Transonic® HD03
Hemodialysis Monitoring

Delivered Flow • Recirculation
Access Flow • Cardiac Function

Measure Dialysis Adequacy
Delivered Flow and Recirculation results identify dose delivery problems in the AV Access and Central Venous Catheters allowing the nurse to optimize the treatment on-the-spot!

Trend Vascular Access Flow
A drop in Access Flow signals the onset of a stenosis, in time for proactive minimally invasive intervention. A high Access Flow can signal a potential cardiac overload.

Assess Cardiac Function:
Measuring Cardiac Output non-invasively identifies ten Cardiac function parameters on-the-spot that can be used to identify patients at risk of increased cardiac related morbidity and mortality, manage fluid status and dry weight, evaluate high flow cardiac output failure and help manage medications.

HD03 Monitor displays vascular access flow results
HD03 Features & Benefits

HD03 Measurements

HD03 measurements can be performed on all Chronic or Acute Adult, and Pediatric Hemodialysis patients’ AV fistulas, grafts and catheters during routine dialysis.

Easy to Use
The HD03 is operator independent and very easy to use with on-screen step-by-step procedure.

Quick and Accurate
Results are displayed immediately on the HD03 monitor screen.

Choice of Results
You have a choice of:
1) HD03 Administrator Management Software (DTM) that trends and archives measurement results under a patient’s name.
Or
2) HD03 Patient-less Measurement Module (PMM) that displays measurement results to be manually recorded in a patient’s chart.

HD03 Monitor
Portable
Rechargeable battery permits portable, easy mobility between patients.

Safety/Infection Control
Touch-screen input prevents cross contamination. The screen can be cleaned with a diluted 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.
HD03 Monitoring of Dialysis Adequacy in Arteriovenous Grafts and Fistulas

- Measure True Delivered Blood Flow to Optimize Dialysis Delivery
- Measure Recirculation to Identify Formation of Stenoses

Measure Delivered Blood Flow

Pump flow errors and recirculation compromise dialysis delivery of a KT/V prescription. The Transonic® Hemodialysis Monitor measures true delivered blood flow through dialysis tubing using “Gold Standard” transit-time ultrasound technology. By comparing true delivered blood flow to the pump’s reading, any flow limiting cause such as small needle diameter or incorrect needle placement can be identified and corrected.

Delivered Blood Flow is used to:
- Test blood pump calibration and its “effective flow” algorithm;
- Diagnose tubing set flow restrictions that could cause hemolysis;
- Determine the most appropriate blood pump setting for a low flow access when it is not feasible to increase access flow;
- Find the cause of excessive negative arterial pressure.

Measure Access Recirculation

With a single infusion of saline, the Transonic Hemodialysis® Monitor detects and quantifies access recirculation, a late indicator of a failing access. Because Transonic® ultrasound dilution technology can separate cardiovascular recirculation from cardiopulmonary recirculation, 0% Recirculation can be quantified.

Measurement of recirculation will:
- Identify inadvertent reversal of blood lines (see box below);
- Confirm proper needle placement;
- Confirm 0% recirculation.

Case Report: Inadvertent Reversal of Blood Lines

When a routine Transonic® hemodialysis screening of a 41-year-old female ESRD patient reported a vascular access recirculation of 22%, the nurse reversed the blood lines and performed a second recirculation measurement. Zero percent recirculation registered. This demonstrated that the hemodialysis lines had been inadvertently reversed when they were first connected for hemodialysis. By leaving the lines in the correct position for the duration of the dialysis session, the patient received her prescribed dialysis prescription.
HD03 Monitoring of Dialysis Adequacy in Central Venous Catheters (CVCs)

Measure True Delivered Blood Flow and Recirculation in CVCs On-the-Spot to Optimize Dialysis Delivery

Catheter Adequacy
Most End-Stage Renal Disease (ESRD) patients will undergo, at some point, dialysis administered through a Central Venous Catheter. Whether dialysis is emergent and temporary, acute or chronic, CVCs will often underdeliver dialysis due to:

• a discrepancy between a dialyzer’s pump setting and its true delivered flow;
• and/or the presence of recirculation during dialysis delivery.

Transonic HD03 Flow-QC® Monitoring of Catheter Dose Delivery
Two potential pitfalls plague the use of catheters for dialysis delivery.

