
Flow-based



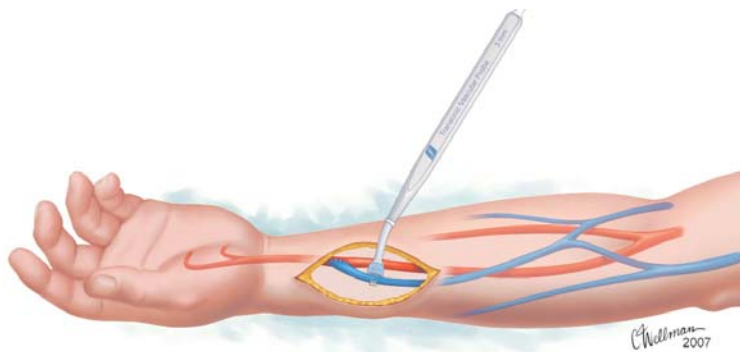
Surgical Creation



Intraoperative
Blood Flow
Measurements

Flow-based Surgery: AV Access Creation

Intraoperative Blood Flow Measurements



A. Measuring Blood Flow during AV Access Creation

Establishment of a viable AV access is the first critical step for longterm and effective hemodialysis. During surgery to construct an AV access, intraoperative blood flow measurements immediately identify flow limiting technical problems, and provide an indication of the future successful maturation of the access.¹⁻³

Quantitative blood flow measurements first validate a surgeon's clinical assessment to assure that the surgery is technically sound. Secondly, good intraoperative flow measurements provide the surgeon with an on-the-spot indication of the probability that the access will mature successfully. Flows below certain thresholds foreshadow poor maturation potential. Intraoperative blood flow have been shown to correlate with access outcomes including patency, number of interventions, and mean time to intervention¹. The greater the blood flow, the longer the patent intervals between interventions or revisions.

This chapter presents the technology and protocols for intraoperative blood flow measurements during surgical creation of an autologous AV fistula and prosthetic AV grafts and reports studies from the literature¹⁻⁶.

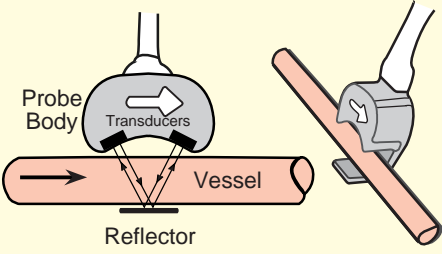
B. Transit-time Ultrasound Flow Measurements

Transit-time ultrasound technology provides quick, quantitative, intraoperative volume flow measurements without constricting the artery or vein. Vascular flow-probes feature a convenient handle and an application specific probe head sized for vessels from 1.3 to 16 millimeters in diameter (Fig. 1.1). Volume flow, measured in milliliters per minute, is displayed on the flowmeter which also features FlowSound®, an audible indication of volume flow, that allows a surgeon to keep attention on the surgical field while “hearing” the flow volumes. Flow wave-forms are recorded and can be printed for the patient’s record.

Measurements are quick and easy when compared to other modalities. In just a few seconds one can slip a Transonic vascular flowprobe around a vessel and document a flow measurement for the patient’s record.



Fig. 1.1: Vascular Flowprobes feature a convenient handle, a flexible neck and customized probe head.

<p>Transit-Time Ultrasound Ultrasound That Measures Volume Flow, Not Velocity</p> <p>Using wide-beam illumination, transducers inside a non-constrictive perivascular flowprobe send ultrasonic signals back and forth, alternately intersecting flowing blood in upstream and downstream directions. The transit time of the ultrasonic beam is decreased when traveling downstream with the blood flow and increased when traveling upstream against the flow. The difference between the integrated transit times is a measure of volume flow.⁷</p>	 <p>Fig. 1.2: Loose-fitting perivascular Flowprobe is applied around a vessel exposed during surgery. Ultrasound couplant provides full ultrasound passage within the flowsensing window.</p>
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C. Flow-based AV Fistula Access Construction (Autogenous Direct Vascular Access)

Autogenous arterial venous fistulas (AVFs) are the preferable vascular access because they remain patent longer and exhibit fewer complications than AV grafts and catheters. No matter where the fistula is constructed, measuring flow intraoperatively at the time of its construction assures the surgeon of early post-op patency and absence of hidden flow obstructions. Secondly, good initial fistula flows bode successful fistula maturation.

