Transonic HD03 Best Practice Protocols for Hemodialysis
Vascular Access Care

Dialysis Adequacy • Access Patency • Cardiac Function

The singular purpose of an arteriovenous (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 Hemodialysis Monitors and Flow/dilution Sensors are used to measure:

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

- **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;

- **Cardiac Output/On-the-spot Assessment/Parameters**: ten cardiac output parameters in patients dialyzing with an AV fistula or AV graft to help evaluate the hemodialysis prescription and/or cardiovascular concerns. A combined measurement of Access Flow and Cardiac Output for the AF/CO ratio can be utilized to identify high output cardiac failure secondary to high flow AV access state.
Overview of AV Fistula or AV Graft Protocols

Dialysis Adequacy/Vascular Access Patency

Start
New patient or revised vascular access

Physical Exam or Check
With One-minute Check

Initial Dialysis Adequacy
Measure initial DF, Recirc, AF

Nurses’ Analysis
Optimize dialysis delivery immediately from DF, Recirc results. Repeat at established intervals.

Access Monitoring
(monthly, or other interval)
Repeat Transonic Measurement if One-Minute Check finds a change

Nephrologist Analysis
Establish Access Flow levels.
Establish a testing schedule.

Is AF outside the critical threshold range?

NO
Post Intervention

YES
Nephrologist Analysis
If ordered, schedule any additional evaluations (such as a fistulogram)

Cardiac Function (AVG & AVF only)

Initial Cardiac Output Parameters Measurement

Nephrologist Review

Repeat Baseline CO Parameters Measurement
Establishes reliable cardiac function parameters for the patient.

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

Further Studies, and/or Treatments

Follow-up Cardiac Parameters
After a weekend break (start and end of treatment).

Nephrologist Review

Cardiovascular Concern

Acceptable

Transonic HD03 Access Flow Protocols

Reference: HD Spot Check Protocols (HD-162-In) Rev B 2019
Lower Arm Arteriovenous (AV) Fistula

**Lower Arm AV Fistula Blood Flow Trending** (mL/min each month)

- **AVF: > 600 mL/min**
- **AVF: < 600 mL/min** AV access flow falls 25% in 4 months
- **AVF: > 2000 mL/min**

13.9 KDOQI considers it reasonable for patients with consistently persistent clinical indicators and underlying AV access stenosis to undergo preemptive angioplasty of their AV access to reduce the risk of thrombosis and AV access loss. (Expert Opinion)

**Fistulogram**
- Normal
- Abnormal

Nephrologist re-evaluates indicators of dysfunction.

**Surgeon (Revision or new access)**

- Presumptive Success
- Technical Failure
- Interventionalism

**Success Criteria Met**
- Post-Intervention Measurements
  - Flow should return to expected access flow range.

**Success Criteria Not Met**

- Evaluate for steal, hand ischemia, high CO including high output cardiac failure

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.

**Upper Arm Arteriovenous (AV) Fistula**

**Access Blood Flow Trending** (mL/min each month)

- AVF: > 800 mL/min
- AVF: < 800 mL/min
- AVF: > 2000 mL/min

13.9 KDOQI considers it reasonable for patients with consistently persistent clinical indicators and underlying AV access stenosis to undergo preemptive angioplasty of their AV access to reduce the risk of thrombosis and AV access loss. (Expert Opinion)

**Fistulogram**

- Normal
- Abnormal

Nephrologist re-evaluates indicators of dysfunction.

- Surgeon (Revision or new access)
- Technical Failure
- Interventional Radiologist/Nephrologist (PTA/Thrombolysis/Stent)

**Presumptive Success**

Post-Intervention Measurements

- Flow should return to expected access flow range.

