Intraoperative Flow Measurements Optimize AV Access Surgery

- Quantify Integrity of Flow
- Foreshadow AV Access Maturation
- Guide Revision Procedures or Banding

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CE 2797

Flow-assisted AV Access Creation & Revision Surgery

Transonic® intraoperative flow measurements provide on-the-spot or continuous measurements of volume flow for a functional assessment of an AV access.

These measurements can foreshadow successful maturation of an AV fistula or graft, alert the surgeon to potential difficulties and guide the surgeon in achieving target flow values during an access revision.

SURGICAL ACCESS CREATION

Measuring flow at the time of AV fistula construction assures the surgeon that hidden flow obstructions do not jeopardize early post-op patency.

Quantitative flow data as fistulas are being surgically created can predict future maturation.

Measuring flow during PTFE graft placements can help predict patency.

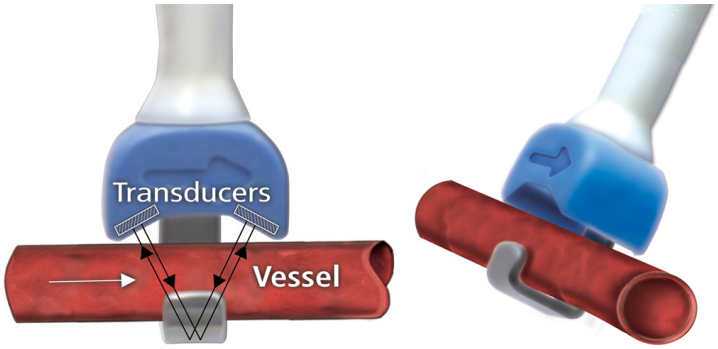
FLOW-BASED ACCESS REVISION SURGERY

Flow guided surgical banding for high flow AV accesses

Take the guesswork out of such revisions by providing the surgeon with quantitative data to reach the desired flow levels.

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.

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Transonic Systems Inc. is a global manufacturer of innovative biomedical flow measurement equipment. Founded in 1983, Transonic sells state-of-the-art, transit-time ultrasound devices for surgical, hemodialysis, perfusion, ECMO, and medical device testing applications, and for incorporation into leading edge medical devices.

USA/Canada
Transonic Systems Inc.
Tel: +1 607-257-5300
Fax: +1 607-257-7256
support@transonic.com

Europe
Transonic Europe B.V.
Tel: +31 43-407-7200
Fax: +31 43-407-7201
europe@transonic.com

Asia/Pacific
Transonic Asia Inc.
Tel: +886 3399-5806
Fax: +886 3399-5805
support@transonicasia.com

Japan
Nipro-Transonic Japan Inc.
Tel: +81 04-2946-8541
Fax: +81 04-2946-8542
japan@transonic.com

AV-AccessCoversheet(VA-100-fly)Rev C 2023

Medical Note

Transit-Time Ultrasound Intraoperative Blood Flow Measurements during Arteriovenous Fistula Creation

Protocol courtesy of Jose Zamora, M.D. San Diego, CA

Introduction

This protocol for measuring intraoperative blood flow during AV fistula creation has two goals:

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.

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 or FTV-Series)

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).

Probe Size	Nonrestrictive Vessel Range
3 mm	2.7 - 4.0 mm
4 mm	3.0 - 5.0 mm
6 mm	4.0 - 7.3 mm

Fig. 1: Outflow vein filling 75- 100% of the Probe's sensing window.

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.[1] 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 90° angle with the Flowprobe handle (Fig. 1).
4. Check the Signal Quality Indicator on the Flowmeter display to verify good acoustic contact.
5. If using a perivascular flowmeter, 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).

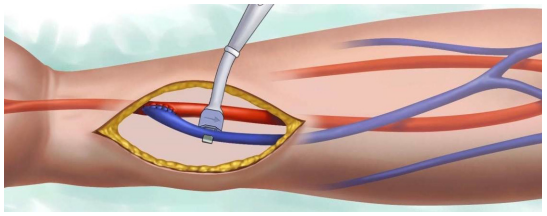

Fig. 2: Measuring venous outflow flow in a fistula anastomosed end to side.

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.