1. Flow Studies at Time of AV Fistula Construction

Clinical researchers at the University of Wisconsin and the Southern Arizona Vascular Institute have measured flows at the time of AV fistula construction to identify fistulas that are unlikely to mature and require immediate revision.

Johnson *et al* measured venous outflows of 227 autologous AV fistulas intraoperatively 5-10 minutes after their completion over a four year period.¹ Berman measured 72 autologous AV fistulas over a 12 month period.²

The Johnson study concluded that flow rate was the single most important determinant of primary and secondary patency. They found that AVFs with flow rates of ≤ 280 ml/min had significantly worse patency rates compared to higher flow counterparts.

Other findings from the Johnson study include:

- 1) Intraoperative measurements of access blood flows are predictive of both short and long-term patency.
- 2) Patency rates in AV fistulas are higher than in PTFE grafts.
- 3) Higher flow AV fistulas and grafts had higher patency rates than lower flow AV fistulas and grafts.
- 4) Blood flow levels in fistulas and grafts correlate with the average number of interventions and the time of intervention.
- 5) Higher flow AV accesses required fewer interventions per patient and a longer time to the first intervention than do low flow accesses.

Tables 1.1 and 1.2 on the next page summarizes some of the Johnson study results.

Flow-based Surgery: AV Access Creation *cont.*

AV FISTULA FLOWS	FAILURE WITHIN 90 DAYS REQUIRING INTERVENTION	
RADIOCEPHALIC FLOW		
<170 ml/min	56%	<i>P</i> = .001
>170 ml/min	15%	
BRACHIOCEPHALIC FLOW		
<280 ml/min	64%	<i>P</i> = .01
>280 ml/min	18%	

Table 1.1: 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

As a result of their study, Johnson *et al* recommended that an access site be abandoned if flow is ≤ 100 ml/min. For flow rates between 100 and 300 ml/min, they recognized that the site was at risk for early failure and recommended close observation of the fistula for at least four to six weeks before its cannulation for hemodialysis. If the initial blood flow rate was > 300 ml/min, they recommended allowing four to six weeks for the fistula to mature before cannulation (Table 1.2).

GUIDELINES FOR AV FISTULA CONSTRUCTION ¹	
FLOW RATE	RECOMMENDATION
≤ 100 ml/min	abandon site
100 -300 ml/min	at risk for early failure: observe closely allow to mature $> 4-6$ weeks before using
> 300 ml/min	allow to mature 4-6 weeks before use

Table 1.2: AV Fistula guidelines as identified by Johnson study.¹

The Berman study showed a significant difference in blood flow rates between both functional and non-functional radiocephalic AV fistulas and brachiocephalic AV fistulas. Their data suggest a threshold value of 179 ml/min for radiocephalic AV fistulas and 308 ml/min for brachiocephalic AV fistulas to predict maturation to a functional access (Table 1.3).²

AV FISTULA	THRESHOLD TO PREDICT MATURATION ²
RADIOCEPHALIC	179 ML/MIN
BRACHIOCEPHALIC	308 ML/MIN

Table 1.3: Berman study's blood flow rates at time of AV fistula construction to predict maturation to a functional access.²

Flow-based Surgery: AV Access Creation *cont.*

2. AV Fistula Measurement Steps

Intraoperative flow measurement with transit time-ultrasound flowprobes during creation of an AV access is quick and easy when following the measurement steps outlined below.

1) Identify Vessel to Be Measured

Expose and identify AV fistula venous outflow.

2) Select Flowprobe Sizes

Measure the diameter of the vein with a gauge. Select a probe size so that the vein diameter is between 60% - 100% of the size of the flowprobe window (Fig. 1.3). Probe size recommendations for autogenous AV fistulas are shown in Table 1.4.



Fig. 1.3: Vessel filling 60% - 100% of flowprobe window.

<u>SITE</u>	<u>PROBE SIZE</u>	<u>NONRESTRICTIVE VESSEL RANGE</u>
RADIAL ARTERY	2 MM	1.8 - 3.0 MM
	3 MM	2.4 - 4.0 MM
BRACHIAL ARTERY	3 MM	2.4 - 4.0 MM
	4 MM	3.2 - 5.3 MM
VENOUS OUTFLOW	4 MM	3.2 - 5.3 MM
	6 MM	6.6 - 9.5 MM

Table 1.4: Probe size recommendation for intraoperative blood flow measurement during construction of AV fistulas and prosthetic grafts.

