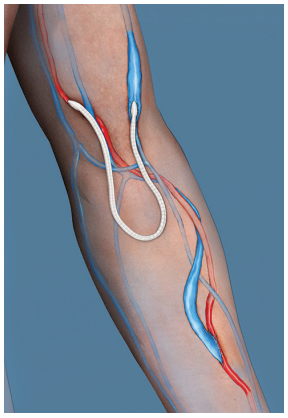
Flow-Assisted Surgical Technique F•A•S•T during Vascular Access Surgery

Contents

Intraoperative Blood Flow Assessment during Vascular Access Surgeries

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


Drawing of upper arm prosthetic loop graft and lower arm AV fistula.

A vascular access is the dialysis patient's lifeline. It is also considered the Achilles Heel of dialysis because they clot, get infected, thrombose and fail. Although dialysis access sites fail for many reasons, most of these are directly affected by the quality of flow through the access.

Intraoperative Flow Measurements Predict Fistula Maturation

During AV access creation, intraoperative blood flow measurements with a Transonic perivascular flowprobe provide quantitative volume flow values that instantly alert the surgeon to any flow-limiting problems that may jeopardize further maturation of the access. The first protocol for measuring flow through an AV access was developed by Drs. Anders Lundell and Nils H. Persson from the Dept. of Surgery, Malmö General Hospital in the early 1990s. They measured flow in the radial and ulnar arteries at the wrist to determine if there was sufficient flow to create a fistula. If flow was under 100 ml/min, they moved to the brachial artery to create a fistula.

Landmark Study

In 1998, Dr. Christopher Johnson, a transplant surgeon at the University of Wisconsin Medical School published a landmark study: *Prognostic Value of Intraoperative Blood Flow Measurements in Vascular Access Surgery* [1]. The paper's conclusion was that intraoperative measurements of access blood flow provide objective, reliable data that correlate with outcome. Johnson's study has been followed by others including key opinion leader Scott Berman from Tucson, AZ who went further to conclude that intraoperative blood flow measurements obtained at the time of autologous AVF construction can identify fistulas that are unlikely to mature; and therefore, require immediate revision or abandonment which will ultimately expedite the establishment of a useful access in the hemodialysis patient [4]. These and other studies provide indisputable evidence that Transonic intraoperative flow measurements with Transonic vascular handle flowprobes provide valuable information to the surgeon during fistula creation.

Fistula First Breakthrough Initiative Drives Measurements

The 2003 Fistula First Breakthrough Initiative sponsored by the Center for Medicaid and Medicare (CMS) in conjunction with the National Kidney Foundation (NKF) is determined to improve care for patients with chronic kidney disease by increasing AV fistula placement and use in suitable hemodialysis patients. Thus maturation of a viable AV access is the initial step in enabling successful long-term hemodialysis. Now over 60% of hemodialysis patients in the United States have a fistula placed. This has underscored the need for quantitative measurements during fistula creation to insure their maturation into a viable fistula.

Measurements during Revisions

Similarly, vascular surgeons tasked with saving or revising a vascular access have relied on intraoperative measurements to guide their banding or revision surgeries. Measuring arteriovenous access flow during revision surgery takes the guesswork out of knowing if the target flow has been reached.

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Flow Protocol: Fistula Creation

Intraoperative Blood Flow Measurements during Arteriovenous Fistula Creation

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

Introduction

The goals for measuring flow during fistula creation are:

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.

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

2. Select Flowprobe Sizes (FMV or FTV-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).

Probe Size	Nonrestrictive Vessel Range
3 mm	1.2 - 3.2 mm
4 mm	3.2 - 5.3 mm
6 mm	4.5 - 7.5 mm

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 AureFlo® or Flowmeter 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).

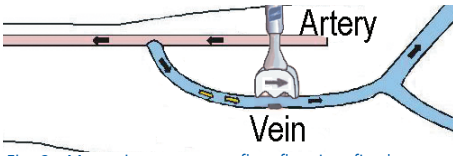

Fig. 2: Measuring venous outflow flow in a fistula anastomosed end to side.

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.

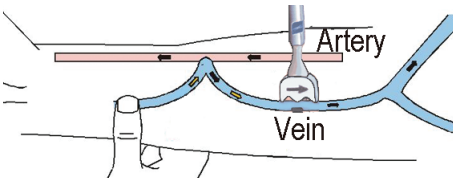

Fig. 3: Measuring venous outflow flow in a fistula anastomosed side to side.