1. A tissue flap can block the lumen of the catheter’s arterial entry port, impeding flow and causing a severe drop in dialysis dose delivery. This can be identified on the spot and often corrected with an HD03 measurement of true delivered blood flow.

2. The close proximity of the catheter’s arterial entry and venous return ports make recirculation likely. For instance, if there is 10% recirculation, the amount of blood cycled through the dialyzer is effectively 10% less and underdialysis can occur. Since the HD03 Monitor can measure recirculation, recirculation in catheters can be identified and optimized to provide the most efficient dialysis possible.

Transonic’s HD03 Hemodialysis Monitor Measurements Optimize Dialysis Catheter Delivery by:

• Helping to establish a maximum dialysis pump setting before recirculation occurs;
• Using known values for flow and recirculation to adjust the length of dialysis;
• Identifying flow restrictions;
• Finding the best catheter configuration between the catheter blood lines (regular or reversed);
• Identifying failing catheters through high

Example: Flow-QC Adequacy Test Detects Hemolysis Risk
75-year-old woman with Central Venous Catheter: Blood Lines: normal line position; Pump Setting: 300 mL/min; Delivered Blood Flow: 190 mL/min; Recirculation: 0%.

A 35% disparity between 300 mL/min pump setting and 190 mL/min delivered blood flow indicated significant hemolysis risk.

Response: Lines were checked to see that they were not kinked. Blood lines were then reversed; the pump was reset to 300 mL/min. Delivered blood flow & recirculation were again measured.

• Delivered Flow: 290 mL/min
• Flow-QC Recirculation: 2-3%

Results: The patient received better treatment with the lines in a reversed position and the pump delivering 290 mL/min.

Take Home: Treatment of patients with CVCs can be optimized with Flow-QC Delivered Flow and Recirculation measurements.
HD03 Measurements of Vascular Access Flow in AV Grafts and Fistulas

Transonic® Hemodialysis Monitoring identifies ESRD patients at risk for underdialysis, thrombotic events and cardiac failure.

Vascular Access Flow
Access flow is the quintessential vital sign for an AV Access. Insufficient flow causes underdialysis. Still lower flow invites thrombosis. Too much flow can lead to heart problems. Each condition harbors associated morbidities.

Transonic® ultrasound dilution technology is the “gold standard” intra-access flow measurement technology to detect flow limiting problems wherever they occur within a vascular access during the dialysis session. The method uses Transonic® Hemodialysis Monitors and Flow/dilution Sensors to measure access flow directly for an instant snapshot of access function.

By measuring vascular access flow routinely and trending the results over several months, a record of access patency is created. A drop in access flow signals formation of a stenosis, in time for proactive minimally invasive intervention.

Why Prevention of Fistula Thrombosis through Access Flow Monitoring Is Worthwhile
A thrombosed vascular access is problematic for: Patients who cope with:
- Discomfort, pain, anxiety and fear
- Delay of dialysis
- Concerns about K+ and fluid
- Disruption to schedule
- Decreased quality of life

Dialysis Staff who need to:
- Assist patient in coping
- Arrange for transportation
- Interface between patient and physicians
- Rearrange dialysis schedule

Nephrologist who needs to:
- Console unhappy patient & family
- Arrange logistics to resolve AVF failure

Fistula and Graft Access Flow Interpretation

**Lower Arm AVF** (wrist and above)

| Flow (mL/min) | 200 | 400 | 600 | 800 | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 | 2200 |

**Upper Arm AVF** (elbow and above)

| Flow (mL/min) | 200 | 400 | 600 | 800 | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 | 2200 | 2400 | 2600 |

**AV Graft** (forearm loop graft)

| Flow (mL/min) | 200 | 400 | 600 | 800 | 1000 | 1200 | 1400 | 1600 | 1800 | 2000 |

**CLINICAL INTERPRETATION KEY:**

- **Probable risk for Hemodynamically Significant Stenosis/Recirculation as flow decreases** (indicated by color progression from blue to purple)
- **Expected Access Flow Range** Expected flow range is ideal. However, a sudden drop of 25% in this range may signal a potential onset of stenosis.
- **Probable risk for Cardiac Failure as flow increases** (indicated by color progression from yellow to red)

