Best Practices: Transonic® Hemodialysis Monitoring

- Vascular Access Flow
- Dialysis Adequacy
- Cardiac Function
Flow-based Vascular Access Management

Trending Vascular Access Flow
Flow-based trending alerts a patient care team to patients at risk for underdialysis, thrombotic events and cardiac failure.

Dialysis Adequacy
Ensure adequate dose delivery by direct, accurate measurement of pump blood flow and access recirculation in AV accesses and catheters. Hemodialysis Adequacy optimization for Catheter Connection Configuration Algorithm using the Transonic Flow-QC® Hemodialysis Monitor can be used as an on-the-spot tool to optimize the dialysis session. Delivered Flow and Recirculation can be quickly measured before the implementation of any interventions to improve catheter dysfunction. The measurements are repeated to determine impact of any interventions including the use of any thrombolytic agents.

Cardiac Function
Transonic Flow-QC® Cardiac Function Assessment with ultrasound indicator dilution technology provides a way to integrate cardiac function studies into a hemodialysis clinic’s treatment protocol in order to forestall the devastating consequences of CVD. Cardiac function measurements help diagnose cardiac overload in ESRD patients. When access flows measured during the dialysis session are unusually high (>2 L/min), cardiac overload can be suspected. A follow-up Flow-QC cardiac output measurement will verify whether the heart is stressed.

Cardiac output measurements during hemodialysis combined with access flow identify:
• Prolonged high access flow to cardiac output ratio that stresses the heart and can result in cardiomegaly and heart failure.
• Dangerously low cardiac index that places patients at high risk for cardiovascular complications and failure.
• Dramatic decreases of cardiac index during hemodialysis due to inaccurate dry weight estimation and/or inadequate medication.
• Dangerous decrease in central blood volume during hemodialysis that may portend hypotensive episodes.

Flow-QC Cardiac Output Measurement: Dialysis lines are reversed at their needle connections to induce recirculation through the access. Vascular access flow can then be calculated from the change in blood concentration detected by the paired flow/dilution sensors. To measure recirculation, saline is introduced into the venous line with the dialysis lines in normal position. Recirculation is calculated from the change in blood concentration between the venous line and the arterial needle.

Krivitski Method® Access Flow Measurement: Dialysis lines are reversed at their needle connections to induce recirculation through the access. Vascular access flow can then be calculated from the change in blood concentration detected by the paired flow/dilution sensors. To measure recirculation, saline is introduced into the venous line with the dialysis lines in normal position. Recirculation is calculated from the change in blood concentration between the venous sensor and arterial sensor.

Transonic Systems Inc. is a global manufacturer of innovative biomedical measurement equipment. Founded in 1983, Transonic sells “gold standard” transit-time ultrasound flowmeters and monitors for surgical, hemodialysis, pediatric critical care, perfusion, interventional radiology and research applications. In addition, Transonic provides pressure and pressure volume systems, laser Doppler flowmeters and telemetry systems.

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

HemodialysisCover(DL-100-fly)ReB 2020 A4
Transonic® HD03 Hemodialysis Monitor

“Gold Standard” Surveillance

The battery-operated, portable HD03 Monitor & Flow/dilution Sensors Measure:

- Delivered Blood Flow
- Vascular Access Recirculation
- Vascular Access Flow
- Cardiac Output

Measurements take less than 10 minutes per patient. Results are displays immediately on the Monitor.
**HD03 Features & Benefits**

**HD03 Monitor**

**Measurements**  
Performed on AV fistulas, grafts and catheters during routine dialysis.

**Easy to Use**  
Measurements are operator independent. Software guides user step-by-step through procedure.

**Easy Set-up**  
Simply clip the arterial and venous flow/dilution sensors onto the respective blood lines.

**Portable**  
Rechargeable battery permits easy mobility between patients.

**Safety/Infection Control**  
Touch-screen input prevents cross contamination. The screen can be cleaned with a dilute solution of bleach or soap.

**H4FX Flow/Dilution Sensors**

Paired sensors pass ultrasound waves through dialysis tubing to measure blood flow and other parameters
- Sensors clip onto tubing connected to the patient’s blood lines.
- Saline can be released directly from saline bag or infused into the dialysis circuit.

**Administrative Software**

**Data Management**  
A removable Data Transfer Module can be uploaded to a computer with HD03 Administration software, and information is synchronized between the Monitor and computer.