A2. 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 Aureflo®, or by pressing PRINT on a HT300-Series Flowmeter. If the HT300-Series 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 Protocol: Fistula Creation 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).

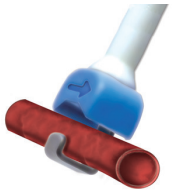


Fig. 4: Artery filling 75- 100% of Probe's sensing window.

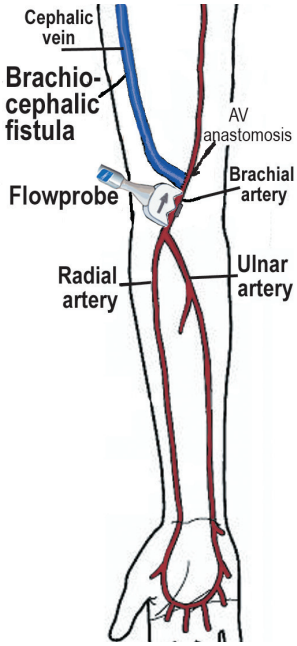


Fig. 5: Flow supplying the hand is measured with the Flowprobe placed on the artery distal to the AV anastomosis.

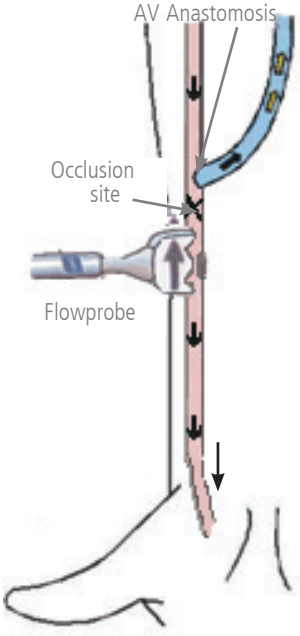


Fig. 6: Flow is zeroed by occluding the artery immediately adjacent to the Flowprobe.

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. 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.*

* Eric S. Chemla, MD, Renal Transplant and Vascular Surgery, St. George's Healthcare NHS Trust, London, UK.

B3. Document Flows

After applying a Flowprobe to the artery, 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 Aureflo®, or by pressing PRINT on a HT300-Series Flowmeter. If the HT300-Series 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]

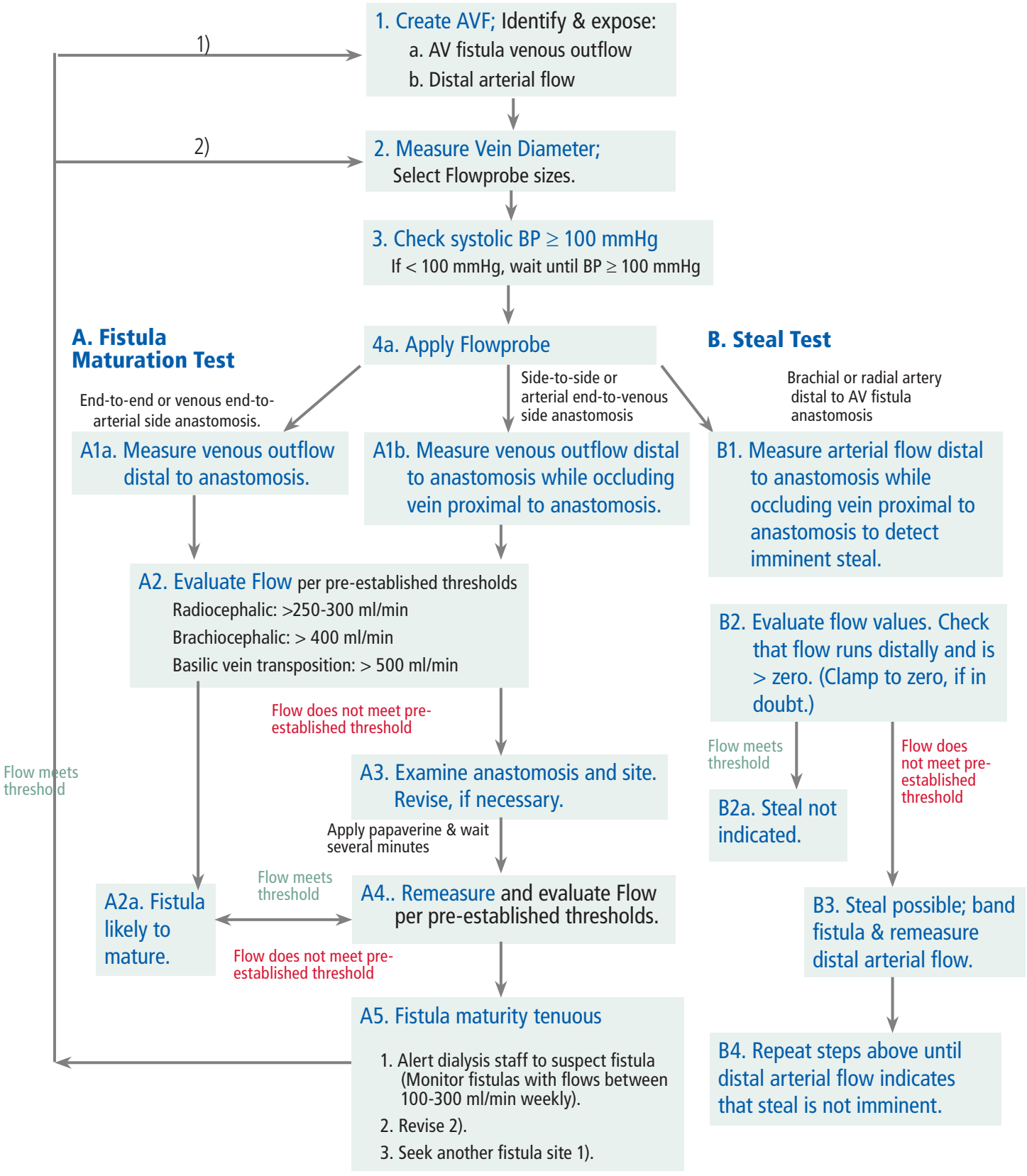
Thresholds (mL/min) Predict Fistula Maturation: Four Studies				
AV Fistulas	Berman 2008[2]	Johnson 1998[1]	Won 2000[3]	Lin 2008[4]
Radio-cephalic	> 140 (n = 21)	> 170 (n = 94)	> 160 (n = 50)	> 200 (n = 109)
Brachio-cephalic	> 308 (n = 49)	> 280 (n = 128)		