3) Apply Flowprobe to Measure Venous Outflow

Select a site on the vein wide enough to accommodate the probe's acoustic reflector. Apply sterile Aquasonic Gel 100™ to the Flowprobe lumen to provide ultrasound coupling between the probe body and probe reflector. Apply the Flowprobe to the vein, bending 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. 1.4). Listen to the pitch of FlowSound® as the Flowprobe is applied to the vessel. The higher the pitch, the greater the flow.

Re-apply sterile gel back into the probe lumen, as needed, and check the Signal Quality Indicator (bucket display) on the Flowmeter's front panel for ultrasound acoustic contact. An acoustic error message will be displayed if ultrasound contact falls below an acceptable minimum.

Flow-based Surgery: AV Access Creation *cont.*

END-TO-SIDE ANASTOMOSIS

When the AVF is constructed with end-to-side anastomosis, simply measure venous outflow distal to the venous anastomosis (Fig. 1.4).

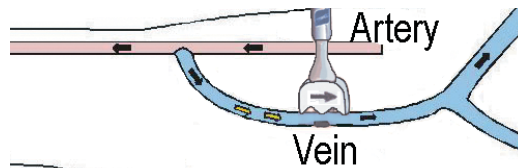


Fig. 1.4: Measuring venous outflow in a fistula anastomosed end to side.

SIDE-TO-SIDE ANASTOMOSIS

If the anastomosis is constructed with a venous-side-to-arterial-side anastomosis, occlude the vein (Fig. 1.5) proximal to the venous anastomosis while measuring flow distal to the anastomosis. If spasm occurs, papaverine can be locally infused along the artery and vein while flow is measured.

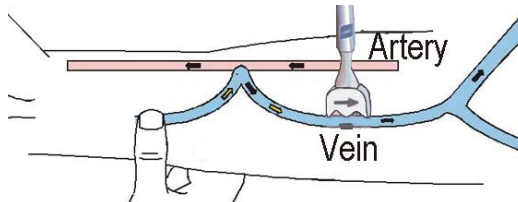


Fig. 1.5: Measuring venous outflow flow in a fistula anastomosed side to side.

4) Document Flows

After applying a Flowprobe to a vein, wait 10-15 seconds for mean readings to stabilize. If flow is negative on the flowmeter display, press the INVERT button to change the polarity before printing the waveform. Press the PRINT button on the flowmeter to document the phasic flow patterns for the case record.

D. Flow-based Prosthetic Graft Access Construction (Non-Autogenous Direct Vascular Access)

1. Non-Autogenous Prosthetic Grafts

When native veins are unsuitable or fistula sites exhausted, a prosthetic bridge graft, usually from expanded polytetrafluoroethylene (ePTFE) is used.

Grafts can be looped or straight (Figs. 1.8-1.10) and are most commonly constructed with inflow from the radial or brachial artery to either the superficial or deep veins (Figs. 1.6). Although grafts have lower patency rates than fistulas and are more prone to infection and thrombosis, their advantage is that a graft can be used for hemodialysis within a couple of weeks of implant which minimizes acute use of a catheter.

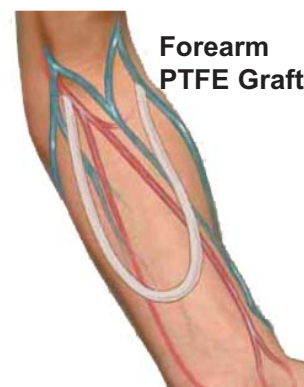


Fig. 1.6: Loop ePTFE graft from brachial artery to cephalic vein.

2. Intraoperative Prosthetic Grafts Flow Study¹

In their study, Dr. Christopher Johnson and colleagues measured 162 prosthetic PTFE grafts venous outflows five to ten minutes after completion of the anastomoses.¹ Grafts with flow rates of ≤ 400 ml/min had significantly worse patency rates than their higher flow counterparts (Table 1.5).

GRAFT TYPE	FAILURE WITHIN 90 DAYS (REQUIRING INTERVENTION)	
PTFE GRAFTS		
Flow <400 ml/min	65%	<i>P</i> =.01
Flow >400 ml/min	40%	

Table 1.5: In prosthetic grafts, initial flows of less than 400 ml/min foreshadowed failure within 90 days.

This and other studies attest to the value of routine intraoperative measurement of access blood flow.^{1,5,8} It is suggested that, if the flow through a prosthetic graft is equal or less than 250 ml/min, the site should be reassessed. If graft flow is 250 to 400 ml/min, consider prophylactic anticoagulation.

The recommendations are summarized in Table 1.6 on the next page.