**Powerful**
- Documents and trends interventions and access history
- Generates High Risk Thrombosis “Alert” List
- Permits schedule planning
- Calculates individual patient and clinic statistics
- Displays comprehensive Patient Status Reports

The portable HD03 Monitor on a rolling stand.
Best Practices in Hemodialysis Care

Access Patency • Dialysis Adequacy • Cardiac Function

The singular purpose of an AV vascular access is to serve as a conduit for sufficient blood flow to sustain hemodialysis delivery. Inadequate flow causes underdialysis; too much flow can lead to cardiac problems. Each has associated morbidities and can lead to serious complications that even include death.

Transonic’s ultrasound dilution technology is the universally recognized gold standard for hemodialysis access flow measurements. The method uses Transonic Flow-QC® Hemodialysis Monitors and Flow/dilution Sensors to directly:

- **Measure Dialysis Adequacy:** (delivered blood flow and recirculation) for on-the-spot identification and correction of dose delivery problems in AV access and central venous catheters;

- **Trend Vascular Access Flow** to detect flow limiting problems wherever they occur in a vascular access. Flow-based trending alerts the patient care team to patients at risk for thrombotic events;

- **Trend Cardiac Function:** to measure ten non-invasive Cardiac Output parameters that can be used to identify patients at risk of increased cardiac related morbidity and mortality, manage fluid status and dry weight, evaluate for high flow cardiac output failure due to high flow AV access, and to help manage blood pressure/cardiac medications.

“Adequate blood flow in peripheral hemodialysis fistulae and grafts is vital to the success of hemodialysis and to the 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.” Depner, TA et al
### Dialysis Adequacy: Delivered Blood Flow; Recirculation

The Transonic Hemodialysis Monitor is used to optimize efficient dialysis delivery through measurement of delivered pump blood flow and recirculation in an AV access and central venous catheters. These measurements are used to:

- Verify true delivered blood flow;
- Test the calibration of the blood pump;
- Avoid underdialysis through inadvertent reversal of the dialysis lines;
- Detect and quantify access recirculation in an AV access, or central venous catheter;
- Help determine proper needle placement;
- Maximize catheter function;
- Identify sources of large negative arterial blood line pressure that causes underdialysis;
- Determine the most appropriate blood pump setting for a low flow access when access flow can’t be increased.
# Access Flow Thresholds in AV Fistulas and Grafts

## Clinical Interpretation Key:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
<th>Action:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant Stenosis/Recirculation as flow decreases</td>
<td>Indicated by color progression from blue to purple</td>
<td>Consider Clinical Examination &amp; Imaging</td>
</tr>
<tr>
<td>Expected Access Flow Range</td>
<td>Expected flow range is ideal. However, a sudden drop of 25% in this range may signal a potential onset of stenosis.</td>
<td>If Flow Is Steady, Continue Monitoring. If 25% Decrease Occurs, Consider Clinical Exam &amp; Imaging</td>
</tr>
<tr>
<td>Probable risk for Cardiac Failure as flow increases</td>
<td>Indicated by color progression from yellow to red</td>
<td>Measure Cardiac Output Evaluate AF/CO% Ratio</td>
</tr>
</tbody>
</table>

### Lower Arm AVF (wrist and above)

| Flow Rate | 200 | 400 | 600 | 800 | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 | 2200 |

### Upper Arm AVF (elbow and above)

| Flow Rate | 200 | 400 | 600 | 800 | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 | 2200 | 2400 | 2600 |

### AV Graft (forearm loop graft)

| Flow Rate | 200 | 400 | 600 | 800 | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 |

### Notes:

- The routine clinical examination (look, listen, feel, arm elevation and augmentation) should be used routinely as part of the pre-cannulation process.
- The Transonic Access Flow measurements are intended to be utilized in conjunction with the clinical examination to detect/confirm indications of access dysfunction.
- Snuffbox or Endovascular Fistulas may have a lower access flow range depending on the location of the anastomosis and the vessel’s outflow configuration.
- Upper arm AV Fistula typically has a higher access flow range due to the larger artery size.
Cardiac Function Assessment in Hemodialysis Patients

Cardiovascular Disease: The Silent Killer of Hemodialysis Patients

- Half of End-stage Renal Disease (ESRD) patients die from Cardiovascular Disease (CVD).
- 1/3 of ESRD patients are hospitalized from CVD.
- CVD is the leading cause of morbidity and mortality and is a major cause of complications during hemodialysis treatments in patients with ESRD.
- In ESRD patients, CVD mortality rates are approximately 30 times higher than those of the general population.
- 35% of deaths occur within the first 12 hours from the beginning of the dialysis session.
- Patients who do not feel well at the end of a dialysis session are subject to an unidentified decrease in Cardiac Index (CI) to critical ICU levels of <2 L/min/m².

