrombosis six times.\(^5\)

### References


Adult Liver Donor Liver Transplantation

Hepatic Artery & Portal Vein

Protocol

Living Donor

Measure right hepatic arterial and portal venous flow before hilar dissection.

Document measurements to serve as guide for expected flows in the recipient.

Recipient

Recipient Hepatic Flow

Measure hepatic blood flow
- following reperfusion
- before biliary anastomosis
- before wound closure

Compare with pre-transplant hepatic arterial flow

< 50 mL/min

Examine anastomosis for arterial thrombosis

> 100 mL/min

Remeasure hepatic flow

Flow has increased

Recipient Portal Flow

Measure portal blood flow
- following reperfusion
- after portal pressure measurement
- before biliary anastomosis

Compare with pre-transplant portal venous flow

Flow increased
up to 3 times
pre-transplant portal flow

or >250 mL/min/110 gram graft weight

Reduced graft inflow by shunting portal flow away from liver

Flow increased > 3 times
pre-transplant portal flow

Remeasure portal flow

Document flows and save waveforms for the operative record for post-op diagnostic consideration

Living Donor

Medical Note

Intraoperative Blood Flow Measurement during Renal Transplantation

Courtesy of Anders Lundell, MD, PhD, Nils H. Persson, MD, PhD, Dept. of Transplantation, Dept. of Surgery, Malmö General Hospital, Malmö, Sweden

Renal Arterial Flow Measurement

Donor: Living Donor Kidney Retrieval
The first measurement is made on the renal artery before the kidney is removed from the donor.

Recipient: Living Donor or Cadaver Kidneys
In primary transplantations, we use the hypogastric artery for the arterial anastomosis. In re-transplantations or in cases where the internal iliac is atherosclerotic the external iliac artery is used. In selected cases, we use a flow measurement to decide which artery to use. For the venous anastomosis, the external iliac is used. No venous flow measurements are made.

After completion of the arterial and venous anastomoses, and immediately after restoration of blood flow to the kidney, but before completion of the ureteroneocystostomy, the flow in the renal artery is measured. We use a 4 or 6 mm Flowprobe which is placed, preferably, distal to the anastomosis. The space between the Probe and the vessel is filled with sterile physiological saline. Care is taken to avoid kinking the artery and to place the Probe perpendicular to the longitudinal axis of the vessel. Before the flow is recorded, we allow the flow signal to stabilize for 15-20 seconds. At the end of the operation, after the ureteroneocystostomy is completed and before the wound is closed, we make a second measurement.

<table>
<thead>
<tr>
<th>MEAN RENAL ARTERIAL FLOWS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRANSPLOATED KIDNEY (N = 34)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Flow: Cadaver Kidney (mL/mm)</th>
<th>Flow: Living Donor Kidney (mL/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Donor</td>
<td></td>
<td>381 ± 150 SD</td>
</tr>
<tr>
<td>Post flow restoration</td>
<td>283 ± 148 SD</td>
<td>338 ± 155 SD</td>
</tr>
<tr>
<td>At end of operation</td>
<td>422 ± 204 SD</td>
<td>505 ± 177 SD</td>
</tr>
</tbody>
</table>
Intraoperative Blood Flow Measurement

Renal Artery Measurement Protocol

**Donor**

**Cadaver Kidney**
No measurements

**Living Donor Kidney**
Measure renal arterial flow before removing the kidney

Document measurements to serve as guide for expected renal flow in the recipient.

**Recipient**

Measure renal arterial blood flow following arterial anastomosis

Adequate flow: > 250 mL/min

Check for technical error:
Apply vasodilator & wait several minutes (up to 1 hour)

Remeasure renal flow

Adequate flow: > 250 mL/min

YES

Document flows and save waveforms for the operative record.

NO

Continue attempts to improve flow.

Document measurement for operative record:
Assess other clinical parameters (perfusion, urine output)
Consider post-op prophylactic treatment.


Renal Transplantation

Case Reports

Fig. 1: The donor’s renal arterial blood flow prior to excision of the kidney measured 376 mL/min. After anastomosis to the recipient’s renal artery, post-reperfusion renal flow measured 91 mL/min. A second measurement was made after 30 minutes. Renal arterial flow had increased to 290 mL/min.

Waveforms courtesy of Renal Transplantation Unit, Hermann Hospital, Texas Medical Center, Houston, TX.