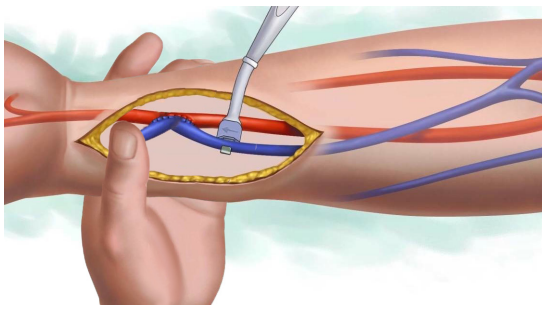

Fig. 3: Measuring venous outflow flow in a fistula anastomosed side to side.

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Intraoperative Blood Flow Measurements

Flow-Assisted Fistula Creation

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. 4-5).

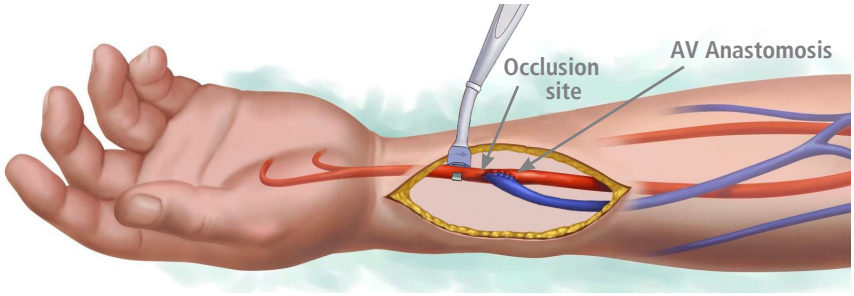


Fig. 5: Flow supplying the hand is measured with the Flowprobe placed on the artery distal to the AV anastomosis. Flow is zeroed by occluding the artery immediately adjacent to the Flowprobe.

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 flow by occluding the artery immediately next to the Flowprobe (Fig. 5).

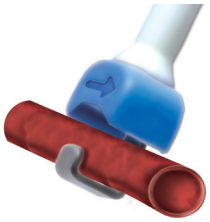


Fig. 4: Artery filling 75-100% of the Probe's sensing window.

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.

DOCUMENT FLOWS

After applying a Flowprobe to the artery or vein, wait ~ 10-15 seconds for mean readings to stabilize. When flow readings are stable, flow data can be captured by recording or taking a snapshot on the flowmeter, or by pressing PRINT on flowmeters equipped with that option. 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.

THRESHOLDS FROM THE LITERATURE

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

Summary of Results of Johnson Fistula Creation Study[1]			
AV-Fistulas	Flow (mL/min)	Failure within 90 days (Requiring Intervention)	p value
Radiocephalic	< 170	56 %	.001
	> 170	15 %	
Brachiocephalic	< 280	64 %	.01
	> 280	18 %	

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.[1]

Guidelines for Fistula Construction[1]	
Flow Rate (mL/min)	Recommendation
≤ 100	Abandon site
100 - 300	At risk for early failure; observe closely; allow to mature > 4-6 weeks before using
> 300	Allow to mature 4-6 weeks before using

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

Thresholds (mL/min) Predict Fistula Maturation: Four Studies				
AV Fistulas	Berman 2008[2]	Johnson 1998[1]	Won 2000[3]	Lin 2008[4]
Radio-cephalic	> 140 (n = 21)	> 170 (n = 94)	> 160 (n = 50)	> 200 (n = 109)
Brachio-cephalic	> 308 (n = 49)	> 280 (n = 128)		

Table 3: Comparison of AV Fistulas threshold studies to predict maturation.

References:

1 Johnson CP et al, "Prognostic Value of Intraoperative Blood Flow Measurements in Vascular Access Surgery," Surgery 1998; 124: 729-38.