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 Radiocephalic Fistulas," Ann Vasc Surg 2000; 14(5): 468-72. 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.

Flow Protocol: Fistula Creation cont.



Flow Protocol: Prosthetic Graft Creation

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).

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

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.

Probe Size	Nonrestrictive Vessel Range
4 mm	3.2 - 5.3 mm
6 mm	4.5 - 7.5 mm

3. Apply Flowprobe

Apply sterile Aquasonic® Gel 100 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). 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 (bucket display) on the Flowmeter's front panel or AureFlo's green bars 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).

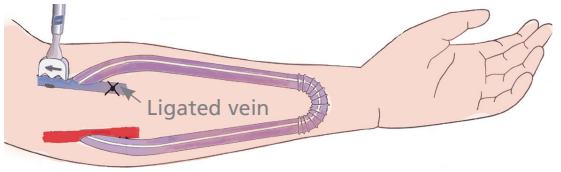


Fig. 2: Loop ePTFE Graft anastomosed to the side of an artery and end of ligated vein.

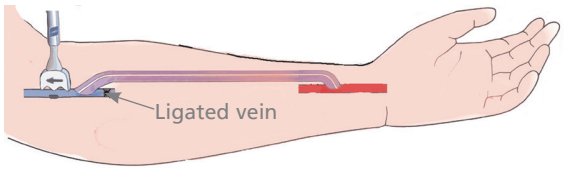


Fig. 3: Straight ePTFE Graft anastomosed to the side of an artery and end of a vein.

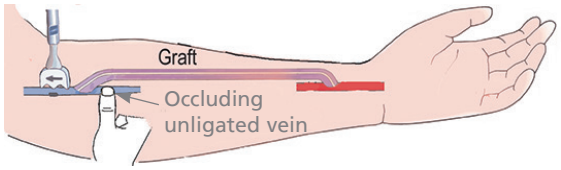


Fig. 4: In a graft anastomosed to an unligated vein, flow is measured while the distal portion of the vein is temporarily occluded.

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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Flow Protocol: Prosthetic Graft Creation cont.