**Success Criteria Met**

**Success Criteria Not Met**

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

<table>
<thead>
<tr>
<th>Flow (mL/min)</th>
<th>Clinical Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>200-400</td>
<td>Probable risk for hemodynamically significant stenosis/recirculation as flow decreases (indicated by color progression from blue to purple)</td>
</tr>
<tr>
<td>400-600</td>
<td>Expected access flow range</td>
</tr>
<tr>
<td>600-800</td>
<td>Probable risk for cardiac failure as flow increases (indicated by color progression from yellow to red)</td>
</tr>
<tr>
<td>800-1200</td>
<td>Expected flow range is ideal. However, a sudden drop of 25% in this range may signal a potential onset of stenosis.</td>
</tr>
<tr>
<td>1200-1600</td>
<td>Action: Consider clinical examination &amp; imaging</td>
</tr>
<tr>
<td>1600-2000</td>
<td>Action: If flow is steady, continue monitoring. If 25% decrease occurs, consider clinical exam &amp; imaging</td>
</tr>
<tr>
<td>2000-2400</td>
<td>Action: Measure cardiac output</td>
</tr>
<tr>
<td>2400-2600</td>
<td></td>
</tr>
</tbody>
</table>

**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.

Hemodialysis

Arteriovenous (AV) Graft

Access Blood Flow Trending (mL/min each month)

- AVG: > 800 mL/min
- AVG: < 800 mL/min
- AVG: > 2000 mL/min

13.9 KDOQI considers it reasonable for patients with consistently persistent clinical indicators and underlying AV access stenosis to undergo preemptive angioplasty of their AV access to reduce the risk of thrombosis and AV access loss. (Expert Opinion)

Evaluate for steal, hand ischemia, high CO and cardiac failure

Normal

Fistulogram

Nephrologist re-evaluates indicators of dysfunction.

Surgeon (Revision or new access)

Technical Failure

Presumptive Success

Success Criteria Met

Post-Intervention Measurements
Fistula should return to expected access flow range.

Success Criteria Not Met

AVG: > 800 mL/min
AVG: < 800 mL/min
AVG: > 2000 mL/min

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.

2019 Vascular Access KDOQI Guidelines

Statements: Appropriate Use of Monitoring/Surveillance for AV Access Flow Dysfunction

Physical Examination (Monitoring)

13.1 KDOQI recommends regular physical examination or check of the AVF, by a knowledgeable and experienced health practitioner, to detect clinical indicators of flow dysfunction of the AVF. (Conditional/Strong Recommendation, Moderate Quality of Evidence) See Table 13.2 for clinical indicators.

13.2 KDOQI recommends regular physical examination or check of the AVG, by a knowledgeable and experienced health practitioner, to detect clinical indicators of flow dysfunction of the AVG. (Conditional/Strong Recommendation, Moderate Quality of Evidence) See Table 13.2 for clinical indicators.

13.3 KDOQI considers it reasonable for nephrology trainees and health practitioners involved with clinical HD patient care to be properly trained in physical examination of the AV access to monitor for and detect AV access flow dysfunction. (Expert Opinion)

Surveillance to Facilitate Patency

13.4 There is inadequate evidence for KDOQI to make a recommendation on routine AVF surveillance by measuring access blood flow, pressure monitoring, or imaging for stenosis, that is additional to routine clinical monitoring, to improve access patency.

Note: In other words, monitoring of vascular access is primary, while surveillance findings are supplementary, and action should not be based solely on surveillance findings.

13.5 KDOQI does not suggest routine AVG surveillance by measuring access blood flow, pressure monitoring, or imaging for stenosis, that is additional to regular clinical monitoring, to Guideline 13. AV Access Flow Dysfunction—Monitoring/Surveillance.

Endovascular Interventions to Improve Patency

13.6 KDOQI does not recommend pre-emptive angioplasty of AVFs with stenosis, not associated with clinical indicators, to improve access patency. (Conditional Recommendation, Moderate Quality of Evidence)

13.7 KDOQI does not recommend pre-emptive angioplasty of AVGs with stenosis, not associated with clinical indicators, to improve access patency. (Conditional Recommendation, Moderate Quality of Evidence)

Surgical Interventions to Improve Patency

13.8 There is inadequate evidence for KDOQI to make a recommendation on pre-emptive surgical interventions in AVFs with stenosis, not associated with clinical indicators, to improve access patency.