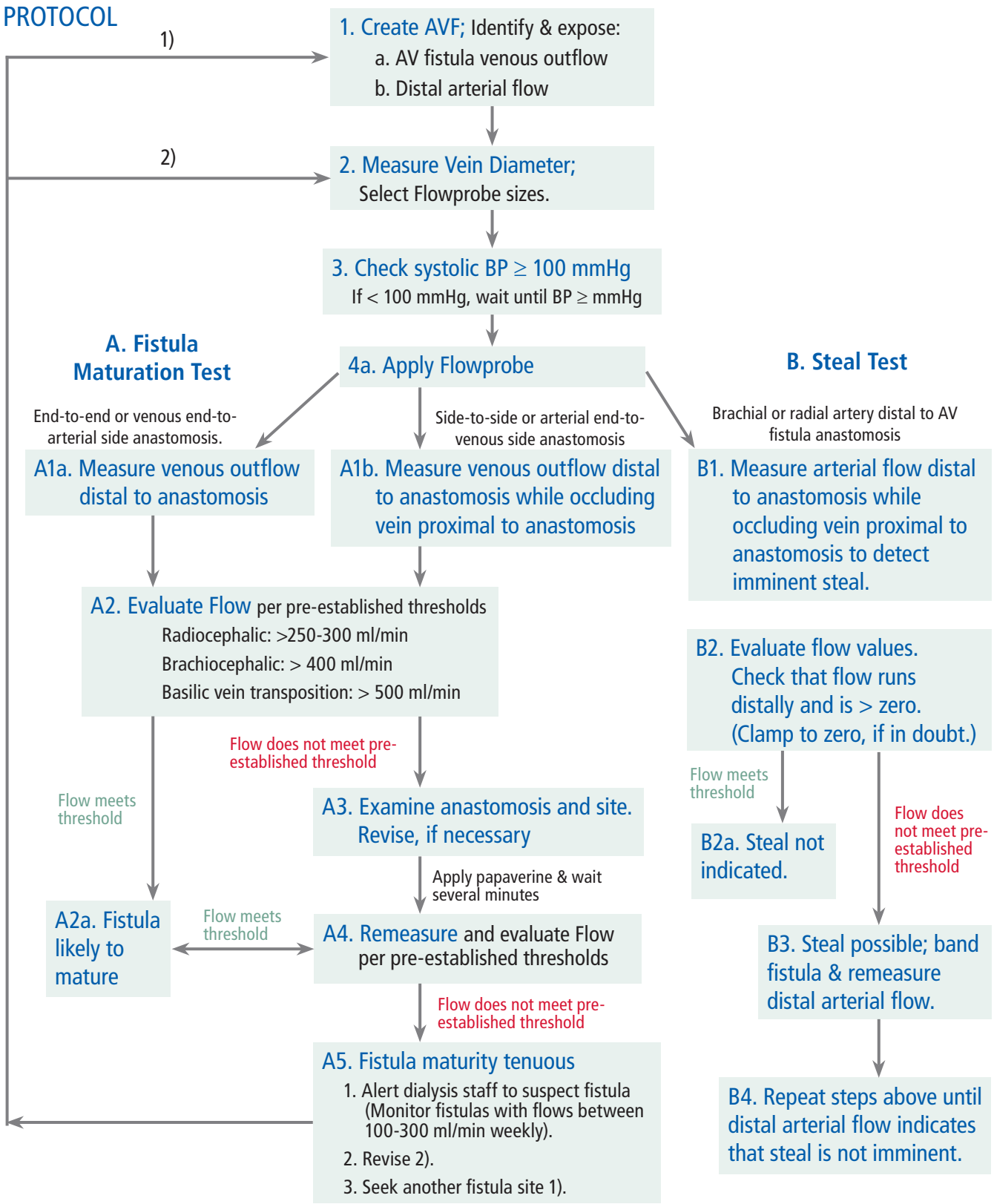
2 Berman SS et al, "Predicting Arteriovenous Fistula Maturation with Intraoperative Blood Flow Measurements," J Vasc Access. 2008; 9(4): 241-7.

3 Won T et al, "Effects of Intraoperative Blood Flow on the Early Patency of Radiocephalic Fistulas," Ann Vasc Surg 2000; 14(5): 468-72.

4 Lin CH et al, "Correlation of Intraoperative Blood Flow Measurement with Autogenous Arteriovenous Fistula Outcome." J Vasc Surg. 2008; 48(1): 167-72.

Arteriovenous Fistula Construction

Fistula Maturation and Steal Tests



Medical Note

Intraoperative Blood Flow Measurement during AV (Prosthetic) Graft Construction

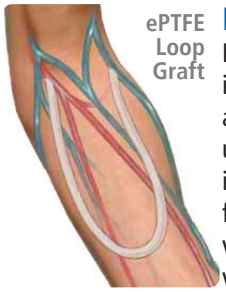


Fig. 1: Loop ePTFE graft from brachial artery to cephalic vein.

INTRODUCTION

Flow cannot be measured directly on newly inserted prosthetic ePTFE grafts (Fig. 1) because air within the synthetic graft walls attenuates ultrasound signal transmission. Graft outflow is therefore measured on the outflow vein following completion of both the 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 STEPS:

1. IDENTIFY VESSELS TO BE MEASURED

Identify the exposed segments of the venous outflow conduit for the graft. Determine the optimum site (wide enough to accommodate the Probe's acoustic reflector) for applying the Probe, and clean the vein at this site from fat and excess tissue.

