Best Practices: Transonic® Hemodialysis Surveillance

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

Vascular Access Surveillance
Flow-based surveillance per KDOQI Guidelines alerts a patient care team to patients at risk for underdialysis, thrombotic events and cardiac failure.

“The [HD03] allows you to proactively manage your patients as part of a multidisciplinary vascular access care program to reduce complications and costs of end-stage renal disease.” Duda, CR et al, Nephrology News & Issues, 2000; 14(5).

Dialysis Adequacy
Ensure adequate dose delivery by direct, accurate measurement of pump blood flow and access recirculation in AV accesses and catheters.

“Recirculation and delivered blood flow measurements provide important information about the most appropriate and effective therapies for your patients.” Sands, JJ et al, ASAIO, 1996; 42(5). Depner, TA et al, ASAIO 1995; 41(3).

Cardiac Function
Cardiac Output profiling with a Transonic® HD Monitor identifies patients with dangerously low Cardiac Index due to inadequate dry weight estimation.

“Integration of cardiac output measurements into an ESRD treatment program forestalls the devastating progression of cardiovascular disease.” MacRae, JM et al, Am J Kid Dis 2004; 43(5).

“The Transonic® Flow-QC® Hemodialysis Monitor has benefited numerous dialysis-dependent patients by reducing and, in many cases, eliminating the agony of a clotted AV graft or fistula, thereby facilitating correction of access stenoses on an elective basis that prevents missed dialyses and the need for placing temporary catheters.” Depner, T, MD, UC Davis

“The comprehensive cost is markedly reduced due to the decreased number of hospitalizations, catheters placed, missed treatments, and surgical interventions. Vascular access blood flow monitoring along with preventive interventions should be the standard of care in chronic hemodialysis patients.”

McCarley, P et al, Kid Int 2001; 60(3).

“Transonic flow monitoring is the cornerstone of my Vascular Access Management Program (VAMP).” Spergel, LM, MD, FACS, Dialysis Management Medical Group, San Francisco

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.
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 (optional)

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

**HD03 Monitor**

**Measurements**
Perform 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.

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**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.

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**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

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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 measurement technology for hemodialysis surveillance. 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 surveillance per KDOQI Guidelines alerts the patient care team to patients at risk thrombotic events.
- **Track Cardiac Function:** to identify patients with dangerously low Cardiac Indices at risk for cardiac failure from inadequate dry weight estimation.

“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
Best Practices

Flow-QC Protocol: AV Graft and Fistula Surveillance

Dialysis Adequacy/Vascular Access Patency

- **Start**
  - New patient or revised vascular access

- **Initial Dialysis Adequacy & Vascular Access Patency**
  - Measure initial Qb, AR, AF,

- **Nurses’ Analysis**
  - Optimize dialysis delivery immediately from Qb, AR results. Repeat at established intervals.

- **Nephrologist Analysis**
  - Establish Access Flow levels
  - Establish testing schedule (monthly per KDOQI)

- **Vascular Access Patency Study**
  - (monthly, or other interval)
  - **NO**
    - Is AF above the critical threshold?
  - **YES**
    - Schedule appropriate flow restoration procedure or refer patient for duplex scan and/or fistulogram.

- **After flow restoration procedure**

Cardiac Function

- **Initial Cardiac Function Study**
  - Hourly CO tests (CHP Study) performed when cardiac complications are suspected during hemodialysis.

- **Baseline Cardiac Studies**
  - A second CHP study and third, one month later, establishes reliable average cardiac function parameters for the patient.

- **Nephrologist Analysis**
  - Set cardiac baseline values, warning levels, testing schedule.

- **Follow-up Cardiac Function Study**
  - CHP study performed after a weekend break.

- **Nephrologist Review**
  - Acceptable

A Flow-based Access Management Protocol includes an initial dialysis adequacy study, access patency surveillance and a cardiac function assessment.

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.
Hemodialysis Surveillance: Trending Vascular Access Flow

Vascular Access Patency

The Kidney/Dialysis Outcomes Quality Initiative (KDOQI) Clinical Practice Guidelines for Vascular Access call for access flow monitoring by stating “prospective surveillance of AV grafts and fistulas for hemodynamically significant stenosis, when combined with correction, improves patency and decreases the incidence of thrombosis.” Canadian, Australian and European Guidelines also call for surveillance during hemodialysis to forestall stenosis formation and prolong the life of the access. Intra-access measurements (ultrasound dilution technology) are cited as the preferred method for surveillance.