Hemodynamic monitoring provides a unique data set to gain insight into the hemodynamic profile of an individual HD patient with regard to cardiac performance, congestion and compensation of Access Flow (indicated by AF/CO). It also allows the identification of patients at increased mortality risk using TEF, which promises to be a robust risk marker that could be implemented for repeated monitoring of HD patients. While cardiac biomarkers represent static risk markers, many of the hemodynamic parameters are amenable to treatment that, in turn, could improve HD treatment and most importantly prognosis of HD patients. Another advantage of hemodynamic monitoring is the fact that it is directly carried out by the dialysis team without the need for external resources or referrals.

The Cardiovascular Effects of Arteriovenous Fistulas in Chronic Kidney Disease

Hemodynamic effects and changes as a result of Arteriovenous Fistula (AVF) creation can be detected immediately with a 10-20% increase in cardiac output, increased stroke volume and heart rate. Within a week of AVF creation there is a decrease in plasma renin and aldosterone levels, and a decrease in systemic vascular resistance and systolic/diastolic blood pressure. In the long-term, AVF creation can lead to high output cardiac failure.
How Ultrasound Dilution Measurement Helps

Blood pressure changes cannot quantify the cardiac status of HD patients; the most accurate assessment of cardiac function is through ultrasound dilution measurements.

The Transonic HD03 can measure a full complement of cardiac parameters during dialysis through a simple innocuous bolus of saline thus safeguarding the patient from cardiovascular collapse. All HD patients should be regularly monitored for cardiac issues and HD patients with active cardiovascular disease should be frequently assessed.

Saline Indicator Route: Body temperature saline is injected into the venous line, travels through the heart and lungs and returns via the arterial system where a flow/dilution sensor records the diluted concentration.

Know your Access Flow to Cardiac Output Ratio

The ratio of access flow to cardiac output is an important clinical indicator. Cardiac function should be assessed with ultrasound dilution technology if the patient displays values in the yellow or red ranges below, recommends MacRae JM et al.

- Up to 25% of cardiac output.
- More than 30% of cardiac output.
- 40% or greater of cardiac output.

New Flow-QC® Cardiac Function Parameters

- Cardiac Output (CO) 5-8 L/min
- Cardiac Index (CI) 2.2 - 3.8 L/min/m²
- Stroke Volume Index (SVI) 32 – 56 mL/m²
- Total Ejection Fraction (TEF) 40 – 76 %
- Systemic Vascular Resistance (SVRI) 1900 – 3200 Dynes sec/cm⁵/m²
- Total End Diastolic Volume Index (TEDVI) 6 - 11 mL/kg
- Central Blood Volume Index (CBVI) ML/KG 13 - 23 mL/kg
- Active Circulation Volume Index (ACVI) 40 - 70 mL/kg
- Oxygen Delivery Index (ODI) 420 -500 mL O2/min/m²

Get the Guide: How Non-Invasive Cardiac Function Assessment Can Help Your Patients

https://info.transonic.com/cardiac-function-assessment-in-hemodialysis

Transonic Systems Inc. is a global manufacturer of innovative biomedical measurement equipment. Founded in 1983, Transonic sells “gold standard” transit-time ultrasound flowmeters and monitors for surgical, hemodialysis, pediatric critical care, perfusion, interventional radiology and research applications. In addition, Transonic provides pressure and pressure volume systems, laser Doppler flowmeters and telemetry systems.
How the HD03 Improves Your Patients’ Outcomes

The Transonic® Gold Standard Hemodialysis Monitor Assures Flow-based Quality Assurance through:

- Dialysis Adequacy Optimization
- Vascular Access Trending
- Cardiac Function Assessment
HD03 Hemodialysis Monitor

1. Identifies Discrepancy Between Pump Setting & Delivered Blood Flow As A Result of:
   - Negative pressure effects of the roller pump
   - Condition of access
   - Needle size
   - Needle placement
   - Kinked or occluded tubing
   - Calibration of dialysis machine
   - Change in type of dialysis tubing
   - Calibration of Transonic® Flow/dilution Sensors

2. Ensures Correct Needle Placement
   When Transonic® Hemodialysis Monitoring first shows vascular access recirculation (Fig. 1), which disappears after the blood lines are reversed and the recirculation measurement is repeated (Fig. 2), the hemodialysis lines have been inadvertently reversed.