**Action:**

- Consider Clinical Examination & Imaging
- If Flow Is Steady, Continue Monitoring. If 25% Decrease Occurs, Consider Clinical Exam & Imaging
- Measure Cardiac Output, Evaluate AF/CO% Ratio

**Notes:**

- Actual flow levels for AV fistula and graft patients should be customized by the nephrologist.
- A clinical examination (look, listen, feel, arm elevation and augmentation) should be used routinely as part of the pre-cannulation process.
- Transonic access flow measurements are intended to be utilized in conjunction with a 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 fistulas typically have a higher access flow range due to the larger artery size.
- A potential for cardiac overload exists at flow >1600-3000 mL/min. Cardiac Output parameters can be utilized to measure AF/CO ratio.

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.
HD03 Monitoring of Cardiac Function

Forestall ESRD patients’ cardiovascular complications with hemodialysis cardiac function screening

Cardiovascular disease (CVD) is the leading cause of morbidity and mortality in patients with End-Stage Renal Disease (ESRD). Transonic’s Cardiac Function Monitoring provides a way to integrate cardiac function studies into a hemodialysis clinic’s treatment protocol to forestall the devastating effects of CVD. Transonic’s proprietary ultrasound indicator dilution technology measures Cardiac Output and reports the following derived cardiac function parameters:

- Cardiac Index (CI);
- Central Blood Volume Index (CBVI);
- Stroke Volume Index (SVI);
- Total End Diastolic Volume Index (TEDVI);
- Total Ejection Fraction (TEF %);
- Systemic Vascular Resistance Index (SVRI);
- Active Circulation Volume Index (ACVI);
- Oxygen Delivery Index (O2DI);
- Access Flow to Cardiac Output Ratio (AF/CO).

Monitoring of these parameters identifies:

1. Excessively high and prolonged levels of access flow (>1,600-2,000 mL/min) stress the heart causing cardiomegaly and heart failure. This can be identified by an access flow to cardiac output ratio (AVF/CO) exceeding 25-30%.

2. Low cardiac output (CI < 2 L/min/m²) which places patients at high risk for cardiovascular complications and failure.

3. Significant 20 - 30% decrease of Cardiac Index during hemodialysis to dangerously low levels due to inaccurate dry weight estimation and/or inadequate medication that places patients at high risk for cardiovascular complications and sudden death following a dialysis session.

4. Significant decreases in Central Blood Volume during dialysis that may portend hypotensive episodes.

“Haemodynamic monitoring identifies a significant number of HD patients with cardiac impairment that are at risk for increased mortality.”


Cardiovascular mortality in ESRD patients, depending on age, is 10 - 500 times greater than the general population. AJKD 1999; 32(5)
Hemodialysis Monitor Specifications

Two HD03 system configurations address different user needs.

- **Patient-less Measurement Module (PMM/PMM-CO):** does not save any patient information or measurement data.
- **Data Transfer Module (DTM/DTM-CO):** records patient information & measurement data to be transferred to a computer loaded with HD03 Administrative software for further analysis.

### Vascular Access Type

<table>
<thead>
<tr>
<th>Vascular Access Type</th>
<th>Transonic Measurement</th>
<th>Clinical Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catheter</td>
<td>Delivered Flow; Recirculation</td>
<td>Dialysis optimization with simple algorithm. Outcomes: improved adequacy; decreased use of thrombotic agents; decreased catheter exchange.</td>
</tr>
<tr>
<td>AV Fistula and/or graft</td>
<td>Delivered Flow; Recirculation</td>
<td>Detection of access dysfunction with customized AVF/AVG protocols. Detection of high flow access and related high flow cardiac failure. Outcomes: improved management of access intervention and measurement to manage intervention outcomes: Cardiac care intervention to reduce morbidity and mortality; Assist with kidney transplant listing.</td>
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</table>

### HD03 Specifications

#### Physical Parameters
- Weight: 6 lbs (2.7 Kg)
- Dimensions: 9.5” x 11.5” x 7” (24cm x 29cm x 18cm)
- Display: VGA LCD Interactive Touch Screen (8.4”) (21cm)
- USB Port: Type A; For connection to Transonic DTM only
- Sensor Connector: 36-pin high-density connector