Transonic hemodialysis surveillance tracks a patient’s vascular access flow over time. If access flow decreases below a critical threshold, fistulograms or interventions can be scheduled proactively to delay access failure. Such early intervention with minimally invasive restorative flow procedures reduces morbidity and costs. The clinic can continue to administer dialysis, collect and analyze data, and reduce its dependence on outside services for lab tests.

“A hemodynamically significant stenosis is the substrate for thrombosis by reducing flow, increasing turbulence, and increasing platelet activation and residence time against the vessel wall.” KDOQI Guidelines 2006

As a cornerstone for a comprehensive Vascular Access Management Program, Transonic Flow-QC hemodialysis surveillance measures:

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

Transonic Flow-QC surveillance implements KDOQI Guidelines.
Cardiac Function Tests

Cardiovascular complications in ESRD patients can be averted or forestalled through routine cardiac function tests with the Hemodialysis Monitor. Reported are Cardiac Output (CO), Cardiac Index (CI), Peripheral Resistance (PR), Central Blood Volume (CBV), Central Blood Volume Index (CBVI) and ratio of Access Flow to Cardiac Output (AF/CO).

“Hemodynamic stability is threatened and often severely compromised by hemodialysis largely because of the obligate fluid removal during a short time span.” Depner, TA

Central Hemodynamic Profiling (CHP) during hemodialysis tracks the heart’s response to the stress of a dialysis treatment and identifies:
1) Prolonged high access flow that can lead to cardiomegaly and high output cardiac failure.
2) Low Cardiac Index (<2L/min/m²) which offers the physician an opportunity to adjust dry weight medication and length of dialysis to improve CI.¹⁰
3) Dramatic Cardiac Output drops during dialysis due to inaccurate dry weight estimation and/or medication that places patients at high risk for cardiovascular complications and sudden death following the dialysis session.

Conclusion

In the current outcomes-driven climate of proactive end-stage renal disease (ESRD) care, Transonic flow measurements are integral to successful and comprehensive vascular access management during hemodialysis. The measurements inform and guide the nephrologist and hemodialysis care team as they seek to optimize dialysis delivery, maintain a healthy access, and oversee the cardiovascular health of their patients. Transonic flow-based surveillance during hemodialysis is the corner stone for Hemodialysis Best Practices.

References


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Why Perform Surveillance?

7 Ways the HD03 Improves Outcomes for Your Patients

The Transonic® Gold Standard Hemodialysis Monitor Assures KDOQI Quality Compliance through:

- Dialysis Adequacy Optimization
- Vascular Access Surveillance
- Cardiac Function Assessment
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 surveillance 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 surveillance to be performed by the clinic’s staff who then can alert nephrologist to possible onset of access dysfunction & referral for early intervention
- Implements KDOQI Guidelines;

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Sudden Cardiac Death & Chronic Kidney Disease

“ESRD patients are prone to sudden death, stroke and myocardial infarction between dialysis sessions.”

transonic

THE MEASURE OF BETTER RESULTS.
Sudden Cardiac Death

Sudden cardiac death (SCD) is defined as death from an unexpected circulatory arrest, occurring within an hour of the onset of symptoms, or an unwitnessed, unexpected death in patients known to be well within the previous 24 hours without an obvious non-cardiac cause.\(^2\)

For the 20 million Americans that suffer from chronic kidney disease (CKD), SCD statistics are alarming. These CKD patients have a four to 20 times greater risk of sudden cardiac death (SCD) than do persons in the general population.\(^3\) As their glomerular filtration rates decline indicating progressively lower kidney function, the risk of sudden cardiac death proportionally increases.\(^2\)

Moreover, it is estimated that the number of patients with End-Stage Renal Disease (ESRD) on hemodialysis will reach one-half million by the year 2020.\(^2,3\) Sudden death among these patients accounts for 25% of all causes of mortality.\(^4\) In 1998, the American Journal of Kidney Disease underscored the gravity of this disease with the following title on the cover of their journal, “Cardiovascular Disease, An ESRD Epidemic.”\(^5\)

Cardiovascular Collapse

Not only is cardiovascular disease (CVD) the leading cause of morbidity and mortality in patients with end-stage renal disease (ESRD), but cardiovascular collapse is a major cause of complications during a hemodialysis treatment. Congestive heart failure (CHF) in ESRD patients results from cardiac overload, anemia, severe hypertension and cardiac dysfunction. CVD mortality rates are about 30 times that of the general population, and in adolescents, CVD mortality rates are over 1,000 times that of their age-related peers.\(^6\)

Multinational data from the Dialysis Outcomes and Practice Patterns (DOPPS) registry suggests that sudden death accounts for the highest proportion of hemodialysis deaths in the United States (33%) whereas lower proportions were observed in Japan (23%), Australia/New Zealand (19%) and Canada (18%).\(^7\)

Identifying SCD in CKD Patients

However, determining the sudden nature of death is problematic particularly among End-Stage Renal Disease (ESRD) patients because:
- Most sudden deaths among CKD patients are unwitnessed. Therefore, clinical information collected around that time is often limited
- ESRD patients are often chronically ill with comorbidities, and are frequently hospitalized.