Statement: Pre-emptive Intervention for AV Access Stenosis Associated With Clinical Indicators

13.9 KDOQI considers it reasonable for patients with consistently persistent clinical indicators and underlying AV access stenosis to undergo pre-emptive angioplasty of their AV access to reduce the risk of thrombosis and AV access loss. (Expert Opinion)

Reference: AJKD Vol 75 | Iss 4 | Suppl 2 | April 2020
Table 13.1. Routine AV Access Monitoring by Physical Examination

<table>
<thead>
<tr>
<th>Exam Steps</th>
<th>Fistula (Normal)</th>
<th>Graft (Normal)</th>
<th>Flow-related Dysfunction or Poor Maturation (Abnormal)</th>
<th>Infection, Steal Syndrome, or Aneurysm/Pseudoaneurysm* (Abnormal)</th>
</tr>
</thead>
</table>
| Look                | Well-developed main venous outflow, no irregular/dilated areas or aneurysm formations, adequate areas of straight vein that can be used for 2-needle, rope-ladder cannulation, Vessel collapses when arm is elevated above head | Uniform-sized graft in a loop or straight configuration, No irregular areas or aneurysm or seroma formations with organized site rotation used for cannulation | AVF with poor maturation—multiple venous outflow veins (accessory veins), poorly defined cannulation areas | Infection: Redness, swelling, induration, drainage, or pus
Steal syndrome: Extremity hand discoloration, skin ulceration due to poor arterial blood flow to the hand
Check nail beds, fingers and hand for unusual skin changes
Aneurysm Abnormal areas of dilatation with overlying skin thinning |

| Listen with a stethoscope | Low-pitch continuous diastolic and systolic | Low-pitch continuous diastolic and systolic | High-pitch discontinuous systolic only | Steal syndrome
AVF: Pulse at the site of a stenotic lesion—may be water-hammer in quality and feel
AVG: Thrill and/or pulse strong at the site of stenotic lesion pulse has a water-hammer feel
An AVG with a low intra-access blood flow feels mushy
Local area of the graft that feels mushy or irregular in shape can be a site of aneurysm formation |

Infection
Warm or painful to touch, swelling
Steal syndrome
Feel bilateral limbs (hands and fingers) and compare for the access limb to be the same as the nonaccess limb
Compare temperature, grip strength, and range of motion and any complaints of changes in sensation or pain
If the access limb has any major differences than the nonaccess limb, consider steal syndrome |

Abbreviations: AVF, arteriovenous fistula; AVG, arteriovenous graft.
*Also see Guidelines 16 through 19 for specific complications.

Table 13.2. Clinical Indicators (Signs and Symptoms) Suggesting Underlying Clinically Significant Lesions During Access Monitoring

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Clinical Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical examination or check</td>
<td>• Ipsilateral extremity edema</td>
</tr>
<tr>
<td></td>
<td>• Alternations in the pulse, with a weak or resistant pulse, difficult to compress, in the area of stenosis</td>
</tr>
<tr>
<td></td>
<td>• Abnormal thrill (weak and/or discontinuous) with only a systolic component in the region of stenosis</td>
</tr>
<tr>
<td></td>
<td>• Abnormal bruit (high pitched with a systolic component in the area of stenosis)</td>
</tr>
<tr>
<td></td>
<td>• Failure of the fistula to collapse when the arm is elevated (outflow stenosis) and lack of pulse augmentation (inflow stenosis)</td>
</tr>
<tr>
<td></td>
<td>• Excessive collapse of the venous segment upon arm elevation</td>
</tr>
<tr>
<td>Dialysis</td>
<td>• New difficulty with cannulation when previously not a problem</td>
</tr>
<tr>
<td></td>
<td>• Aspiration of clots</td>
</tr>
<tr>
<td></td>
<td>• Inability to achieve the target dialysis blood flow</td>
</tr>
<tr>
<td></td>
<td>• Prolonged bleeding beyond usual for that patient from the needle puncture sites for 3 consecutive dialysis sessions</td>
</tr>
<tr>
<td></td>
<td>• Unexplained (&gt;0.2 units) decrease in the delivered dialysis dose (Kt/V) on a constant dialysis prescription without prolongation of dialysis duration</td>
</tr>
</tbody>
</table>

Reference: AJKD Vol 75 | Iss 4 | Suppl 2 | April 2020
AV Fistula or AV Graft
Delivered Blood Flow Protocol