#### Power Supply
- External AC Input: 100 - 240 VAC (±10%); 50-60 Hz. nominal
- External Connector: International 3 conductor type IEC 320
- Output: 15 VDC, 2.6A
- Battery: 12.6 VDC (max) 8.7 Ahr (min) Li-ion

#### Electrical Isolation
Hemodialysis monitor complies with USA standards for medical and dental equipment (IEC60601), and with European standards for medical and ultrasonic apparatus (DIN IEC 601-1, VDE 0750 -1/5.82, IEC 62D Sec. 31). Input leakage current < 50 uA; Patient leakage current < 10 uA; Patient Isolation > 2500 V, double insulated. Meets IEC 60601-1 Cardiac Floating (CF) specification.

### HD03 Accuracy

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Delivered Flow</th>
<th>Recirculation</th>
<th>Access Flow</th>
<th>CO2 (Optional)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>-2 to +2 L/min</td>
<td>0 to 100%</td>
<td>0 to 4000 ml/min</td>
<td>1 to 16 L/min</td>
</tr>
<tr>
<td>Accuracy</td>
<td>± 6% of the flow reading ± the zero offset</td>
<td>&gt; 2% Recirculation detected ± 3% of displayed value. For example: a 15% reading is between 12% and 18%</td>
<td>The larger of: ±100 ml/min ±15% of reading</td>
<td>The larger of: ±0.5 L/min ±15% of flow reading</td>
</tr>
<tr>
<td>Repeatability</td>
<td></td>
<td>Clinical correlation coefficient = 0.98</td>
<td>Clinical correlation coefficient = 0.98</td>
<td></td>
</tr>
<tr>
<td>Maximum zero flow offset:</td>
<td>± 10 ml/min</td>
<td></td>
<td></td>
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</tbody>
</table>

### H4FX Flow/Dilution Sensors
Sensor pair transmits ultrasound waves through dialysis tubing to measure blood flow and other parameters
- Sensors clip onto tubing connected to a patient’s blood lines.

### H4FX Ultrasonic Sensor Specifications
- Frequency of Operation: 3.6 MHz
- Mode of Operation: Transit-time burst excitation, 1.6% duty factor
- Ultrasound Output Level: Factory-set, no interactive system features. Settings use “ALARA” principles (As Low As Reasonably Achievable) and are more than 30dB below FDA “pre-amendment levels,” recognized as acceptable USA insonification limits.
HD03 Theory of Operation

Transit-Time Ultrasound Technology: Delivered Flow
A Transonic® Clamp-on Flow/Dilution Flowsensor houses ultrasonic transducers and a tubing channel which holds the dialysis tubing containing the fluid being measured. The transducers in the sensor are positioned on opposite sides of the tubing. An electrical excitation from the flowmeter causes the transducers to emit waves of ultrasound that intersect the tubing in both upstream and downstream directions. The ultrasound waves are received by the opposing transducers where they are converted into electrical signals. As the ultrasound waves travel downstream or with the flow within the tube, its velocity increases. As ultrasound waves travel upstream or against the flow, its velocity decreases. From these velocity signals, the Flowmeter derives an accurate measure of the "transit time" it takes for the wave of ultrasound to travel from one transducer to the other from which it then derives volume flow.

Ultrasound Indicator Dilution Technology: Recirculation, Access Flow, Cardiac Output
The Transonic Hemodialysis Monitor with its Flow/Dilution Sensors measure ultrasound velocity. The velocity (1560-1590 m/sec) of ultrasound in blood is determined primarily by its blood protein concentration. A bolus of isotonic saline (ultrasound velocity: 1533 m/sec) introduced into the blood stream dilutes the blood and, thereby, reduces its ultrasound velocity. When a bolus of saline indicator is introduced into the blood line, arterial and venous Flow/dilution Sensors record this saline bolus as a conventional indicator dilution curve.

The following measurements can be selected:

Recirculation
The Hemodialysis Monitor identifies the direct reflux of the venous saline indicator bolus into the arterial line. The ratio of indicator concentrations equals access recirculation. The HD03 Monitor’s high timing resolution separates cardiopulmonary circulation from systemic circulation and allows identification of zero access recirculation.
**ACCESS FLOW**

Access Flow is measured by the The Krivitski Method®, a pioneering Transonic® contribution to vascular access management. After reversing the blood lines at the needle connections, the upstream (venous) access needle introduces an indicator into the access flow stream. The downstream (arterial) access needle samples the blood concentration diluted by the indicator.