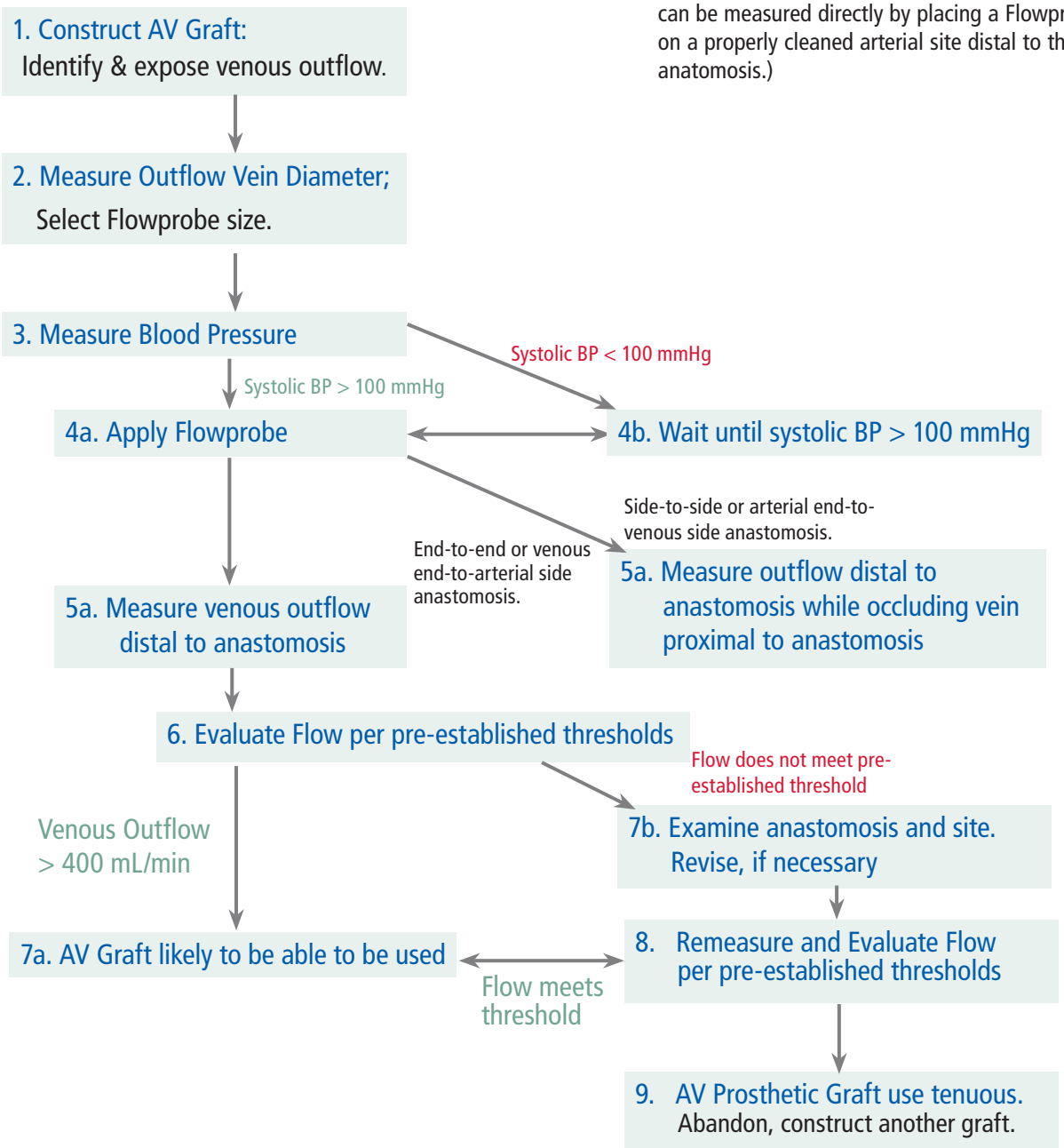
5. Document Flows

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 Aureflo®, or by pressing PRINT on a HT300-Series Flowmeter. If the HT300-Series 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.)

Flow Measurement Protocol



Flow Protocol: Fistula Revision

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

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

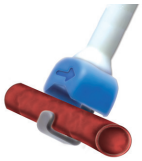


Fig. 1: Align the probe on the vessel as shown.

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 (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 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 entire vein lies within the Probe's sensing window (Fig. 1).

d) Check the Signal Quality Indicator on the AureFlo® or Flowmeter display 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 Aureflo®, or by pressing "PRINT" on a HT300-Series Flowmeter. If the HT300-Series 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.

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).

↓

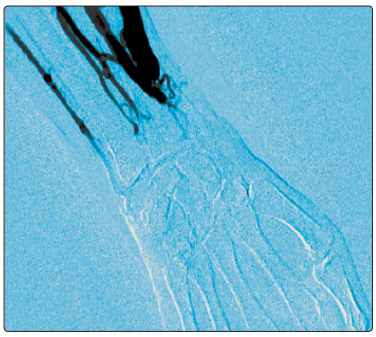
5. Tighten band. Remeasure flow.