Fig. 2: The donor’s renal arterial blood flow before traditional removal of the kidney measured 538 mL/min. After anastomosis to the recipient’s renal artery, renal flow post-reperfusion measured 766 mL/min.

Fig. 3: Before a difficult laparoscopic removal of the kidney, the donor’s renal arterial blood flow measured 622 mL/min. After anastomosis to the recipient’s renal artery, renal flow post-reperfusion measured 322 mL/min. One hour later, flow had increased to 442 mL/min.

Fig. 4: Before laparoscopic removal of the kidney, the donor’s renal arterial blood flow measured 91 mL/min. After anastomosis to the recipient’s renal artery, renal flow post-reperfusion measured 290 mL/min.

Waveforms courtesy of Renal Transplantation Unit, Hermann Hospital, Texas Medical Center, Houston, TX.
Equipment

HT354 single-channel Optima Flowmeter to acquire precise actual flow measurement quickly and easily.

HT163 dual-channel Optima Flowmeter, permits simultaneous measurements with two Flowprobes. This allows the ability to compare flows simultaneously, or in quick succession, without the need for a second meter.

References:


Wolters HH et al, “The anastomosis between renal polar arteries and arteria epigastrica inferior in kidney transplantation: an option to decrease the risk of ureter necrosis?” Transplant International 14(6): (Transonic Reference # 7025AH)


FMV Vascular Handle Flowprobes for spot flow checks during renal transplant surgery

FLOWPROBE RECOMMENDATIONS

<table>
<thead>
<tr>
<th>VESSEL</th>
<th>Probe Size (mm)</th>
<th>Handle Probe Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renal artery</td>
<td>4, 6</td>
<td>-FMV</td>
</tr>
<tr>
<td>Renal vein</td>
<td>10</td>
<td>-FMV</td>
</tr>
<tr>
<td>External iliac artery</td>
<td>6, 8</td>
<td>-FMV</td>
</tr>
<tr>
<td>Hypogastric a</td>
<td>4, 6</td>
<td>-FMV</td>
</tr>
</tbody>
</table>

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Flow Measurement during Islet Infusion
Excising a diseased pancreas removes not only pancreatic cells that produce digestive enzymes but also islet of Langerhans cells that produce insulin to control blood sugar. Without insulin a patient becomes diabetic and requires lifelong use of insulin to control blood sugars.

Auto islet cell transplantation takes these islet of Langerhans cells from the pancreas and transplants them to the liver to reduce the diabetic risk. To do this, the removed pancreas is processed to isolate the insulin-producing islets of Langerhans cells. The isolated cells are suspended in a solution and are then slowly infused through the splenic vein back into the patient’s liver where it is hoped that they will implant, grow and produce insulin to metabolize sugar.

Typically, 800 - 1500 cc of solution is infused into the portal vein distal to the splenic vein (Fig. 2) over an extended period of time. The team may elect to infuse a small amount over 5 minutes and allow the patient to recover before resuming the infusion. Blood pressure and flow are monitored continuously and for ten minutes after the infusion is completed (Fig. 1).

Flow Measurement during Islet Infusion
Surgeons measure portal venous flow during islet cell infusion to detect any sudden decrease in flow that may foreshadow a problem with the infusion. A 10 mm to 14 mm Perivascular Flowprobe is placed on the portal vein and flow is measured continuously. The Flowprobe is chosen to comfortably encompass - but not constrict - the portal vein. If needed, saline can be used to provide acoustic contact between the vein and Flowprobe. Readings stabilize within 1-2 minutes. Wide fluctuation of measurements may indicate improper positioning of the Flowprobe with poor alignment or fat within the ultrasonic sensing window. Repositioning can normally correct this problem.

Discussion
In this high stakes auto islet cell transplantation procedure, Flowprobes provide a continuous volumetric measure of portal vein flow to inform the surgeon about the safety, fluidity and success of auto islet cell transplantation.

Equipment Needs

HT354 Single-channel Optima Flowmeter. Acquire precise actual flow measurement quickly, easily and cost effectively.

COnfidence Flowprobes® provide highly accurate measurements in vessels with fluctuating flows such as the portal vein. The Probes may be left in place for extended measurements and then easily removed via a ring attached to the pliable liner that cushions and protects the vessel.