**CARDIAC OUTPUT**

With blood lines in the normal configuration and no direct recirculation present, cardiopulmonary recirculation provides a measure of cardiac output.

The full saline indicator bolus travels into the heart where it is mixed (diluted) into the full cardiac output. Part of this diluted indicator then reappears at the Arterial Sensor. Cardiac output and Cardiac Index, and a host of other parameters including stroke volume, stroke volume index, ejection fraction, ejection fraction index, systemic vascular resistance index, total end diastolic volume, total end diastolic volume index, central blood volume, central blood volume index, active circulation volume index, oxygen delivery index and access flow to cardiac output ratio are calculated via conventional Stewart-Hamilton analysis.
Hemodialysis Annotated References

Theory & Validations (UDT, TTFM)

Ultrasound Dilution (UDT)

Krivitski NM, "Novel Method to Measure Access Flow during Hemodialysis by Ultrasound Velocity Dilution Technique," ASAIO 1995; 41(3): M741-M745. (Transonic Reference # HD4T) Theory and bench validation of access flow measurement by ultrasound velocity dilution. Reversal of dialysis lines creates a zone of mixing in the vascular access, allowing the use of dilution technique for access flow measurement. Data show that access flow can be accurately measured by sound velocity dilution technique.


Krivitski NM, Depner TA, "Cardiac output and central blood volume during hemodialysis: methodology," Adv Ren Replace Ther. 1999;6(3):225-232. (Transonic Reference # HD9T) "CO and CBV can be routinely and reliably measured during hemodialysis if precautions are taken to avoid specifically identified sources of error."

Kislouchine VV, Dean DA, "Validation of a Novel Ultrasound Dilution Method to Measure Cardiac Output during Hemodialysis," ASAIO J 1996; 42(5): M906-M907. (Transonic Reference # HD16V) "Cardiac output measured by ultrasound velocity dilution during hemodialysis is in good agreement with well established, but invasive, transit time and pump standards."

Nikiforov UV, Kislouchine VV, Chaus NI, "Validation of a New Method to Measure Cardiac Output during Extracorporeal Detoxification," ASAIO J 1996; 42(5) M903-M905. (Transonic Reference # HD17V) "Data suggest agreement between the ultrasound dilution technique and thermodilution. Ultrasound dilution is preferable in patients undergoing extracorporeal detoxification when pulmonary artery catheterization is not required or dangerous."

Numbers in parentheses ( ) are Transonic Reference #s.
Predictive Power of Arteriovenous Access Flow Measurements

Salman L et al, “A multicenter randomized clinical trial of hemodialysis access blood flow surveillance compared to standard of care: The Hemodialysis Access Surveillance Evaluation (HASE) Study.” Kidney International Reports (2020). (Transonic Reference # HD11823AH) “The HASE study demonstrated that monthly surveillance using UDT flow measurement has resulted in lower per patient and per visit thrombosis rates as compared to the control group.”


Ashoor IF, Hughson EA, Somers MJ, “Arteriovenous access monitoring with ultrasound dilution in a dialysis hemodialysis unit.” Blood Purif. 2015;39(1-3):93-8. (Transonic Reference: HD10296AH) “Thrombosis rate dropped from 13.5 per 100 patient-months on HD during the baseline period to 3.5 per 100 patient-months on HD during the surveillance period. Ultrasound Dilution surveillance is very sensitive in detecting hemodynamically significant stenosis and can decrease AV access thrombosis rates.”

Park HS, Kang SH, Chung BH et al, “Effect of intradialytic change in blood pressure and ultrafiltration volume on the variation in access flow measured by ultrasound dilution,” Kidney Res Clin Pract. 2013;32(1):16-20. (Transonic Reference # HD11074AH) Variation in access flow during HD is relatively small. Decreased blood pressure is a risk factor for variation in access flow measured by ultrasound dilution. In most patients whose blood pressures are stable during HD, the access flow can be measured at any time during the HD treatment.