**Measure Delivered Blood Flow Rate**

With the bloodlines configured as normally used (document configuration), measure flow. Transonic Delivered blood Flow rate (Qb) is within 0-10% of the hemodialysis machine’s set blood pump speed or delivery flow rate.*

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>
| Transonic Delivered Blood Flow Rate (Qb) is within 0-10% of Hemodialysis Machine’s Set Blood Pump Speed or Delivery Flow Reading  
CTrue Delivered Blood Flow correlates with the Hemodialysis machine’s setting  
Proceed to Recirculation Measurement | The Descrepancy between Transonic’s Delivered Blood Flow Rate (Qb) and the Hemodialysis Machine’s Set Blood Pump speed is >10% or Delivery Flow Reading* is >10%.  
Turn pump speed to 200 mL/min and repeat the blood flow measurement. |

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>
| Transonic Delivered Blood Flow rate (Qb) is within 0-10% of Hemodialysis Machine’s Set or Delivered Flow Reading  
True Delivered Blood Flow correlates with the Hemodialysis machine’s setting. The previous deviations at high pump settings could be due to needle size, and/or site of needle placement.  
Proceed to Recirculation Measurement | Transonic Delivered Blood Flow Rate (Qb) Dies Not Agree with the Hemodialysis Machine’s Blood Pump Speed Setting at 200 mL/min  
Check tubing selection on the Hemodialysis machine to make sure that it agrees with the dialysis tubing being used.  
1. Other reasons for the descrepancy could be:  
   - The HD03 is not in calibration.  
   - The arterial need tip is too close to the vessel wall.  
2. Correct tubing type, verify. |

*Some Hemodialysis Machines display both a Set Blood Pump Speed and Delivery Flow Reading. If both readings are displayed on your Hemodialysis machine use the Delivery Flow Reading.
Dialysis Adequacy

Recirculation Management in AV Accesses & Catheters
Recirculation Protocol: AV Fistulas & Grafts

Perform Initial Recirculation Measurement

YES: 0% Recirculation
Proceed to Access Flow Measurement

NO: > 0% Recirculation

Perform Second Recirculation Measurement

Evaluate access for inadvertent line reversal, if suspected. Reverse blood lines at needle tubing connection.

Perform a Reversed Line Recirculation Measurement

0% Recirculation

Lines are now in conventional position for dialysis, but were reversed for initial measurement

> 0% Recirculation

Is reversed line recirc > or < than initial Recirc?

greater

Lines are now reversed, initial measurements were made with lines in conventional position.

less

Lines are now in conventional position for dialysis, but were reversed for initial measurement

Document Correct Line Placement & Direction of Access Flow
Optimizing HD Adequacy in Catheters

Catheter Configuration with the Transonic HD Monitor

Step 1:

<table>
<thead>
<tr>
<th>MEASURE DELIVERED BLOOD FLOW RATE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>With the bloodlines configured as normally used (document configuration), measure flow.</td>
<td></td>
</tr>
<tr>
<td>Transonic Delivered blood Flow rate (Qb) is within 0-10% of the hemodialysis machine's set blood pump speed or delivery flow rate.*</td>
<td></td>
</tr>
</tbody>
</table>

**YES**

<table>
<thead>
<tr>
<th>TRANSONIC DELIVERED BLOOD FLOW RATE (QB) IS WITHIN 0-10% OF HEMODIALYSIS MACHINE’S SET OR DELIVERY FLOW READING</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Current blood pump setting is maximizing the Delivered blood Flow with the current catheter to bloodline configuration.</td>
<td></td>
</tr>
<tr>
<td>PROCEED TO RECIRCULATION MEASUREMENT</td>
<td></td>
</tr>
</tbody>
</table>

**YES**

<table>
<thead>
<tr>
<th>TRANSONIC DELIVERED BLOOD FLOW RATE (QB) IS &gt;10% LOWER THAN THE HEMODIALYSIS MACHINE’S SET BLOOD PUMP SPEED OR DELIVERY FLOW READING*</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Only proceed if both catheter lumens had blood return with treatment initiation. Using aseptic technique, reverse the catheter configuration by reversing the bloodlines to the opposite lumens of the catheter used for the initial measurement. Document configuration.</td>
<td></td>
</tr>
<tr>
<td>Repeat the blood flow measurement.</td>
<td></td>
</tr>
</tbody>
</table>

