Introduction
Surgical creation and maturation of a viable AV access is the first step in enabling successful long-term hemodialysis. During fistula AV access creation, a surgeon may elect to use intraoperative blood flow measurements to:
1) To increase the probability of successful AV fistula maturation with quantitative blood flow measurements.
2) To ensure that the newly created fistula is not immediately robbing the lower arm of flow and setting the stage for ischemic steal syndrome (ISS).

Measurement Steps after AV Fistula Construction
1. Identify Vessel to Be Measured
Identify and expose the AVF’s venous outflow. Identify and expose the arterial conduit distal to the AVF anastomosis.

2. Select Flowprobe Sizes (FMV Series Flowprobes)
Measure the vein and artery’s diameters with a gauge. Select a probe so that the vein will fill between 75% - 100% of the ultrasonic sensing window of the Flowprobe (Fig. 1).

3. Check Blood Pressure
If systolic BP is greater than 100 mmHg, continue with measurement. If systolic BP is less 100 mmHg, low AV fistula flow may be caused by low BP. Wait until BP increases to more than 100 mmHg.

4. Apply Flowprobe to Vessel
1. Select a site wide enough to accommodate the Probe’s acoustic reflector.
2. Apply sterile gel to the Flowprobe to ensure good ultrasound coupling.
3. Apply the Flowprobe to the vessel, bending the Flowprobe’s flexible neck so that the entire vessel lies within the sensing window of the probe and aligns at a 90º angle with the Flowprobe handle (Fig. 1).
4. Check the Signal Quality Indicator display to verify good acoustic contact.
5. Listen to the pitch of FlowSound®. The higher the pitch, the greater the flow.

A. FISTULA MATURATION TEST
A1. Measure Venous Outflow

END-TO-END OR VENOUS END-TO-ARTERIAL SIDE ANASTOMOSIS: When the AVF is constructed with an end-to-end or venous-end-to-arterial-side anastomosis, simply measure venous outflow distal to the venous anastomosis (Fig. 2).

If the anastomosis is constructed with a venous-side-to-arterial-side anastomosis or end-artery-to-venous-side anastomosis, occlude the vein proximal to the venous anastomosis while measuring flow distal to the anastomosis (Fig. 3). If spasm occurs, papaverin can be locally infiltrated along the artery and vein while flow is continuously monitored.

A2. Document Flows
After applying a Flowprobe to a vein, wait ~ 10-15 seconds. When flow readings are stable, document flow data. If the flow reading is negative on the LED, press INVERT to reverse the polarity of the flow reading from negative to positive before printing out the waveform.

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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*
Arteriovenous Fistula Creation Protocol cont.

B. STEAL TEST

B1. Measure Fistula Arterial Flow
Measure brachial or radial arterial flow that supplies the fistula distal to the AV fistula anastomosis in order to detect imminent threat of ischemic steal syndrome (ISS) (Figs. 4-6).

B2. Evaluate Flow Values
Check that flow values are well above zero and that the direction of flow is running toward the hand (distally) and not reversed so that it is flowing (proximally) into the AV fistula. If in doubt, zero the flow by occluding the artery immediately next to the flow probe (Fig. 6).

No Steal Indication
If the blood flow running distally to the hand is well above zero, there is no imminent threat of steal.

Steal Indication
If blood flow running to the hand is close to zero and/or flow is reversed and moving up the arm toward the AV fistula, the fistula may be banded. Flow is then remeasured in the arterial segment of the artery distal to AV anastomosis (Fig. 5). This step is repeated until the surgeon is satisfied that there is sufficient flow running distal from the AV fistula anastomosis to the hand and the threat of steal is not imminent.1

B3. Document Flows
After applying a Flowprobe to the artery, wait ~ 10-15 seconds for mean readings to stabilize. When flow readings are stable, document flow. If the Flowprobe reading is negative on the LED, press INVERT to reverse the polarity of the flow reading from negative to positive before printing out the waveform.