   Transonic® Hemodialysis Monitor screenings show that dialysis occurs with the needles inadvertently reversed in more than 4% of cases.

3. Confirms 0% Recirculation
   In contrast to measurement technologies that cannot separate vascular access recirculation from cardiopulmonary recirculation and, therefore, show false positives, Transonic® Hemodialysis Monitoring can separate access recirculation from the cardiopulmonary (the red curve in Fig. 3) and can report zero % recirculation.

4. Optimizes Dialysis in Dual-lumen Catheters
   Catheter recirculation is an early sign of catheter failure and usually depends on dialysis blood flow. The patient in Fig. 4 was dialysed at flows up to 300 mL/min without any recirculation. At flows higher than 300 mL/min, such as 450 mL/min shown in Fig. 5, 19% recirculation occurred.

   Therefore, increasing delivered blood flow (Qb) did not proportionally increase the quality of dialysis.

   Note: Discrepancies between pump flow and real delivered flow can also be more dramatic with catheters than with vascular accesses.
5. **Recirculation with Low Access Flow Detects Significant Inflow/Outflow Stenoses**

Unlike other technologies that can only identify outflow stenoses in AV accesses, HD03 Monitor trending can detect a stenosis wherever it occurs within the vascular access circuit: inflow, outflow or between the needles in both fistulas or grafts.

In the example on the right, access recirculation (Fig. 6), accompanied by low vascular access flow (Fig. 7), indicated the presence of a significant stenosis which was then confirmed by color Doppler and fistulogram.

6. **0% Recirculation & Low Access Flow Pinpoints Stenoses Between Needles**

When a significant stenosis is located between the hemodialysis needles, hemodialysis pump flow simply bypasses the stenosis without producing any recirculation.

When low access flow (Fig. 9) is accompanied by 0% recirculation (Fig. 8), a stenosis between the dialysis needles can be suspected. A stenosis between the needles can be confirmed by a color Doppler image.

7. **Cardiac Output Check Indicates Potential Cardiac Overload**

In the case example on the right, vascular access flow measured more than 3 L/min (Fig. 10). Cardiac output exceeded 10 L/min (Fig. 11). When the vascular access was briefly occluded by the tip of the examiner’s finger, the patient’s pulse rate dropped from 112 to 88 per min. This patient had complained of chest pains and had been diagnosed with cardiomegaly.

The access was surgically revised by banding. Following the revision, access flow then measured 1700 mL/min. Cardiac output dropped to 7-8 L/min. The patient exhibited fewer post-dialysis hypotensive episodes, his dry weight decreased, his chest X-Ray cleared and he reported significant improvement in his previous symptoms.
Summary: Flow-based Quality Assurance

Hemodialysis Adequacy

- Tests calibration of the blood pump;
- Verifies true delivered blood flow and compares delivered blood flow to pump setting to identify flow disparity and avoid underdialysis. If disparity is significant, Flow-QC® assists in determining cause (blood pump calibration versus inflow restriction/excessive pre-pump negative arterial pressure);
- Detects and quantifies access recirculation in AV access and catheters;
- Identifies inadvertent reversal of dialysis lines to prevent recirculation and/or underdialysis;
- Determines proper needle placement;
- Identifies sources of large negative arterial blood line pressure (and its resulting underdialysis);
- Determines the most appropriate blood pump setting for a low flow access when it is not feasible to increase access flow;
- Provides delivered flow and recirculation measurements to maximize catheter function.

Vascular Access Measurements

- Tells actual function in AV grafts and fistulas in order to identify failing accesses and avert underdialysis and/or thrombosis;
- Indicates effectiveness of interventions (post-intervention surveillance) or limb ischemia;
- Excludes access dysfunction quickly as cause of underdialysis;
- Identifies a mid-access obstruction;
- Identifies high-flow versus low flow accesses to select ideal treatment plan for correction (flow-restricting versus re-vascularization procedure);
- Permits access trending to be performed by the clinic’s staff who then can alert nephrologist to possible onset of access dysfunction & referral for early intervention;

Transonic Systems Inc. is a global manufacturer of innovative biomedical measurement equipment. Founded in 1983, Transonic sells “gold standard” transit-time ultrasound flowmeters and monitors for surgical, hemodialysis, pediatric critical care, perfusion, interventional radiology and research applications. In addition, Transonic provides pressure and pressure volume systems, laser Doppler flowmeters and telemetry systems.