Wijnen E, van der Sande F et al, “Impact of a quality improvement programme based on vascular access flow monitoring on costs, access occlusion and access failure,” Nephrol Dial Transplant. 2006 Dec;21(12):3514-9. (Transonic Reference # HD7340A) “A quality improvement programme based on periodical access flow measurement reduced the number of acute vascular access failures due to thrombotic events and also significantly reduced health care costs in patients with AVG, but not in patients with AVF.”

Lopot F et al, “Comparison of different techniques of hemodialysis vascular access flow evaluation,” J Vasc Access. 2004 Jan-Mar;5(1):25-32. (Transonic Reference # HD11188R) “Ultrasound Dilution measurements were used as the gold standard to compare other surveillance methodologies. The very high reproducibility seen in UD, both for measurements at the same extracorporeal blood flow (QB) and for measurements at two different QB justifies its current status of a reference method in vascular access flow.”

Lok CE, Bholia C, Croxford R, Richardson RM, “Reducing vascular access morbidity: a comparative trial of two vascular access monitoring strategies,” Nephrol Dial Transplant. 2003 Jun;18(6):1174-80. (Transonic Reference # HD306A) “A three-year study, 300-400 patients. Low flow rates detected using Transonic monitoring were associated with increased thrombosis, while stenosis detected using Duplex ultrasonography was not a strong predictor of incipient thrombosis.”


Sands JJ, Jaybac PA, Miranda CL, Kapsick BJ, “Intervention based on monthly monitoring decreases hemodialysis access thrombosis,” ASAIO J. 1999 May-Jun;45(3):147-50. (Transonic Reference # HD088A) “We believe that monthly access flow measurement will ensure the lowest incidence of thrombosis and decrease the cost of access maintenance.”

Neyra NR, Ikizler TA, May RE, Himmelfarb J, Schulman G, Shyr Y, Hakim RM, “Changes in access flow over time predicts vascular access thrombosis,” Kidney Int 1998; 54: 1714-1719. (Transonic Reference # HD82A) “There is a 13.6-fold increase in the relative risk of thrombosis for accesses with more than 35% decrease in vascular access blood flow. Study prospectively determined that measurement of blood flow plays an important role in evaluation and detection of PTFE grafts at higher risk of thrombosis.”

May RE, Himmelfarb J, Yenicesu M et al, “Predictive measures of vascular access thrombosis: A prospective study,” Kidney Int 1997;52:1656-1662. (Transonic Reference # HD42A) Three-center study of 170 patients over six months. “The blood flow by Dilution (for grafts) was the best predictor of thrombosis within the subsequent three months. Multi-variate analysis showed a significantly increasing risk of thrombosis with decreasing access blood flow.”

Dialysis Adequacy

Zero Vascular Access Recirculation - A New Reality


Discrepancy between Prescribed & Delivered HD Pump Flow

Sands J, Glidden D, Jacavage W, Jones B, “Difference between delivered and prescribed blood flow in hemodialysis,” ASAIO J 1996;42(5):M717-M719. (Transonic Reference # HD5A) Delivered and prescribed blood flow (QB) was compared during 208 hemodialysis treatments using the Transonic hemodialysis monitor. Delivered QB averaged 205.6, 300.6, 384.3 (p < .0001), and 467.7 cc/min (p < .0001) at pump settings of 200, 300, 400, and 500 cc/min.

Depner TA, Rizwan S, Stasi TA, “Pressure effects on roller pump blood flow during hemodialysis,” ASAIO Trans. 1990;36(3):M456-M459. (Transonic Reference # HD10A) Blood pump meter readings greater than 400 ml/min were usually inaccurate because of low Pa.

Kelber J, Delmez JA, Windus DW. “Factors affecting delivery of high-efficiency dialysis using temporary vascular access,” Am J Kidney Dis. 1993;22(1):24-29. (Transonic Reference # HD19A) In spite of the change in arterial line pressure, measured blood flow rate increased appropriately at all set blood flows and with all catheter sites studied.


Measurements of Recirculation and Delivered Flow in Catheters

Twardowski ZJ, Van Stone JC, Haynie JD, “All Currently Used Measurements of Recirculation in Blood Access by Chemical Methods are Flawed Due to Intradialytic Disequilibrium or Recirculation at Low Flow,” Am J Kid Dis 1998; 32(6): 1046-1058. (Transonic Reference # HD84A) “The ultrasound dilution method usually gave lower values than the chemical methods, most likely because of overestimation of recirculation by chemical methods.”