**NO**

<table>
<thead>
<tr>
<th>TRANSONIC DELIVERED BLOOD FLOW RATE (QB) IS &gt;10% LOWER THAN THE HEMODIALYSIS MACHINE’S SET BLOOD PUMP SPEED OR DELIVERY FLOW READING*</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Carefully document measurement and catheter configurations. Proceed to recirculation measurements with both catheter configurations. Escalate the results of the findings to the nephrologist for possible catheter evaluation or prescription adjustment to address catheter dysfunction.</td>
<td></td>
</tr>
</tbody>
</table>

*Catheter Configurations:
- Normal Configuration: Arterial Catheter Hub to Arterial Bloodline + Venous Catheter Hub to Venous Bloodline
- Reverse Configuration: Arterial Catheter Hub to Venous Bloodline + Venous Catheter Hub to Arterial Catheter Hub

Transonic 1-800-353-3569 Support Line

Optimizing HD Adequacy in Catheters

Catheter Configuration with the Transonic HD Monitor

Step 2:

**CHECK RECIRCULATION**
With the bloodlines configured from Step One with maximized Delivered Blood Flow Rate,

**MEASURE RECIRCULATION**
Recirculation is within 0 - 10%

**NO**

**RECIRCULATION IS GREATER THAN 10%**
Only proceed if both catheter lumens had blood return with treatment initiation
Using aseptic technique, reverse the catheter configuration by reversing blood lines to the opposite lumens of the catheter than used for the initial measurements.

**REPEAT RECIRCULATION MEASUREMENT**

**YES**

**RECIRCULATION IS WITHIN 0-10%**
Current blood pump setting is maximizing Delivered Blood Flow with the current catheter to bloodline configuration.

**NO**

**RECIRCULATION IS GREATER THAN 10%**
Carefully document measurement and catheter configurations.
Escalate the results of the findings to the nephrologist for possible catheter evaluation or prescription adjustment to address catheter dysfunction.

**YES**

**RECIRCULATION IS WITHIN 0-10%**
Current blood pump setting is maximizing the Delivered Blood Flow with the current catheter to bloodline configuration.

Reference: Hemodialysis Catheter Optimization (HD-150-tr) Rev A 2017
Optimizing HD Adequacy in Catheters cont.

Catheter Configuration with the Transonic HD Monitor
For Use with Fresenius 5008 or other Hemodialysis machines that have Compensated Blood Flow Rate Capabilities

Step 1:

**MEASURE DELIVERED BLOOD FLOW RATE**

With the bloodlines configured as normally used (document configuration), measure flow. Transonic delivered blood flow rate (Qb) is higher than the Fresenius 5008 set blood pump speed or within 0-10% lower than the set blood pump speed.

**NOTE:** Both higher and lower differences are displayed in RED on the Transonic screen.

**YES**

**TRANSONIC DELIVERED BLOOD FLOW RATE (QB) IS HIGHER THAN THE FRESENIUS 5008 SET BLOOD PUMP SPEED OR IS WITHIN 0-10% LOWER THAN THE SET BLOOD PUMP SPEED.**

Current blood pump setting is maximizing the Delivered Blood Flow with the current catheter to bloodline configuration.

**PROCEED TO RECIRCULATION MEASUREMENT**

**NO**

**TRANSONIC DELIVERED BLOOD FLOW RATE (QB) IS >10% LOWER THAN THE FRESENIUS 5008 SET BLOOD PUMP SPEED**

Only proceed if both catheter lumens had blood return with treatment initiation.

Using aseptic technique, reverse the catheter configuration by reversing bloodlines to the opposite lumens of the catheter used for the initial measurement. Document configuration.

Repeat the blood flow measurement.

**YES**

**TRANSONIC DELIVERED BLOOD FLOW RATE (QB) IS HIGHER THAN THE FRESENIUS 5008 SET BLOOD PUMP SPEED OR IS WITHIN 0-10% LOWER THAN THE SET BLOOD PUMP SPEED.**

Current blood pump setting is maximizing the Delivered Blood Flow with the current catheter to bloodline configuration.