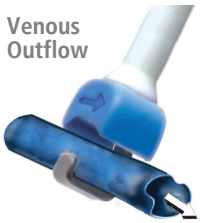


Fig. 5: Outflow vein filling 75- 100% of the Probe's sensing window.

2. SELECT FLOWPROBE SIZES

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

Nominal Probe Size	Acceptable Vessel Range
4 mm	3.0 - 5.0 mm
6 mm	4.0 - 7.3 mm

3. APPLY FLOWPROBE

Apply sterile gel to the Flowprobe to provide ultrasound coupling between the Probe body and Probe reflector. Apply the Flowprobe to the vein, proximal to the anastomosis, bend the Probe's flexible neck segment as necessary, so that the entire vein lies within the lumen of the Probe and aligns with the Probe body (Fig. 5). If desired, 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 display for 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.[1] As the site recovers from surgery, flow will increase to levels preferred for hemodialysis (> 600 mL/min).

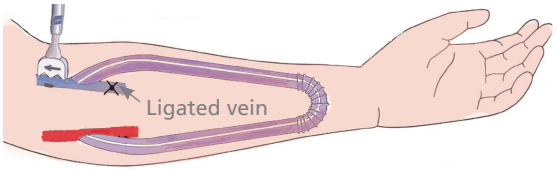


Fig. 2: Loop ePTFE Graft anastomosed to the side of an artery and end of ligated vein.

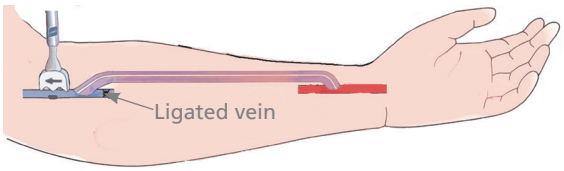


Fig. 3: Straight ePTFE Graft anastomosed to the side of an artery and end of a vein.

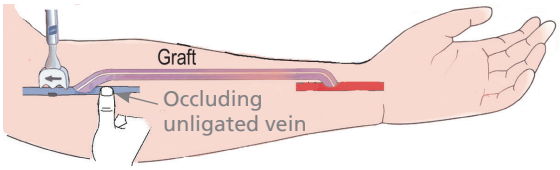


Fig. 4: In a graft anastomosed to an unligated vein, flow is measured while the distal portion of the vein is temporarily occluded.

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 foreshadowed failure within 90 days.[1]

ePTFE-Grafts [1,2]	
Flow Rate	Recommendation
≤ 250 mL/min	Abandon site immediately
250 - 400 mL/min	Consider prophylactic anti-coagulation

References

1 Johnson CP et al, "Prognostic Value of Intraoperative Blood Flow Measurements in Vascular Access Surgery," Surgery 1998; 124: 729-38.
2 Berman SS et al, "Predicting Arteriovenous Fistula Maturation with Intraoperative Blood Flow Measurements," J Vasc Access. 2008; 9(4): 241-7.

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Intraoperative Blood Flow Measurement during AV (Prosthetic) Graft Construction Cont.