Leblanc M, Bosc JY, Paganini EP, Canaud B. “Central venous dialysis catheter dysfunction,” Adv Ren Replace Ther. 1997;4(4):377-389. (Transonic Reference # HD45A) Several recent studies confirm that short femoral catheters recirculate significantly more than is desirable. Well functioning and nonreversed internal jugular and subclavian venous catheters have, in general, recirculation rates less than 5%.

Little MA, Conlon PJ, Walshe JJ, “Access Recirculation in Temporary Hemodialysis Catheters as Measured by the Saline Dilution Technique,” Am J Kid Dis 1998; 33(6): 1135-1139. (Transonic Reference # HD171A) Using ultrasound dilution technology the researchers found “that temporary femoral catheters shorter than 20 cm are associated with increased recirculation rates....when dialysis dose delivery is a priority, locating the temporary catheter in the internal jugular vein is an advantage.”

Leblanc M, Bosc JY, Vausseren F, Maurice F, Leray-Moraques H, Canaud B, “Effective Blood Flow and Recirculation Rates in Internal Jugular Vein Twin Catheters: Measurement by Ultrasound Velocity Dilution,” Am J Kid Dis 1998; 31(1): 87-92. (Transonic Reference # HD43A) “TwinCath delivers an effective Qb of nearly 375 mL/min when Qb is set at 400 mL/min on most dialysis machines. Mean R in TwinCath varies between 5% and 11% for Qb within the range of 200 to 400 mL/min.”

doi:10.1159/000045647. (Transonic Reference # HD145A) The blood flow indicated by the dialysis blood roller pump is always greater than the delivered blood flow, and this difference is in turn conditioned by the negative pressure induced by the blood roller pump in the arterial blood line.

Ward RA, “Blood Flow Rate: An Important Determinant of Urea Clearance and Delivered Kt/V,” Adv Ren Replace Ther 2001; 6(1): 75-79. (HD193A) For quality assurance purposes, actual blood flow rates should be determined by correcting nominal blood flow rates for pressure effects using empirical relationships or by using an ultrasonic flow meter. Because a poorly functioning blood access may further reduce the effective blood flow rate, blood access performance should also be monitored regularly.

Mehta HK, Deabreu D, McDougall J G, Goldberg MB, “Correction of discrepancy between prescribed and actual blood flow rates in chronic hemodialysis patients with use of larger gauge needles,” Am J Kidney Dis. 2002;39(6):1231-1235. (Transonic Reference # HD262A) This study shows that the use of larger gauge needles can significantly increase d-BFR and PRU as a result of changes in arterial and venous pressures, resulting in a significantly increased dialysis dose at no additional cost.


Haag S, Friedrich B, Peter A, Härting HU, Heyne N, Artunc F. “Systemic haemodynamics in haemodialysis: intradialytic changes and prognostic significance.” Nephrol Dial Transplant. 2018;33(8):1419-1427. (Transonic Reference # HD11205AH) “HD leads to a reduction of CI due to ultrafiltration. Haemodynamic monitoring identifies a significant number of HD patients with cardiac impairment that are at risk for increased mortality.”


Basile C, Lomonte C, Vernaglione L et al. “The relationship between the flow of arteriovenous fistula and cardiac output in haemodialysis patients,” Nephrol Dial Transplant. 2008; 23: 282-287. (Transonic Reference # HD7542A) “Relationship between Qa of AVFs and CO is complex...first study to clearly show the high predictive power for high-output cardiac failure occurrence of Qa cut-off values »r= 2.1 mmHg/lmin.”


MacRae JM, “Vascular access and cardiac disease: is there a relationship?” Curr Opin Nephrol Hypertens. 2006;15(6):577-582. (Transonic Reference # HD7382A) “The relationship between vascular access and cardiac disease exists at different levels, ranging from inflammation promoting atherosclerotic disease to vascular remodelling changes of stenosis formation and left ventricular hypertrophy.”


Tucker T et al, “Central Hemodynamic Profiling (CHP) during Outpatient Hemodialysis (HD),” JASN 2002; 13: 209A. (HD268A) Ultrasound dilution is preferable in patients undergoing extracorporeal detoxification when PA catheterization is not required or dangerous.