**PROCEED TO RECIRCULATION MEASUREMENT**

**NO**

**TRANSONIC DELIVERED BLOOD FLOW RATE (QB) IS 10% LOWER THAN THE FRESENIUS 5008 SET BLOOD PUMP SPEED**

Carefully document measurement and catheter configurations.

Proceed to recirculation measurements with both catheter configurations.

Escalate the results of the findings to the nephrologist for possible catheter evaluation or prescription adjustment to address catheter dysfunction.

This protocol only applies when using Fresenius 5008 Hemodialysis Machines

**Catheter Configurations:**

- Normal Configuration: Arterial Catheter Hub to Arterial Bloodline + Venous Catheter Hub to Venous Bloodline
- Reverse Configuration: Arterial Catheter Hub to Venous Bloodline + Venous Catheter Hub to Arterial Catheter Hub

**Transonic 1-800-353-3569 Support Line**

Reference: Hemodialysis Catheter Optimization (HD-152-tn) Rev A 2017
Optimizing HD Adequacy in Catheters cont.

Catheter Configuration with the Transonic HD Monitor

For Use with Fresenius 5008 or other Hemodialysis machines that have Compensated Blood Flow Rate Capabilities cont.

Step 2:

**CHECK RECIRCULATION**

With the bloodlines configured from Step One with maximized Delivered Blood Flow Rate,

**MEASURE RECIRCULATION**

Recirculation is within 0 - 10%

**NO**

**RECIRCULATION IS GREATER THAN 10%**

Only proceed if both catheter lumens had blood return with treatment initiation

Using aseptic technique, reverse the catheter configuration by reversing blood lines to the opposite lumens of the catheter than used for the initial measurements.

**REPEAT RECIRCULATION MEASUREMENT**

**YES**

**RECIRCULATION IS WITHIN 0-10%**

Current blood pump setting is maximizing Delivered Blood Flow with the current catheter to bloodline configuration.

**YES**

**RECIRCULATION IS WITHIN 0-10%**

Current blood pump setting is maximizing the Delivered Blood Flow with the current catheter to bloodline configuration.

**NO**

**RECIRCULATION IS GREATER THAN 10%**

Carefully document measurement and catheter configurations.

Escalate the results of the findings to the nephrologist for possible catheter evaluation or prescription adjustment to address catheter dysfunction.

Reference: Hemodialysis Catheter Optimization (HD-152-tn) Rev A 2017
Transonic HD03 Cardiac Function Protocol in AV Fistulas & AV Grafts
Cardiac Function Assessment Protocol in AV Fistulas and AV Grafts only

**Initial Cardiac Function Study**
Measure All Cardiac Output Parameters immediately after measuring Access Flow during the first part of a hemodialysis treatment session (CO, CI, SVI, TEF, SVRI, TEDVI, CBVI, ACVI, ODI, AF/CO ratio).

**Nephrologist Review**
Parameters related to dialysis prescription can include: CI, CBVI, ACVI & ODI, Parameters related to Cardiovascular Concern can include: CO and AF/CO ratio, CI, TEF & TEDVI

**Repeat Cardiac Function Studies:**
• Consider measuring the Cardiac Parameters & Access Flow at the start of the hemodialysis treatment session.
• Measure the Cardiac Parameters at the end of the hemodialysis treatment session.
• Compare the pre and post results to see if fluid removal improves parameters related to fluid status.
• Consider repeating this process to compare the results after the weekend dialysis break compared to the end of the week when the target weight might be achieved.
• Measure the Cardiac Parameters at the end of the hemodialysis treatment session. Compare the pre and post results to see if fluid removal improves parameters related to fluid status.
• Consider repeating this process to compare the results after the weekend dialysis break compared to the end of the week when the target weight might be achieved.

**Nephrologist Analysis**
Review all results and compare to other patient status including hemodynamics such as fluid volume.

**Follow-up Cardiac Function Study**
Repeat Cardiac Output Parameters after any interventions such as prescription alterations (such as target/dry weight adjustments or medications changes), S/P any cardiac related events or post hospitalizations.