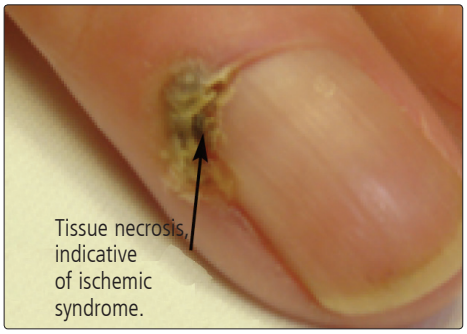
↓

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

Flow Protocol: Fistula Revision cont.

Flow-guided AV Fistula Banding cont.





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.

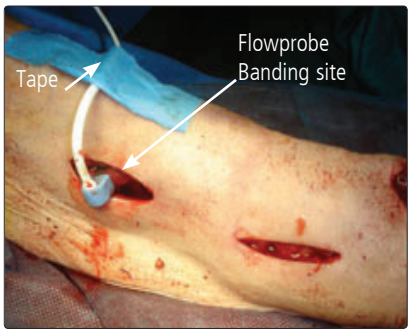


Fig. 3: Banding: Minimally invasive positioning of a Transonic volumetric flowprobe guides the degree of tightening of a 5 mm Dacron band during this procedure.

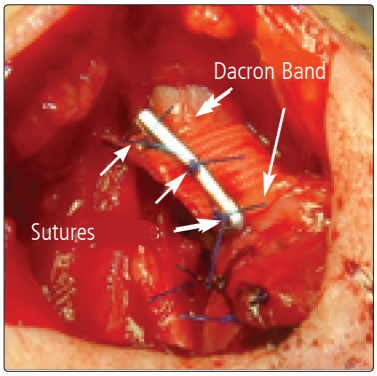


Fig. 4: A 5 mm Dacron band is fixed using a clip and stitches. In this patient, AVF thrill was maintained and radial arterial pulses returned.

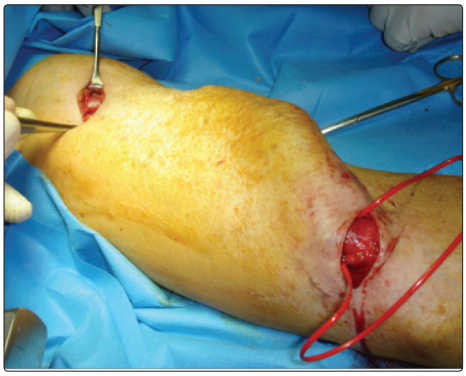


Fig. 5: Banding may also be performed for a high flow AV fistula (HFA) > 2L/min. This patient suffered from fatigue in the presence of a 3.7 L/min upper arm AVF.

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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Flow Case Report: Fistula Revision

Flow-Guided Fistula Artegraft® Banding

Zamora JU II, MD, Balboa Transplant Institute, San Diego, CA

Introduction

Clinically significant steal syndrome is a potentially devastating complication of an arteriovenous (AV) fistula or graft and is often characterized by negative (reversed) flow in the distal artery. The challenge for the surgeon is to relieve the distal ischemia, but maintain a functional AV access with sufficient flow to deliver dialysis. One strategy is to band the access to increase flow resistance, thereby reducing access flow and increasing distal arterial flow.

Traditional banding methods modify the arterial or venous ends of a graft. This can compromise both the efficacy of hemodialysis and/or the life of the AV access. The Zamora Method™ is a novel banding procedure that uses hemoclips on collagen AV Artegrafts® and intraoperative flow measurements with Transonic perivascular Flowprobes to guide the banding procedure. One advantage of the Zamora banding procedure is that the hemoclips can be adjusted and/or removed during angioplasty. Traditional banding methods do not lend themselves to modification or reversal without surgical intervention.

Method

Pre-operative AV access flow is measured during dialysis with a Transonic Hemodialysis Monitor. The surgeon then determines the percent decrease in access flow to be achieved by the banding procedure. Medium hemoclips are then placed on the midsegment of an Artegraft® (Fig. C).

Artegraft flow is decreased by the depth of the hemoclip position on the graft and the distance between the clips. The clips are generally placed 10 mm apart (range: 8 - 20 mm) depending on the "length" of band desired. The angle of placement varies from 30 to 90 degrees varying the "depth" into the graft needed. A medium hemoclip placed at 90 degrees occludes to a 3.5 - 3.7 mm opening. As the clips are applied, Artegraft® flow is measured at the venous end of the graft with a 6 mm Transonic Flowprobe (Fig. D).