Thresholds from the Literature

Thresholds (mL/min) to Predict AV Fistula Maturation: Comparison of Studies

<table>
<thead>
<tr>
<th>AV-Fistulas</th>
<th>Flow (mL/min)</th>
<th>Failure within 90 days (Requiring Intervention)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiocephalic</td>
<td>&lt; 170</td>
<td>56 %</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>&gt; 170</td>
<td>15 %</td>
<td></td>
</tr>
<tr>
<td>Brachiocephalic</td>
<td>&lt; 280</td>
<td>64 %</td>
<td>.01</td>
</tr>
<tr>
<td></td>
<td>&gt; 280</td>
<td>18 %</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: In radiocephalic fistulas, initial flows of less than 170 mL/min correlated with failure within 90 days. In brachiocephalic fistulas, that threshold was 280 mL/min.

Table 2: AV Fistula guidelines as identified by Johnson study.1

<table>
<thead>
<tr>
<th>Flow Rate (mL/min)</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 100</td>
<td>Abandon site</td>
</tr>
<tr>
<td>100 - 300</td>
<td>At risk for early failure; observe closely; allow to mature &gt; 4-6 weeks before using</td>
</tr>
<tr>
<td>&gt; 300</td>
<td>Allow to mature 4-6 weeks before using</td>
</tr>
</tbody>
</table>

Table 3: Comparison of AV Fistula thresholds studies to predict maturation.

References:
Flow-assisted Surgical Techniques and Notes*
Arteriovenous Fistula Creation Protocol cont.

1. Create AVF
   Identify & expose:
   a. AV fistula venous outflow
   b. Distal arterial flow

2. Measure Vein Diameter
   Select Flowprobe sizes.

3. Check systolic BP ≥ 100 mmHg
   If < 100 mmHg, wait until BP ≥ 100 mmHg

A. Fistula Maturation Test
   End-to-end or venous end-to-
   arterial side anastomosis.

A1a. Measure venous outflow
distal to anastomosis.¹

A2. Evaluate Flow per pre-established thresholds¹
   Radiocephalic: >250-300 mL/min
   Brachiocephalic: > 400 mL/min
   Basilic vein transposition: > 500 mL/min

A1b. Measure venous outflow distal
to anastomosis while occluding
vein proximal to anastomosis.¹

A2a. Fistula likely to mature.¹

A3. Examine anastomosis and site.
   Revise, if necessary.¹

A4. Remeasure and evaluate Flow
   per pre-established thresholds.¹

B. Steal Test
   Brachial or radial artery
distal to AV fistula anastomosis

B1. Measure arterial flow distal
to anastomosis while
occluding vein proximal to
anastomosis to detect
imminent steal.¹

B2. Evaluate flow values. Check
that flow runs distally and is
> zero. (Clamp to zero, if in
doubt.)

B2a. Steal not indicated.¹

B3. Steal possible; band
fistula & remeasure
distal arterial flow.¹

B4. Repeat steps above until
distal arterial flow indicates
that steal is not imminent.¹

*Flow-assisted Surgical Techniques and Notes*
Arteriovenous Fistula Creation Protocol cont.
Flow-assisted Surgical Techniques and Notes* Prosthetic Graft Creation Protocol

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Introduction1-3
Surgical creation and maturation of a viable AV access is the first critical step in enabling successful long-term hemodialysis. During AV access graft creation, a surgeon may elect to use intraoperative blood flow measurements to increase the probability of successful AV fistula maturation with quantitative blood flow measurements.

Air within synthetic graft walls attenuates ultrasound signal transmission. Therefore, flow cannot be measured directly on prosthetic PTFE grafts (Fig. 1). Graft outflow is therefore measured on the outflow vein following completion of both arterial and venous anastomoses (Figs. 2, 3). If the distal vein has not been ligated, flow is still measured proximal to the anastomosis, while the distal unligated section of the vein is temporarily occluded (Fig. 4).

Measurement Steps1

1. Identify Vessels to Be Measured
Identify the graft’s venous outflow conduit. Determine an optimum site wide enough to accommodate the Probe’s acoustic reflector for applying the Probe. Clean the vein at this site from fat and excess tissue.

2. Select Flowprobe Size
Estimate the outflow vein diameter with a gauge. Select a Probe size so that the vein will fill between 75% - 100% of the lumen of the Probe.