**Further Studies, Treatments**
Note: If AF/CO ratio is the concern—proceed to investigate the vascular access and patient for possible high-output cardiac failure (HOCF)

<table>
<thead>
<tr>
<th>HD CARDIAC PARAMETERS</th>
<th>TYPICAL RANGE (OBSERVED IN 70% OF DATA)</th>
<th>ATYPICAL RANGE*</th>
<th>CLINICAL RELEVANCE</th>
<th>INTERPRETATION &amp; RECOMMENDATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac Output (CO) L/min</td>
<td>5 - 8 L/min</td>
<td>&lt; 2 L/min / &gt; 10 L/min</td>
<td>Increased risk for cardiovascular complications and failure.</td>
<td>CO varies by patient parameters and is used to calculate AF/CO ratio. CO alone should not be used for guidance.</td>
</tr>
<tr>
<td>Cardiac Index (CI) L/min/m²</td>
<td>2.2 - 3.8 L/min/m²</td>
<td>&lt; 2.0 L/min/m²</td>
<td>If measurement of &lt; 14 mL/kg is taken at the beginning of the session, indicates significant deterioration of CO function.</td>
<td>Refer to cardiologist for full study.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A 20-30% drop in CI during the session: indicates inadequate dry weight estimation and/or effects of medication.</td>
<td>The dry weight and medications should be clinically evaluated and updated if needed and these measurements should be repeated at the beginning and end of session.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&gt; 4 L/min/m²</td>
<td>Determine reason for increased CI. Implement proper treatment:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>In approximately 50% of cases, high CI is associated with increased fistula flow. In other cases, high CI is associated with fluid overload or low hematocrit levels.</td>
<td>• AV access evaluation/intervention;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&gt; 60 L/min²</td>
<td>Determine if a referral to a cardiologist for additional clinical assessment is appropriate.</td>
</tr>
<tr>
<td>Stroke Volume Index (SVI) mL/m²</td>
<td>32 - 56 mL/m²</td>
<td>&lt; 20 mL/m²</td>
<td>Usually indicates low preload (hypovolemic status).</td>
<td>Suggest SVI parameters be included in the clinical evaluation.</td>
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<tr>
<td>Total Ejection Fraction** (TEF) %</td>
<td>40 - 76 %</td>
<td>&lt; 40 %</td>
<td>Effective heart performance is decreased. Low value may increase mortality.</td>
<td></td>
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<tr>
<td>Systemic Vascular Resistance (SVRI) dynes-sec/cm²/m²</td>
<td>1900 - 3200</td>
<td>In non-hemodialysis adult patients, expected value is 2000-2400.</td>
<td>Currently, there are no clear guidelines for the expected SVRI. SVRI in dialysis patients may be higher than in the non-hemodialysis population.</td>
<td></td>
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<tr>
<td>Total End Diastolic Volume Index (TEDVI) mL/kg</td>
<td>6 - 11 mL/kg</td>
<td>&gt; 11 mL/kg</td>
<td>Increased TEDVI potentially indicates cardiomegaly and increased mortality.</td>
<td>Determine if a referral to a cardiologist for additional assessment is appropriate.</td>
</tr>
<tr>
<td>Central Blood Volume Index (CBVI) mL/kg</td>
<td>13 - 23 mL/kg</td>
<td>&lt; 14 mL/kg</td>
<td>If measurement of &lt; 14 mL/kg is taken at the beginning of the session, the patient started on the hypovolemic side. If patient is on the lower end at the end of session, this is less of an issue.</td>
<td>Special care should be taken during HD session to avoid hypotensive episode.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&gt; 25 mL/kg</td>
<td>Assess patient for fluid volume overload. Evaluate if any adjustment for the Dry Weight/Target Weight is indicated. Evaluate if the patient may need additional education/assistance with the fluid restriction included in their diet prescriptions. Repeat study</td>
</tr>
<tr>
<td>Active circulation Volume Index (ACVI) mL/kg</td>
<td>40 - 70 mL/kg</td>
<td>&lt; 45 mL/kg</td>
<td>If measurement of &lt; 45 mL/kg is taken at the beginning of the session, the patient started on the hypovolemic side. If patient is on the lower end at the end of session, this is less of an issue.</td>
<td>Special care should be taken during HD session to avoid hypotensive episode.</td>
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<tr>
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<td>&gt; 65 mL/kg</td>
<td>Assess the patient for fluid volume overload. Evaluate if any adjustment for the Dry Weight/Target Weight is indicated. Evaluate if the patient may need additional education/assistance with the fluid restriction included in their diet prescriptions. Repeat study</td>
</tr>
<tr>
<td>Oxygen Delivery Index (ODI) mL O₂/min²</td>
<td>420 - 500 mL O₂/min²</td>
<td>&lt; 400 mL O₂/min²</td>
<td>Under O₂ delivery may be related to low hemoglobin, low CI or high fistula flow.</td>
<td>Refer to nephrologist for evaluation to determine source of issue.</td>
</tr>
<tr>
<td>Access Flow / Cardiac Output (AF/CO) %</td>
<td>15 - 25 %</td>
<td>&gt; 25 - 30 %</td>
<td>Increased risk for cardiovascular complications and failure. High flow fistulas can lead to high output cardiac failure.</td>
<td>For high fistula flows, repeat AF and CO at the end of the session to re-evaluate ratio. Consider evaluating patient for high output cardiac failure. Consider reducing AF by banding or other surgical procedure.</td>
</tr>
</tbody>
</table>