Fig. 1: Upper arm site marked for Artegraft.

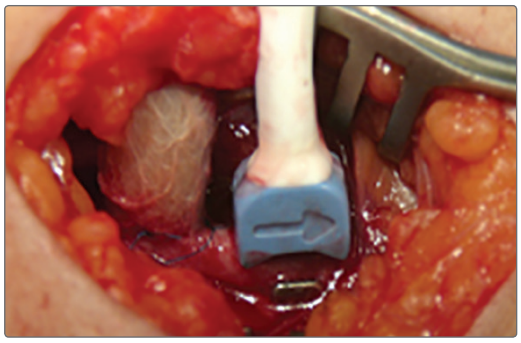

Fig. 2: 3 or 4 mm Flowprobe measures distal arterial flow.

Fig. 3: Hemoclips are applied to the Artegraft midsegment.

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Flow Case Report: Fistula Revision cont.

Flow-Guided Fistula Artegraft® Banding cont.

Results

This method was utilized in over 250 patients over the past eight years with excellent results in both graft patency and correction of Steal Syndrome. The method maintains both a "maximal" inflow and outflow of the Artegraft® at the time of hemodialysis. Optimally, the arterial (inflow) needle is placed on the arterial ½ of the graft, and the venous (outflow) needle is placed on the venous ½ of the graft (Fig. E). During dialysis, the flows both into and out of the dialysis machine are maximized. Clips (banding) can be "reversed/removed" with an angioplasty balloon at the time of the first graft thrombectomy, if necessary. Often in older, diabetic patients with peripheral artery disease, banding reversal will not be tolerated. Steal syndrome returns, and a more permanent banding method can still be utilized to maintain optimal, long-term, lower Artegraft® flow.

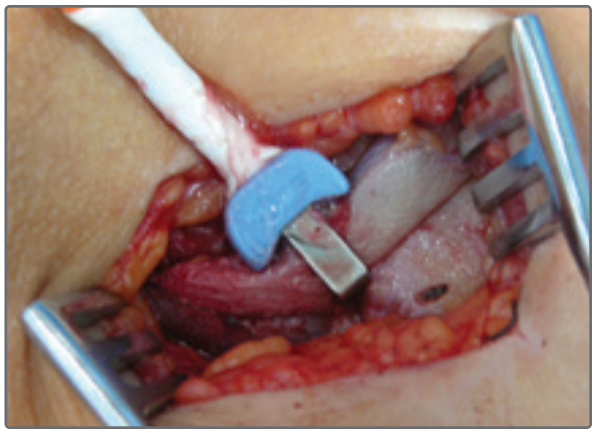

Fig. D: Artegraft® outflow is measured with a 6 mm Flowprobe as the hemoclips are applied.

Conclusion

Transonic Flowprobes provide on-the-spot measurements of volume flow within an Artegraft® as the graft is banded to treat steal syndrome.

Fig. E: Artegraft inflow and outflow marked for hemodialysis needle cannulation.

Reference

Zamora JU II, "A Novel, Adjustable and Reversible Banding Procedure for Artegraft," 13th Biennial VASA Dialysis Access Symposium, May 9-11 2012, Orlando, FL

Artegraft® is a bovine carotid artery graft processed into a biological fibrous matrix to enhance long-term patency and to provide a flexible and compliant tightly woven conduit for hemodialysis cannulation. www.artegraft.com

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Flow Protocol: Fistula Revision

Flow-Guided Fistula Surgical Revision

Fistula banding to relieve Dialysis Access-Induced Steal Syndrome (DASS) can be counter-productive. Therefore, alternative methods to reduce flow through an high access bypass have been developed. They include the following:

Distal Revascularization-Interval Ligation (DRIL)

DRIL eliminates a potential pathway for steal syndrome by ligating the artery distal to the origin of the AV fistula, and revascularizing the extremity through creation of a bypass (saphenous vein, bovine or PTFE graft) from above the AV fistula to below the AV fistula.

Revision Using Distal Inflow (RUDI)

RUDI technique calls for ligation of the fistula at a site slightly proximal to the fistula's origin and then re-establishes flow via a bypass from a more distal arterial source to the venous limb of the fistula.

