

Flow-based

Surgical Creation

A photograph showing three surgeons in blue scrubs and masks, focused on a surgical procedure in an operating room.

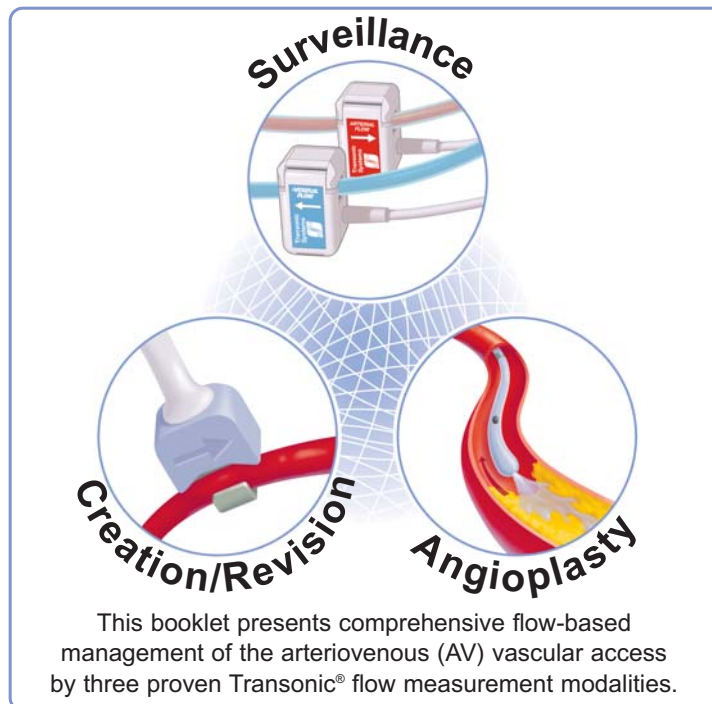
Access Surveillance

A photograph of a female nurse in a white coat and glasses, looking towards the camera in a clinical setting.

**Intervention
Surgical Revision**

A photograph of a surgeon wearing a blue cap and mask, standing next to a monitor displaying a medical ultrasound image.

Vascular Access Management



This booklet presents comprehensive flow-based management of the arteriovenous (AV) vascular access by three proven Transonic® flow measurement modalities.

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Flow-based Arteriovenous (AV) Access Management

***Blood Flow:** the quantity of blood that passes a given point in the circulation in a given time (ml/min or L/min). The pumping of blood by the heart through a closed circulatory system was first described in 1628 by English physician William Harvey. His work was influenced by René Descartes and Spanish physician Michael Servetus who were thought to have “re-discovered” and extended the findings of Ibn al-Nafis, a thirteenth century Muslim physician.*

A. Why Flow-based AV Access Management?

For the millions of end-stage renal disease (ESRD) patients who replace the function of their kidneys through hemodialysis, successful long-term treatment requires a “well-functioning” arteriovenous (AV) vascular access. A well-functioning access delivers a sufficient rate of blood flow to sustain administration of the dialysis prescription, but does not deliver a flow rate so high that it may cause cardiac complications.

Blood flow is therefore the quintessential performance parameter. Measurement of AV access blood flow is thus the quintessential functionality test for managing AV access patency - hence, “Flow-based AV Access Management.”

B. Flow-based Access Management Capabilities

AV access blood flow is measured with Transonic flow technology at distinct times in the natural history of an access: during access creation, during hemodialysis, and during an intervention and/or surgical revision that seeks to restore flow when an access is failing.

1. Flow-based AV Access Creation Surgery

Creation and maturation of a viable AV access is the first step in enabling successful long-term hemodialysis. During AV access creation, intraoperative blood flow measurements with a Transonic perivascular flowprobe (Fig. 1.1) provide quantitative flow values that instantly alert the surgeon to any flow-limiting problems that may jeopardize maturation of the access.



Fig. 1.1: Intraoperative perivascular flowprobe measures direct volume flow during AV access creation or revision surgeries.

2. Flow-based Hemodialysis Surveillance

Once an AV fistula or graft has matured, the access must remain patent with sufficient flow to sustain hemodialysis.

The primary clinical indicator of patency is flow. Pressure readings, bruit and pulse are surrogates for flow. Monthly vascular access flow surveillance during routine dialysis detects precipitous decreases in access flow, or drops below flow safety thresholds. These telltale signs of a failing access signal and alert dialysis staff in time for minimally invasive corrective action.

Pressure: Not Proportional to Flow

Cardiovascular pressure drives cardiovascular flow. Medical texts cite many mechanisms by which the body controls flow by regulating pressure. “*McDonald’s Blood Flow in Arteries*”¹ offers a cardiovascular pulsatile flow and pressure wave (Figure A). However, note that the flow pulse precedes the pressure pulse in this figure contradicting any causal relationship of pressure driving flow? In describing that pulsatile flow in vessels is driven, not by spot pressure, but by the pressure difference over the vessel segment carrying flow, J.B.S. Haldene called this observation “a blinding glimpse of the obvious.”²

$$\Delta P = Q \cdot Z$$

where: Q = flow

ΔP = pressure differential over a vessel segment carrying flow (Q)

Z = Impedance (=dynamic resistance) to flow of vessel segment

A physiological pressure measurement is a spot measurement compared to ambient atmospheric pressure. It is not a differential pressure measurement across a vessel segment. Therefore, a single pressure measurement can never serve as a flow surrogate.