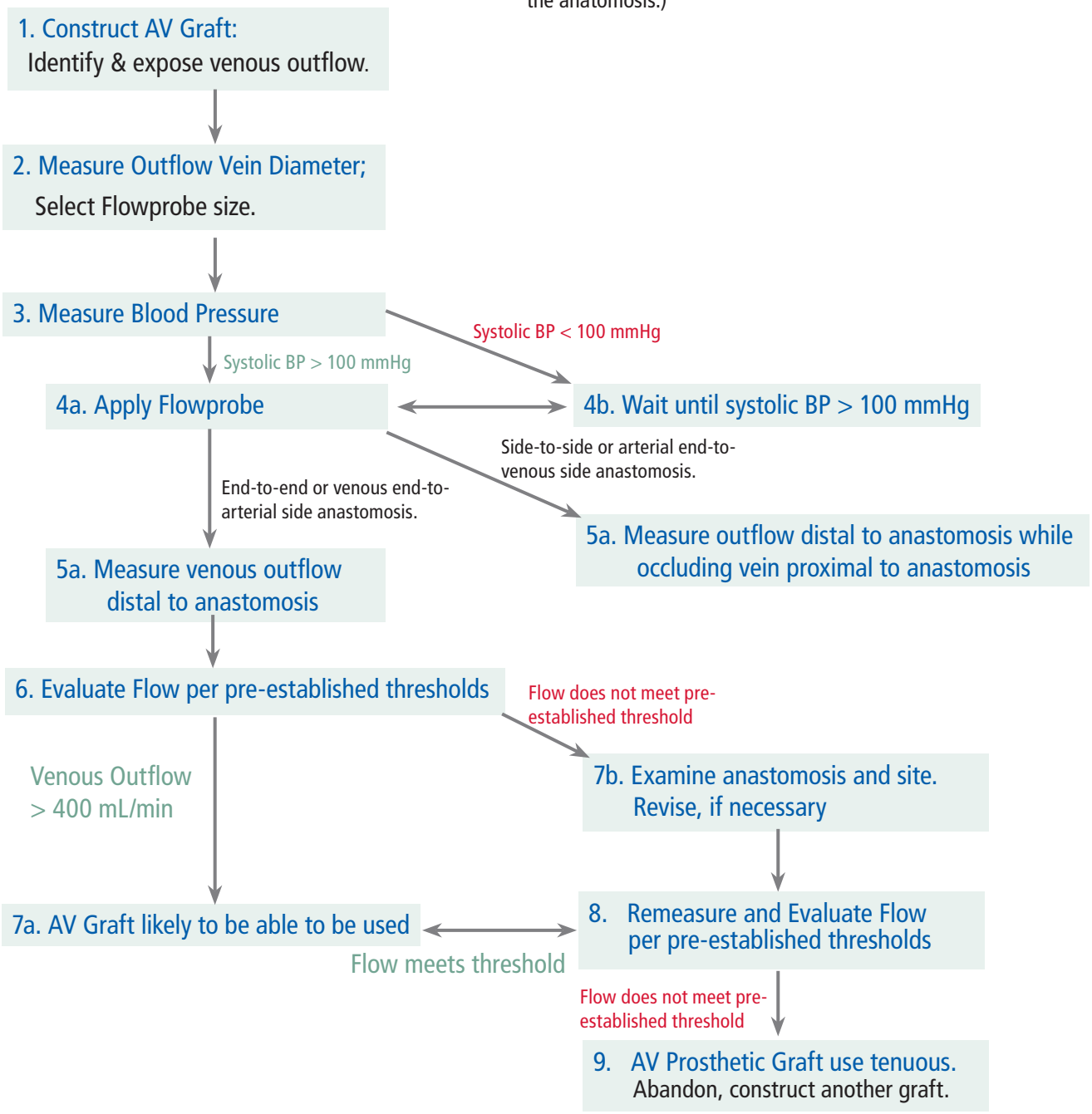
5. DOCUMENT FLOWS

After applying a Flowprobe to a vein, wait ~ 10-15 seconds. When flow readings are stable, flow data can be captured by recording or taking a snapshot on the Flowmeter or by pressing PRINT on Flowmeter equipped with that option. 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.

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 anatomosis.)

PROTOCOL



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Medical Note

Flow-guided AV Fistula Banding

Courtesy of M. R. Scheltinga, M.D., Máxima Medical Center, Veldhoven, The Netherlands.

Why Band a High Flow Fistula?

The need to increase venous outflow resistance in an arteriovenous fistula (AVF) used to deliver hemodialysis results from:

Hemodialysis Access-Induced Distal Ischemia (HAIDI)

Clinically significant HAIDI, that occurs primarily in diabetic patients, is a potentially devastating complication of an AVF. The surgeon's challenge is to relieve the distal ischemia, but maintain a functional AVF for hemodialysis. One strategy is to band the AVF to increase AVF flow resistance, thereby reducing AVF flow and increasing distal flow.

Cardiac Overload

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 Banding

The surgeon begins with a pre-operative AVF flow level (determined by a Transonic® hemodialysis monitor in the dialysis clinic) and pre-sets 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 Steps

0. Preoperative: From preoperative surveillance in the hemodialysis clinic, determine % drop in flow to be achieved by banding.
1. Identify & Expose Venous Outflow of Fistula: 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 (FTV-Series): 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 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 entire vein lies within the Probe's sensing window (Fig. 1).
   d) Check the Signal Quality Indicator on the Transonic flowmeter display to verify good acoustic contact.
   e) If using a perivascular flowmeter, 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, or by printing on a flowmeter equipped with this option. If the flow reading is negative, press "INVERT" to reverse the polarity of the flow reading from negative to positive before printing out the waveform.

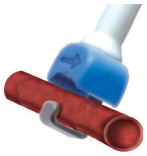

Fig. 1: Align the Probe on the vessel as shown.

Flow Measurement Protocol

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.