3. Apply Flowprobe
Apply sterile gel to the Flowprobe and apply the Flowprobe to the vein, proximal to the anastomosis. Bend the Probe’s flexible neck as necessary, so that the entire vein can lie within the lumen of the Probe and aligns with the Probe body (Fig. 5). Listen to the pitch of FlowSound® as the Flowprobe is applied to the vein. The higher the pitch, the greater the flow. Check the Signal Quality Indicator on the Flowmeter for adequate ultrasound acoustic contact. An acoustic error message will be displayed if ultrasound contact falls below an acceptable minimum.

4. Measure and Evaluate Venous Outflow
With the Flowprobe positioned as under Step 3 (above), measure venous average flow as displayed on the Flowmeter. An initial venous outflow < 400 mL/min is associated with a higher rate of initial graft failure.2 As the site recovers from surgery, flow will increase to levels preferred for hemodialysis (> 600 mL/min).1

Graft Type | Flow (mL/min) | Failure within 90 Days (Requiring Intervention) | p value
---|---|---|---
PTFE Grafts | < 400 | 65 % | .01
| > 400 | 40 % | |

Table 1: In prosthetic grafts, initial flows of less than 400 mL/min foreshadow failure within 90 days.2

PTFE-Grafts2-3

<table>
<thead>
<tr>
<th>Flow Rate</th>
<th>Recommendation</th>
</tr>
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<tbody>
<tr>
<td>≤ 250 mL/min</td>
<td>Abandon site immediately</td>
</tr>
<tr>
<td>250 - 400 mL/min</td>
<td>Consider prophylactic anti-coagulation</td>
</tr>
</tbody>
</table>

References

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Flow-assisted Surgical Techniques and Notes*
Prosthetic Graft Creation Protocol cont.

5. Document Flows
After applying a Flowprobe to a vein, wait ~ 10-15 seconds. When flow readings are stable, document flow data. If a Flowmeter reading is negative on the display, press INVERT to reverse the polarity of the flow reading from negative to positive before printing out the waveform.

Flow Measurement

1. Construct AV Graft
   Identify & expose venous outflow.

2. Measure Outflow Vein Diameter
   Select Flowprobe size.

3. Measure Blood Pressure
   Systolic BP > 100 mmHg

4a. Apply Flowprobe

4b. Wait until systolic BP > 100 mmHg
   Side-to-side or arterial end-to-venous side anastomosis.

5a. Measure venous outflow distal to anastomosis

5b. Measure venous outflow proximal to anastomosis

6. Evaluate Flow per pre-established thresholds
   Flow does not meet pre-established threshold
   Flow meets threshold

7a. AV Graft likely to be able to be used

7b. Examine anastomosis and site.
    Revise, if necessary

8. Remeasure and Evaluate Flow
   per pre-established thresholds

9. AV Prosthetic Graft use tenuous.
    Abandon, construct another graft.

6. Measure Potential for Steal Syndrome
   (OPTIONAL)
   With the Flowprobe placed on the vein as previously, measure flow with, and without, occlusion of the artery distal to the arterial anastomosis. The difference between the two readings equals flow in the distal branch of the artery. When the flow reading without distal occlusion is higher than the reading with occlusion, blood in the distal branch is flowing retrograde to augment fistula flow and vascular steal may develop. (Note: Alternately, distal arterial flow can be measured directly by placing a Flowprobe on a properly cleaned arterial site distal to the anastomosis.)
Flow-assisted Surgical Techniques and Notes*

AV Fistula Banding Protocol

Drawn from the clinical expertise of MR Scheltinga, MD, Máxima Medical Center, Veldhoven, The Netherlands.

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Introduction: Why Band a High Flow Fistula?1-8
Clinically significant Hemodialysis Access-Induced Distal Ischemia (HAIDI) is a potentially devastating complication of having a arteriovenous fistula (AVF) vascular access for hemodialysis. Published data demonstrate the need to increase AVF venous outflow resistance in HAIDI patients in order to improve their outcomes. One strategy is to band the AVF to increase AVF flow resistance, thereby reducing AVF flow and increasing distal flow. Clinical data, including cases from F van Hoek and MR Scheltinga show that banding a high-flow fistula to reduce HAIDI generally correlates with positive outcomes.2-7 In each surgical instance, a trained physician must make an expert determination on the appropriate course of action. The surgeon’s challenge is to relieve the distal ischemia while maintaining a functional AVF for hemodialysis.