Flow-based Surgery: AV Access Creation *cont.*

PTFE GRAFTS	
<u>FLOW RATE</u>	<u>RECOMMENDATION</u>
≤ 250 ml/min	abandon site immediately
250-400 ml/min	consider prophylactic anticoagulation

Table 1.6: In prosthetic grafts, initial flows of less than 400 ml/min foreshadowed graft failure within 90 days.

3. Intraoperative Graft Flow Measurements

Flow cannot be measured directly on a newly inserted prosthetic ePTFE grafts because the presence of air within the synthetic graft walls blocks ultrasound transmission. Graft outflow is therefore measured on the outflow vein following completion of both the arterial and venous anastomoses (Figs. 1.7, 1.8).

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. 1.9).

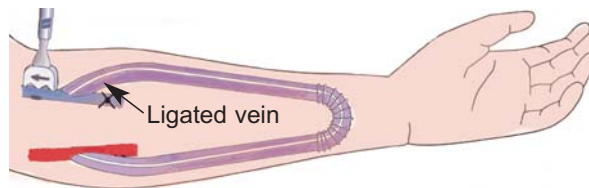


Fig. 1.7: Loop ePTFE Graft anastomosed to the side of an artery and end of ligated vein.

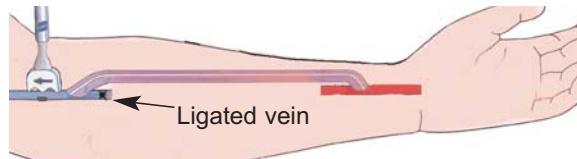


Fig. 1.8: Straight ePTFE Graft anastomosed to the side of an artery and end of a vein.

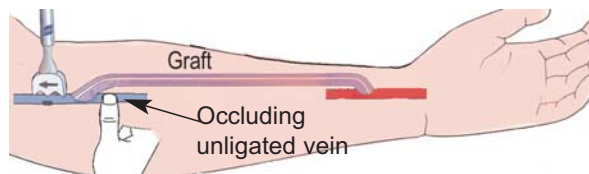


Fig. 1.9: In a graft anastomosed to an unligated vein, flow is measured while the distal portion of the vein is temporarily occluded.

Flow-based Surgery: AV Access Creation *cont.*

4. AV Prosthetic Graft Measurement Steps

To measure flow intraoperatively during creation of a prosthetic graft access, the following protocol is suggested.

1) Identify & Prepare Vein to Be Measured

Identify 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 of fat and excess tissue.

2) Select Flowprobe Sizes

Estimate the diameter of the vein with a gauge. Select a probe size so that the vein diameter will fill 60% - 100% of the probe window (Fig. 1.3).

<u>SITE</u>	<u>PROBE SIZE</u>	<u>NONRESTRICTIVE VESSEL RANGE</u>
VENOUS OUTFLOW OF GRAFT	4 mm	3.2 - 5.3 mm
	6 mm	4.5 - 7.5 mm

Table 1.7: Probe size recommendations for venous outflows of prosthetic grafts.

3) Apply Flowprobe to Measure Venous Outflow

Apply sterile gel to the Flowprobe and apply the Flowprobe to the vein, proximal to the anastomosis, bending the probe's flexible neck segment as necessary, so that the entire vessel lies within the flowprobe window and aligns with the probe body (Fig. 1.4). Listen to FlowSound® as the probe is applied. The higher the pitch, the greater the flow.

Check the Signal Quality Indicator (bucket display) on the meter display for acoustic contact.

4) Measure and Evaluate Venous Outflow

With the Flowprobe positioned as described in Step 3, measure average venous flow. Flow is displayed on the flowmeter. As the surgical site recovers, graft flow will increase to hemodialysis flow levels (> 600 ml/min).

5) Document Flows

After applying a Flowprobe to the vessel, wait 10-15 seconds for mean readings to stabilize. Then press the PRINT button on the flowmeter to document the phasic flow patterns for the case record. If flow has a negative sign on the flowmeter display, press the INVERT button to change the polarity before printing the waveform.

E. References

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- 5 Won, T et al, "Effects of Intraoperative Blood Flow on the Early Patency of Radiocephalic Fistulas," *Ann Vasc Surg* 2000; 14(5): 468-72. (2411AH)
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- 7 Drost, CJ, "Vessel Diameter-Independent Volume Flow Measurements Using Ultrasound," *Proceedings San Diego Biomedical Symposium* 1978; 17: 299-302.