8 mm to 14 mm FMV Vascular Handle Flowprobes are recommended for portal venous flow measurements during islet cell infusion.

References


http://www.hopkinsmedicine.org/transplant/programs/auto_islet/description.html#total_pancreatectomy


Medical Note


Courtesy of J. Michael Henderson, M.D., F.A.C.S., The Cleveland Clinic Foundation

Rationale
A distal spleno-renal shunt (DSRS) provides selective variceal decompression to control bleeding gastroesophageal varices, while maintaining portal hypertension and prograde portal flow to the liver (Fig. 2).

Thrombosis of distal spleno-renal shunts occur in less than 10% of patients, but usually occurs early (in the first week) and requires reoperation. Intraoperative measurement of shunt flow shows great potential to reduce the risk of this complication.

Surgical Approach
On completion of the distal spleno-renal shunt anastomosis, 2-3 cm of the splenic vein is free below the pancreas before it is anastomosed to the left renal vein. A Transonic® Flowprobe can be placed on this segment of the splenic vein for volumetric flow measurement (Fig. 2). A Probe is chosen to fit comfortably around the vein without compressing it. It should lie in line with the vessel, and no tissue should be interposed. Contact is assured by immersing the field in saline. Flow measurements stabilize within one minute, and fluctuate less than ± 10%.

Discussion
What should the flow be in a distal spleno-renal shunt? This is a high flow shunt, with volumetric flows determined largely by spleen size. There appears to be approximately 1 mL/min flow per cubic centimeter spleen volume - i.e. a 750 cc spleen will give a shunt volumetric flow of approximately 750 mL/min.

After first removing the clamps, flow tends to be higher than it will be after 5-10 minutes when the initial hyperemia has resolved. If flow is significantly less than this approximation, a technical error should be considered.

• Is the splenic vein kinked?
• Is there a problem with the anastomosis?

Now is the time to identify and correct a technical problem: transit-time ultrasound Flowprobes offer a method for identifying low flow in this shunt.

Reference
http://www.vesalius.com/cfoli_frms.asp

Fig. 1: Schematic of splenic vein in relation to renal vein.

Fig. 2: Schematic of anastomosis of the splenic vein to the renal vein to create a distal Spleno-renal shunt.

Fig. 3: Flowprobe measuring flow in the splenic vein following anastomosis of the splenic vein to the renal vein.

Equipment Needs

HT353 Single-channel Optima Flowmeter. Acquire precise actual flow measurement quickly, easily and cost effectively. 8 mm, 10 mm and 12 mm FMV Vascular Handle Flowprobes are recommended measurement of distal spleno-renal shunt (venous) flow.

Background

Alcoholic (Laennec’s) cirrhosis of the liver is a common cause of portal hypertension. Portal hypertension extends to esophageal veins via gastric, splenic and gastroepiploic veins. When bulging esophageal varices are eroded by food passage through the esophagus, massive bleeding can result.

In 40% of U.S. cirrhosis patients, portal hypertension causes acute bleeding from the varices of the esophagus or stomach. This variceal bleeding accounts for one-third of all deaths related to cirrhosis. A significant bleeding episode is fatal 50% of the time. Of those surviving, two-thirds will rebleed. It is therefore crucial to first arrest the acute bleeding episode and then treat the portal hypertension.

One way to treat portal hypertension is through portal decompression via a surgically-created distal spleno-renal (DSRS) or Warren shunt.

A distal spleno-renal shunt is a high volume shunt that diverts splenic venous flow from the portal venous system to the renal venous system. An enlarged spleen (splenomegaly) is common in patients with end-stage-liver disease. A distal spleno-renal shunt provides good long-term control of variceal bleeding.

How Is a Distal Spleno-renal Shunt Constructed?