CKD Sudden Death Pathophysiology

In the general population, coronary heart disease that leads to ventricular fibrillation or sustained ventricular flutter is the major cause of sudden death.

In the case of CKD patients, studies suggest fundamental differences in the causes and pathology of sudden heart disease. In these patients, their coronary artery disease involves multi-vessel arterial stiffening and calcification rather than an ischemic myocardium that might trigger a terminal arrhythmia and death. Rather, CKD patients, especially those on hemodialysis, are subject to a wide array of potential arrhythmic triggers.

When Does Sudden Death Occur

It has been observed that SCD in CKD occurs most frequently on days when hemodialysis is being administered, particularly on the first day after a three day weekend without dialysis.\(^2\) Moreover, as illustrated in the graph below, the probability of sudden death increases in the time period immediately following dialysis.\(^8\)

Sudden Death Risks Factors

In ESRD patients on hemodialysis, an increased risk of SCD has been linked to:
- Rapid ultrafiltration rate
- Low calcium during hemodialysis
- Low potassium (hypokalemia) or high potassium (hyperkalemia) levels in the blood

“Given the heightened risk of SCD in the CKD population and the abysmal long-term survival rate following a cardiac arrest, primary prevention of SCD should be a major priority.”\(^2\)

Fig. 1: The graph illustrates the spike in the probability of sudden death immediately following dialysis. “35% of deaths occurred in the 1st 12-hour interval... 27% of these deaths occurred during dialysis and 33% occurred in the hour after the dialysis treatment (8).” “Critically low CI levels (<2 L/min/m\(^2\)) can occur in patients who do not feel well at the end of a dialysis session.”
“The ability to monitor cardiac output is one of the important cornerstones of hemodynamic assessment ...in particular in patients with pre-existing cardiovascular comorbidities.”

Proactive Patient Care
Cardiovascular complications in ESRD patients can be averted or reduced through periodic exams by the patient’s nephrologist, and routine screening of cardiac function with the Transonic HD03 Monitor.

Cardiac Function Stressed
The rapid removal of large volumes of fluid during hemodialysis severely tests the limits of a patient’s cardiac function. Cardiac output decreases an average of 20% during the hemodialysis treatment causing less and less blood flow to be available to sustain the body’s vital functions. HD03 cardiac output measurements monitor a heart’s response to fluid removal during dialysis.

Central Hemodynamic Profiling (CHP)
Cardiovascular parameters can change dramatically during dialysis. Therefore, multiple cardiac measurements are advised during a dialysis session for patients at risk for SCD in order to create a CHP (Fig. 5) to track the heart’s response to the stress of a dialysis treatment. CHP Monitoring identifies:

- Dramatic 20-30% CO drop during dialysis due to inaccurate dry weight estimation and/or medication that places patients at high risk for cardiovascular complications and sudden death following the dialysis session (Fig. 2).
- Prolonged high levels of access flow (>1,600-2,000 ml/min) that can lead to cardiomegaly and high output cardiac failure. This can be identified by an access flow to cardiac output ratio (AVF/CO) exceeding 25-30% (Fig. 3).
- Cardiac Index of <2 L/min/m².

Routine Flow-QC® Cardiac Function screening commenced 40 minutes into the hemodialysis session for a patient with ischemic heart disease. The first Cardiac Output measurement was 4.3 L/min with a Cardiac Index of 2.5. When the cardiac function test was repeated two hours later, the patient’s Cardiac Output had dropped to 2.7 L/min and his Cardiac Index was 1.6. The nephrologist was alerted, the patient’s hemodialysis prescription was adjusted, and his cardiac condition was closely monitored.

Deterioration of CO & CI during Hemodialysis
Case Report, courtesy of Dr. T.A. Depner
References: Sudden Death & Chronic Kidney Disease

17. van der Mark WAMA et al, "Decreased access resistance in haemodialysis patients with upper arm arteriovenous fistulae," Nephrol Dial Transplant. 200; 23(6): 2105-6. (Transonic Reference # HD1102V)