Proximalization of Arterial Inflow (PAI)

PAI converts the arterial supply of the arteriovenous access to a more proximal artery with higher capacity by using a small-caliber polytetrafluoroethylene (PTFe) graft as a feeder.

Flow Measurement Protocol

Pre-operative: Determine % fistula flow decrease to be achieved by inflow reduction.

1. Expose arterial segment of fistula for pre-bypass flow.
2. Select Flowprobe Size: the vessel diameter should fill 75 - 100% of the Probe's sensing window.
3. Apply Flowprobe as shown in Fig. 1 using sterile Aquasonic Gel 100 between the probe body and probe reflector to provide ultrasound coupling. Check the Signal Quality Indicator on the Flowmeter's front panel or the AureFlo® display to ensure good acoustic contact.

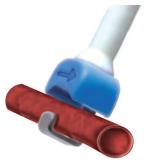

Fig. 1: Align the probe on the vessel as shown.

4. Measure Baseline Flow. Listen to the pitch of FlowSound® as the Probe is applied to the vessel. The higher the pitch, the higher the flow.
5. Note: if flow is traveling antegrade or retrograde. Retrograde flow indicates the presence of DASS.
6. Construct the Bypass.
7. Measure and evaluate bypass outflow.

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THE MEASURE OF BETTER RESULTS.

References: Vascular Access Surgery

THEORY

1 Drost CJ, "Vessel Diameter-Independent Volume Flow Measurements Using Ultrasound," Proceedings San Diego Biomedical Symposium 1978; 17: 299-302. (Transonic Reference # 3T)

ACCESS CREATION

2 Johnson CP *et al,* "Prognostic Value of Intraoperative Blood Flow Measurements in Vascular Access Surgery," Surgery 1998; 124: 729-38. (Transonic Reference # 1504AH)

3 Berman SS *et al,* "Predicting Arteriovenous Fistula Maturation with Intraoperative Blood Flow Measurements," J Vasc Access. 2008; 9(4):241-7. (Transonic Reference # 7710AH)

4 Won T *et al,* "Effects of Intraoperative Blood Flow on the Early Patency of Radiocephalic Fistulas," Ann Vasc Surg 2000; 14(5): 468-72. (Transonic Reference # (2411AH)

5 Lin CH *et al,* "Correlation of Intraoperative Blood Flow Measurement with Autogenous Arteriovenous Fistula Outcome." J Vasc Surg. 2008; 48(1): 167-72. (Transonic Reference # 7637AH)

6 Welander G *et al,*"Can Intraoperative Measurement of AV Fistula Predict Outcome," 5th International Congress of the Vascular Access Society. June 11-13, 2007 Nice, France, Abstract P-004A. (Transonic Reference # 7469AHM)

7 Saucy F *et al,* "Is intra-operative blood flow predictive for early failure of radiocephalic arteriovenous fistula?" Nephrol Dial Transplant. 2010; 25(3): 862-7. (Transonic Reference # 7875AHM)

8 Saucy F *et al,* "Intraoperative assessment of vascular access." J Vasc Access. 2014;15 Suppl 7:S6-9. (Transonic Reference # 10100AHM)

9 Usta E *et al,* "Risk factors predicting the successful function and use of autogenous arteriovenous fistulae for hemodialysis," Thorac Cardiovasc Surg. 2013; 61(5): 438-44. (Transonic Reference # 10051AHM)

ACCESS REVISION

10 Zanow J *et al,* "Flow Reduction in the High-flow Arteriovenous Access Using Intraoperative Flow Monitoring," J Vasc Surg 2006;44: 1273-1278. (Transonic Reference # 7410AHM)

11 Wong, V et al, "Factors Associated with Early Failure of Arteriovenous Fistulae for Haemodialysis Access," Eur J Vasc Endovasc Surg 1996; 12(2): 207-13. (Transonic Reference # 6943AH)

12 Asif A *et al,* "Early arteriovenous fistula failure: a logical proposal for when and how to intervene," Clin J Am Soc Nephrol 2006; 1(2): 332-9. (Transonic Reference # VA9687R)

13 Schanzer H *et al,* "Treatment of Angio-access-induced Ischemia by Revascularization," J Vasc Surg 1992; 16(6): 861-4.

14 Berman SS *et al,* "Distal Revascularization-Interval Ligation for Limb Salvage and Maintenance of Dialysis Access in Ischemic Steal Syndrome." J Vasc Surg 1997; 26(3): 93-402; discussion 402-4.