* Suggests additional clinical evaluation for clinical relevance.
** Each chamber of the heart has its own Ejection Fraction. Total Ejection Fraction is the aggregate measures of all 4 chambers and is not interchangeable with EF.

# Technical Note:

## Hemoglobin Conversion Tables for the HD03 Monitor

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Reference: Hemoglobin Conversion Table (DL-370-tn) Rev A 2020 US
## Results: CO Parameter Measurements

**Patient Sticker/Stamp Here**

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<th>TRANSONIC CO PARAMETERS MEASUREMENTS</th>
<th>RESULTS</th>
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<tr>
<td>Delivered Flow at Blood Pump Speed</td>
<td>__________ mL/min at Pump speed of _________ mL/min</td>
</tr>
<tr>
<td>Recirculation %</td>
<td>__________ % Notes:</td>
</tr>
<tr>
<td>Access Flow</td>
<td>__________ mL/min</td>
</tr>
<tr>
<td>Cardiac Output (CO) L/min</td>
<td>__________ L/min</td>
</tr>
<tr>
<td>Cardiac Index (CI) L/min/m2</td>
<td>__________ L/min/m2</td>
</tr>
<tr>
<td>Stroke Volume Index (SVI) mL/m2</td>
<td>__________ mL/m2</td>
</tr>
<tr>
<td>Total Ejection Fraction: Each chamber of the heart has its own Ejection Fraction. Total Ejection Fraction is the aggregate measures of all 4 chambers and is not interchangeable with EF.</td>
<td>__________ %</td>
</tr>
<tr>
<td>Systemic Vascular Resistance (SVRI) dynes.sec/cm5/m2</td>
<td>__________ dynes.sec/cm5/m2</td>
</tr>
<tr>
<td>Total End Diastolic Volume Index (TEDVI) mL/kg</td>
<td>__________ mL/kg</td>
</tr>
<tr>
<td>Central Blood Volume Index (CBVI) mL/kg</td>
<td>__________ mL/kg</td>
</tr>
<tr>
<td>Active circulation Volume Index (ACVI) mL/kg</td>
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</tr>
<tr>
<td>Oxygen Delivery Index (ODI) mL O2/min/m2</td>
<td>__________ mL O2/min/m2</td>
</tr>
<tr>
<td>Access Flow / Cardiac Output (AF/CO) %</td>
<td>__________ %</td>
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</table>

### Clinical Interpretation of Results:

Please repeat the measurement if the parameters are outside of the expected patient ranges. A single result out of range is not intended to be the source for a clinical interpretation and recommendation. For Cardiac Output measurements verify that the Target Weight or Dry Weight was entered properly under Required Parameters screen. Then repeat the Cardiac Output parameter measurement and also consider repeating the Cardiac Output parameter measurement at the next dialysis session to confirm results.

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. Transonic® also provides pressure and pressure volume systems, laser Doppler Flowmeters and telemetry systems.

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