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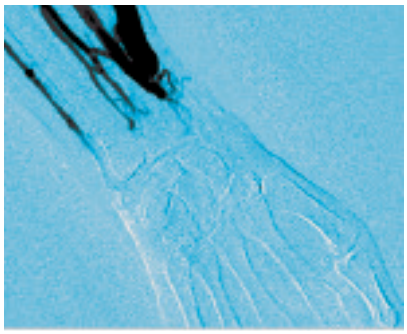
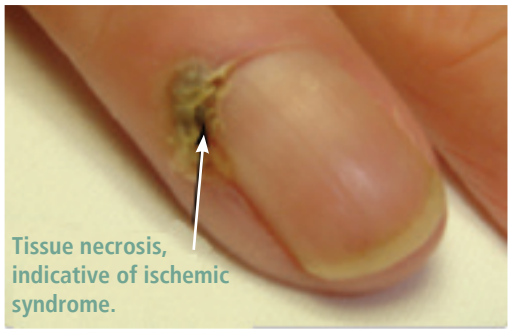
Flow-guided AV Fistula Banding Cont.

Photo essay below shows continuous measurement of blood flow with a vascular flowprobe directing a fistula banding procedure, courtesy of M. R. Scheltinga, M.D., Dept. of Surgery, Máxima Medical Center, Veldhoven, The Netherlands.





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.

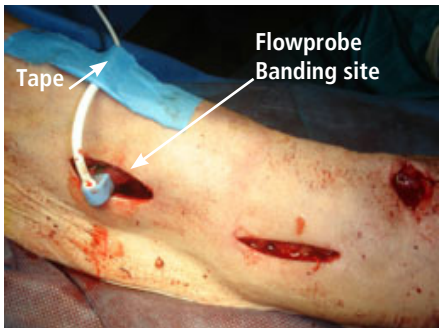


Fig. 3: Banding: Minimally invasive positioning of a Transonic® Flowprobe guides the degree of tightening of a 5 mm Dacron band during this procedure.

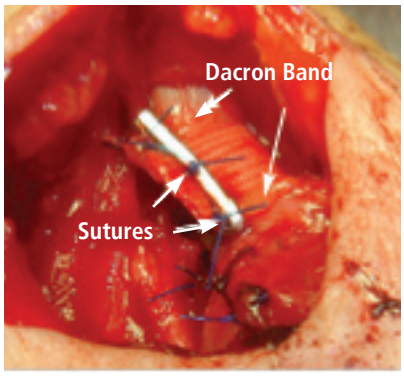


Fig. 4: A 5 mm Dacron band is fixed using a clip and stitches. In this patient, AVF thrill was maintained and radial arterial pulses returned.

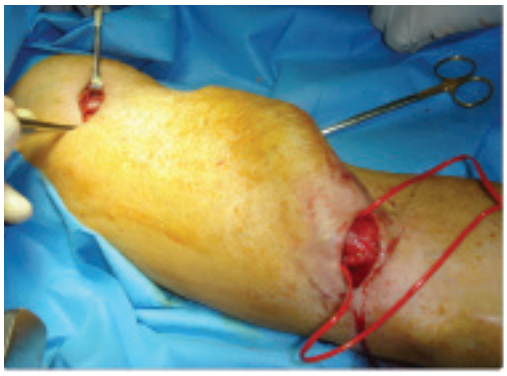


Fig. 5: Banding may also be performed for a high flow AV fistula (HFA) > 2L/min. This patient suffered from fatigue in the presence of a 3.7 L/min upper arm AVF.

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.

REFERENCES

www.vascularprocedures.com/html/algemeen/home.php

1. van Hoek F et al, "Steal in hemodialysis patients depends on type of vascular access," Eur J Vasc Endovasc Surg 2006; 32: 710-717.
2. van Hoek F, Scheltinga MR et al, "Access flow, venous saturation and digital pressures in hemodialysis," J Vasc Surg 2007;45: 968-73.
3. van Hoek F, Scheltinga MR et al, "Banding of hemodialysis access causing hand ischemia or cardiac overload," Seminars in Dialysis 2009; 22: 204-208.
4. Scheltinga MR, van Hoek F, Bruyninckx CMA, "Surgical banding for refractory Hemodialysis Access-Induced Distal Ischemia (HAIDI)," J Vasc Acc 2009;10: 43-49.
5. Scheltinga MR, van Hoek F, Vascular Access. J. Tordoir (ed). "Banding for high flow hemodialysis access (HFA)," Minerva, Turin, 2009, pp 141-150.141-150.

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