This booklet describes diagnostic and surgical procedures used to monitor potential flow deficiencies. In reading this booklet it is important to be reminded that flow, the primary parameter in these procedures, cannot be deduced from a simple arterial pressure measurement.

¹Nichols, Wilmer W., and Michael F. O’Rourke. *McDonald’s Blood Flow in Arteries, Theoretical, Experimental and Clinical Principles, Fifth Edition*, London, Hodder Arnold, 2005, p 137.

² ibid p.138,

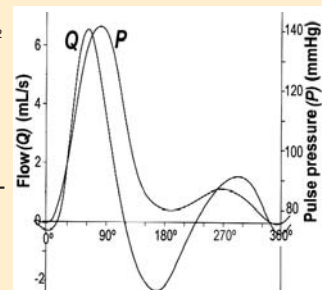


Fig. A: A simultaneously recorded flow velocity pulse (Q) and arterial pressure pulse (P) of a dog femoral artery.¹

Flow-based AV Access Management *cont.*

Transonic ultrasound dilution technology “The Krivitski Method®” is recognized as the “Gold Standard” for hemodialysis patient management. Transonic® Flow-QC® Hemodialysis Monitors and Flow/dilution Sensors (*Fig. 1.2*) determine Dialysis Adequacy by measuring Delivered Blood Flow and Recirculation; detect early signs of flow limiting problems wherever they occur in a vascular access by directly measuring Vascular Access Flow; and monitor Cardiac Function through measurement of Cardiac Output with calculations of Cardiac Index, Central Blood Volume, Central Blood Volume Index and Peripheral Resistance.



Fig. 1.2: Flow/dilution sensors clamp onto blood lines to measure Delivered Blood Flow, Recirculation, Vascular Access Flow and Cardiac Output during hemodialysis.

3. Flow-based AV Access Intervention and/or Surgical Revision

When an AV access exhibits early signs of access failure, restoration of adequate flow through the access to its earlier level is the singular goal of endovascular intervention (angioplasty) and/or surgical revision.

3:1. Flow-guided Percutaneous Transluminal Angioplasty (PTA)

PTA is now considered the primary intervention to restore flow within an AV access. Elective rather than emergent, less invasive and more cost effective than surgery, it also preserves future access sites. On-the-spot intra-graft flow measurements with the Transonic® ReoCath™ Flow Catheter and Endovascular Flowmeter (HVT100) guides interventional radiologists during PTA as they try to restore AV access flows (*Fig. 1.3*).



Fig. 1.3: A ReoCath™ Flow Catheter injects saline into access to measure intragraft flow during PTA.

3:2. Flow-based Access Revision Surgery

Restoring flow in a problematic access is a surgical challenge. A variety of surgical techniques and protocols are used to adjust access flows that can be too low or too high. During these procedures, quantitative values of Transonic intraoperative flow measurements assist in intraoperative decision making. This continuum of flow measurements during creation of an AV vascular access, during hemodialysis surveillance and/or during angioplasty or surgical revision encompass Flow-based Vascular Access Management and has become a cornerstone of AV access patency management.

C. ESRD Quality of Care

In the outcomes-driven climate of proactive ESRD vascular access management, the imperative to measure flow is clear to successfully manage an AV vascular access with objective access flow measurements.

This handbook presents flow measurement capabilities for AV access management. The handbook also offers an overview of some of the current Flow-based AV Vascular Access Management findings, practices, and protocols.

Summarized are the pioneering contributions of several clinical researchers. As procedural innovations in patient care continue to evolve, the challenge for ESRD health care providers is to further refine and standardize these flow-based AV access management protocols. Feedback and new study findings for the next revision of this “work-in-progress” handbook are welcome.

“Adequate blood flow in peripheral hemodialysis fistulae and grafts is vital to the success of hemodialysis and to survival of the patient. Reduction in flow . . . presages failure of the access device itself. Access flow can therefore be considered a fundamental property of the access that should be monitored.” TA Depner, *ASAIO J* 1995;41(3):M745-9.

Transonic® Flow Measurement Tools		
<p>Flow-based Surgery: AV Access Creation, Access Revision</p> <p>Measurement: Volume flow in ml/min or L/min</p> <p>Equipment</p> <p>Surgical Flowmeters: 300-Series, Aureus</p> <p>Flowprobes: Vessel size dependent</p> <p>Technology Transit-time Ultrasound</p>	<p>Flow-based Hemodialysis Surveillance</p> <p>Measurements: Vascular Access Patency: Access Flow; Dialysis Adequacy: True Delivered Blood Flow, Access Recirculation; Cardiac Function: Cardiac Output</p> <p>Equipment</p> <p>Flow Monitor: Flow-QC® Hemodialysis System (HD02, HD03)</p> <p>Flow/dilution Sensors: Paired sensors: H4D, H4E</p> <p>Technology: Ultrasound Dilution</p>	<p>Flow-guided Percutaneous Transluminal Angioplasty: Access Revision</p> <p>Measurement: Intra-access blood flow (ml/min)</p> <p>Equipment</p> <p>Flowmeter: HVT100 Endovascular Flowmeter</p> <p>Flow Catheter: ReoCath™ Flow Catheter: antegrade, retrograde</p> <p>Technology Thermal Dilution</p>

Table 1.1: A summary of the three measurement modalities that provide quantitative vascular access flow data during vascular access surgeries, hemodialysis and angioplasty.