15 Wixon CL *et al,* "Distal Revascularization-Interval Ligation for Maintenance of Dialysis Access and Restoration of Distal Perfusion in Ischemic Steal Syndrome," Semin Vasc Surg 2000; 13(1): 77-82.

16 Jean-Baptiste RS, Gahtan V, "Distal Revascularization-interval Ligation (DRIL) Procedure for Ischemic Steal Syndrome (ISS) after Arteriovenous Fistula Placement," Surg Technol Int 2004;12: 201-5.

17 Knox RC *et al,* "Distal Revascularization-Interval Ligation: a Durable and Effective Treatment for Ischemic Steal Syndrome after Hemodialysis Access," J Vasc Surg 2002; 36(2):250-5.

18 Asciutto G *et al,* "Distal Revascularization-Interval Ligation for the Treatment of Angioaccess-induced Ischemia. Case Report," Minerva Urol Nefrol, 2006 Mar;58(1):91-5.

19 Diehl L *et al,* "Operative Management of Distal Ischemia Complicating Upper Extremity Dialysis Access," Am J Surg 2003;186(1): 17-9.

20 Sessa C *et al,* "Treatment of Hand Ischemia Following Angioaccess Surgery Using the DRIL Technique with Preservation of Vascular Access: Description of An 18 Case Series," Ann Vasc Surg 2004; 18(6): 685-94.

21 Walz P *et al,* "Distal Revascularization and Interval Ligation (DRIL) Procedure for the Treatment of Ischemic Steal Syndrome after Arm Arteriovenous Fistula." Ann Vasc Surg 2007.

22 Illig KA *et al,* "Ischemia: DRIL," 5th International Congress of the Vasc Access Soc 2007 Nice France, Extended Abstract L-075. (Transonic Reference #7466AHR)

23 Illig KA *et al,* "Hemodynamics of Distal Revascularization Interval Ligation," Ann Vasc Surg 2005; 19:199-207. (Transonic Reference #7228AH)

24 Gradman, WS, Pozrikidis C, "Analysis of Options for Mitigating Hemodialysis Access-Related Ischemic Steal Phenomena," Ann Vasc Surg 2004; 18: 59-65. (Transonic Reference #2938AH)

25 Tynan-Cuisinier GS et al, "Strategies for Predicting and Treating Access Induced Ischemic Steal Syndrome," Eur J Vasc Endovasc Surg 2006; 32(3): 309-15.

26 Minion DJ *et al,* "Revision Using Distal Inflow: A Novel Approach to Dialysis-associated Steal Syndrome." Ann Vasc Surg 2005; 19(5): 625-8.

27 Callaghan CJ *et al,* "Treatment of dialysis access-associated steal syndrome with the "revision using distal inflow" technique." J Vasc Access. 2011r;12(1):52-6.

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THE MEASURE OF BETTER RESULTS.

References: Vascular Access Surgery cont.

28 Zanow J *et al,* "Proximalization of the Arterial Inflow to Treat Access-related Ischemia" 5th International Congress of the Vascular Access Society (VAS) 2007, Nice, France, Abstract L-076. (Transonic Reference #7467AHR)

29 Themann F, Wollert U, "Proximalization of the arterial inflow: new treatment of choice in patients with advanced dialysis shunt-associated steal syndrome?" Ann Vasc Surg. 2009 Jul-Aug;23(4):485-90. (Transonic Reference #7468AHR)

30 Zanow J *et al,* "Flow Reduction in the High-flow Arteriovenous Access Using Intraoperative Flow Monitoring," J Vasc Surg 2006; 44. (Transonic Reference # 7410AHM)

31 Chemla E *et al,* "Intraoperative Flow Measurements Are Helpful in the Treatment of High-Inflow Steal Syndrome on a Predialysis Patient with a Brachiocephalic Fistula: A Case Report," Ann Vasc Surg 2007. (Transonic Reference #7402AH)

32 Chemla, E, et al, "Inflow Reduction by Distalization of Anastomosis Treats Efficiently High-Inflow Cardiac Output Vascular Access for Hemodialysis," Sem Dialysis 2007; 20(1): 68-72. (Transonic Reference #7355AH)

33 Lundell A, Begqvist D, "Intraoperative Flow Measurements in Vascular Reconstruction," Annales Chirurgiae Gynaecologie 1992; 81(2): 187-191. (Transonic Reference #3G)

34 Chemla, E *et al,* "Complex Bypasses and Fistulas for Difficult Hemodialysis Access: A Prospective Single-Center Experience," Seminars in Dialysis 2006; 19(3): 246-250. (Transonic Reference # 7273AH)

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