Cardiac Overload4,7
When AVF flow is too high (~>2L/min), cardiac function can become compromised resulting in cardiomegaly. Banding increases AVF resistance and lowers fistula flow, thereby reducing excessive stress on the heart.

Flow-Guided Fistula Banding1-9
The surgeon begins with a pre-operative AVF flow level (determined by a Transonic® Hemodialysis Monitor in the dialysis clinic) and determines the percent decrease in AVF flow to be achieved by banding. As the band is tightened, AVF venous outflow is measured intraoperatively. These continuous measurements guide the surgeon in achieving a target AVF flow value.

Flow Measurement Steps1

Preoperative: From preoperative surveillance in the hemodialysis clinic, determine % drop in flow to be achieved by banding.

1. Identify /Expose Fistula Venous Outflow
   Make a second 1.5-cm incision at least 10 cm downstream (of the upper arm cephalic or basilic vein) towards the axilla away from the dialysis cannulation sites. Identify and expose the AVF venous outflow. Check if this part of the vein is suitable for measurements (no scar tissue/aneurysms/adhesions).

2. Select Flowprobe Size
   Measure the vein’s diameter. Select a probe so that the vein will fill between 75% - 100% of the flowsensing window of the probe (Fig. 1).

3. Measure Fistula Venous Outflow
   a) Confirm that the outflow site is wide enough to accommodate the Flowprobe’s acoustic reflector.
   b) Apply sterile gel inside the Flowprobe’s sensing window to ensure good ultrasound coupling.
   c) Apply the Flowprobe to the vein, bending the probe’s flexible neck so that the vein lies entirely within the Probe’s sensing window (Fig. 1).
   d) Check the Signal Quality Indicator on the Flowmeter to verify good acoustic contact.
   e) Listen to the pitch of FlowSound®. The higher the pitch, the greater the flow.

4. Document Flows
   When flow readings are stable, flow data can be captured by recording or taking a snapshot on the Flowmeter. If the Flowmeter reading is negative on the LED, press “INVERT” to reverse the polarity of the flow reading from negative to positive before printing out the waveform.

Flow Measurement Steps1,9

0. Pre-operative: Determine % fistula flow decrease to be achieved by banding.

1. Expose AV fistula and its venous outflow (2 incisions).

2. Expose venous outflow diameter and select Flowprobe size.

3. Apply Flowprobe to venous outflow site.

4. Measure baseline flow. Calculate target flow (baseline flow times % decrease).

5. Tighten band. Remeasure flow.

6. Repeat step 5 until flow reaches intraoperative target flow.

Fig. 1: Align the probe on the vessel as shown.
Flow-assisted Surgical Techniques and Notes*

AV Fistula Banding Protocol cont.9

Figs. 1, 2: HAIDI: Banding of an AV fistula (AVF) may be indicated for hemodialysis access induced distal ischemia (HAIDI). Preoperative angiography of HAIDI patient with radiocephalic AVF shows the absence of hand arteries visualization (Fig. 1). Tissue necrosis in the hand (Fig. 2) also indicates presence of HAIDI.

Fig. 3: Banding: Minimally invasive positioning of a Transonic volumetric flowprobe guides the degree of tightening of a 5 mm Dacron band during this procedure.

Fig. 4: A 5 mm Dacron band is fixed using a clip and stitches. In this patient, AVF thrill was maintained and radial arterial pulses returned.

Fig. 5: Banding may also be performed for a high flow AV fistula (HFA) > 2L/min. This patient suffered from chronic fatigue due to the presence of a 3.7 L/min upper arm AVF.

Fig. 6: If HFA is also associated with HAIDI, measurement of finger pressures is also required. Once an optimal combination of access flow (> access thrombotic threshold level, generally > 500 mL/min) and finger pressure (>50 mmHg) is attained, the band is fixed.

2. van Hoek F et al, ”Steal in hemodialysis patients depends on type of vascular access,” Eur J Vasc Endovasc Surg 2006; 32: 710-717.