The abdomen is opened. The stomach and pancreas are elevated to expose the splenic vein which is isolated and mobilized by detaching it close to its junction with the portal vein. The vein is then reattached to the renal vein via an end-to-side anastomosis (Figs. 2,3). Intraoperative flow measurement during creation of a DSRS ensures good shunt flow without kinking of the vein or a problem with the anastomosis.
## Flowprobe Selection Guide

### Recommended Sizes and/or Flowprobe Series for Specific Vessels or Applications

<table>
<thead>
<tr>
<th>SUFFIX</th>
<th>DESCRIPTION</th>
<th>SIZES (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-FMC</td>
<td>Coronary (J-reflector, extended neck)</td>
<td>1.5, 2, 3, 4</td>
</tr>
<tr>
<td>-FMV</td>
<td>Vascular (J-reflector, standard handle)</td>
<td>1.5, 2, 3, 4, 6, 8, 10, 12, 14</td>
</tr>
<tr>
<td>-FME</td>
<td>Carotid (L-reflector, standard handle)</td>
<td>4, 6, 8, 10</td>
</tr>
<tr>
<td>-FTV</td>
<td>OptiMax® (J-reflector, hands-free butterfly wings)</td>
<td>4, 6, 8, 10, 12</td>
</tr>
<tr>
<td>-FTE</td>
<td>OptiMax® (L-reflector, hands-free butterfly wings)</td>
<td>4, 6, 8, 10, 12</td>
</tr>
<tr>
<td>-MU</td>
<td>Microvascular (L-reflector, standard handle)</td>
<td>0.7, 1, 1.5, 2, 3</td>
</tr>
<tr>
<td>-AU</td>
<td>Cardiac Output Confidence Flowprobe® (C-shaped design, no handle)</td>
<td>4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36</td>
</tr>
<tr>
<td>-MB;</td>
<td>Intracranial Charbel Micro-Flowprobe® (L-reflector, long bayonet handle)</td>
<td>1.5, 2, 3</td>
</tr>
<tr>
<td>-MR</td>
<td>Intracranial Charbel Micro-Flowprobe® (L-reflector, long bayonet handle)</td>
<td>3, 4, 6</td>
</tr>
<tr>
<td>-MB-S</td>
<td>Extracranial EC-IC Bypass: Micro-Flowprobe (L-reflector, short bayonet handle)</td>
<td>1.5, 2, 3, 4, 6, 8, 10, 12, 14</td>
</tr>
<tr>
<td>-MR-R</td>
<td>Extracranial EC-IC Bypass: Micro-Flowprobe (L-reflector, short bayonet handle)</td>
<td>1.5, 2, 3, 4, 6, 8, 10, 12, 14</td>
</tr>
<tr>
<td>-P</td>
<td>Port Access (J-reflector, long port-access handle)</td>
<td>2, 3, 4</td>
</tr>
<tr>
<td>-FD</td>
<td>Port Access (J-reflector, long port-access handle)</td>
<td>1.5, 2, 3, 4</td>
</tr>
</tbody>
</table>

### Cardiac Surgery

**Arterial conduits**
- Saphenous vein: 2, 3, 4
- Port access - coronary arteries: 1.5, 2, 3, 4

**Cardiac output**
- Ascending aorta: 28, 32, 36
- Pulmonary artery: 24, 28, 32
- Pediatric heart: 4, 6, 8, 10, 12, 14, 16, 20

### Transplant Surgery

**Liver**
- Hepatic artery: 4, 6, 8
- Portal vein: 10, 12, 14

**Kidney**
- Renal artery: 4, 6
- Renal vein: 10
- External iliac artery: 6, 8
- Hypogastric artery: 4, 6

**Pancreas**
- Common iliac artery: 8

### Cerebrovascular Surgery

**Aneurysm Clipping**
- Cerebral arteries: 1.5, 2, 3

**EC-IC Bypass**
- Extracranial: 3, 4, 6
- Intracranial: 1.5, 2, 3

**AVM, Tumor Resection, Dural Fistula**
- Outflows: variable

### Vascular Surgery

**Carotid Endarterectomy**
- Common carotid artery: 8, 10
- External carotid artery: 6
- Internal carotid artery: 6

**AV Fistulas & Grafts**
- Radial artery: 2, 3
- Brachial artery: 3, 4, 6
- Graft venous outflow: 4, 6

**Abdominal**
- Renal bypass: 4, 6
- Aorta: 16, 20
- Common iliac: 10, 12
- Portocaval shunt: 10, 12, 14
- Splenorenal shunt: 10, 12, 14

**Lower Extremity Bypass**
- Profunda femoris: 8
- Common femoral: 8, 10
- Popliteal: 4, 6
- Tibial: 3, 4

### Microvascular Surgery

**Reattachments/Flaps**
- Microvessels in hand, wrist: 0.7, 1, 1.5, 2, 3

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