Utility of Duplex Ultrasound for Hemodialysis Access Volume Flow and Velocity Measurements

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DISCLOSURES
None

Achille’s Heel

Stenosis
Thrombosis

Surveillance

• Physical Examination
  • One minute check
  • HD Efficacy

• Measured Parameters
  • Access flow
  • HD Efficacy
  • Access flow
  • Recirculation
  • Venous pressure

• Ultrasound

Table 1. Access Flow Protocol Surveillance

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access flow decrease &lt;600cc/min OR if &gt;1000cc/min with &gt;25% decrease over 4m prior</td>
<td>Check hemoglobin and perform serial volume cap stimulation trial</td>
</tr>
<tr>
<td>Increased venous pressure during dialysis</td>
<td>&gt;150mmHg or trend of persistent increasing pressure over time</td>
</tr>
</tbody>
</table>

Grayscale and color Doppler
• Inflow
• Anastomosis
• Outflow
• +/- subclavian vein

Spectral waveforms and velocity
• Inflow
• Anastomosis
• Proximal
• Outflow (beyond anastomosis
• Subclavian vein

Blood flow volume at least one site.

Additional images, waveforms, velocity measurements.
Local Coverage Determination (LCD): Non-Invasive Peripheral Venous Studies (L35451)

Not medically reasonable or necessary for HD Access surveillance

A Meta-analysis of randomized clinical trials assessing hemodialysis access thrombosis based on access flow monitoring: Where do we stand?
Timothy Mushegy, Loay Soliman, Leonardo J.Tenaro, Aref Asif, Abid Rizvi, Oliver Lenz, Roberto I. Vazquez-Fortuna, Narwan Tabbara, and Gabriel Contreras

Our results add to the uncertainty of access blood flow monitoring as a surveillance method of hemodialysis accesses.

Volume Flow
Continuity equation

\[
V_{\text{cc/min}} = A (\text{cm}^2) \times V (\text{cm/s}) \times 60
\]

\[
Q = A \times V \times 60
\]

Volume Flow

- Longitudinal view
- Systole
- Measure in non-aneurysmal area

Ultrasound – Dialysis Circuit

- Tortuosity
- Aneurysms/pseudoaneurysms
- Diameter of vein varies along its length
- Compliance of vein/grafts different from arteries

Volume Flow
Continuity equation

\[
V_{\text{cc/min}} = A (\text{cm}^2) \times V (\text{cm/s}) \times 60
\]

\[
Q = A \times V \times 60
\]
Normal Velocity

100-300 cm/s

Stenosis in AVF

PSV > 400-500 cm/s suggest > 50% stenosis

Turbulence – Dialysis Circuit

Fluid Dynamics Model

Stenosis at anastomosis

PSV > 600 cm/s suggest stenosis?

Flow Dynamics

Volume flow

Volume (cc/min) = Area (cm^2) x Velocity (cm/s) x 60

Sample volume needs to include the whole diameter of the vessel and not just the middle

Parabolic flow

rtcs in the middle of the vessel travel faster
rtcs in at the periphery of the vessel travels slower
Volume Flow

$$\text{Volume}_{\text{flow}} = \text{Area} \times \text{Velocity} \times 60$$

Mean velocity throughout the blood vessel - average over a few cycles. TAMV: Time-Averaged Mean Velocity

Ultrasound – Dialysis Circuit

- Tortuosity
- Aneurysms/pseudoaneurysm
- Diameter varies along its length
- Angulation of anastomosis
- Compliance of vein/grafts different from arteries

Volume Flow

$$\text{Volume}_{\text{flow}} = \text{Area}_{\text{longitudinal}} \times \text{Velocity}_{(cm/s)} \times 60$$

Diameter (longitudinal)

Volume flow

- Straight segment
- 5cm away from anastomosis/stenoses/major abnormalities
- Some recommend measuring at brachial artery

Volume Flow

Challenges

- Branches or bifurcations
- Pseudoaneurysms
- Central Occlusions
- Inflow disease
- Heart failure

Volume Flow

Challenges

SIMPLE MATH

- Area = \(\frac{1}{2} \times \text{diameter}^2\)
- Measurement error with electronic calipers
- Velocity
  - Sampling error
  - Anatomy distorts velocity
  - Angle must be \(\leq 60^\circ\)

\[Q = A \times V \times 60\]
Pilot Study

- 82 patients
- Double blind
  ✓ Duplex exam prior to fistulagram
  ✓ Duplex flow (3) and velocity (5)
  ✓ Fgram-degree of stenosis
- Diameters and aneurysmal areas

<table>
<thead>
<tr>
<th>Fgram stenosis</th>
<th>Velocity Mean (SD)</th>
<th>Flow Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;50%</td>
<td>207 (±128)</td>
<td>2236 (±1611)</td>
</tr>
<tr>
<td>50-70%</td>
<td>222 (±189)</td>
<td>2579 (±2368)</td>
</tr>
<tr>
<td>&gt;70%</td>
<td>262 (±197)</td>
<td>1743 (±1407)</td>
</tr>
</tbody>
</table>

Pilot Study Conclusions

- Clinical examination
- Abnormalities on HD
- Duplex U/S in ESRD?

Pilot Study Conclusions

Current Value of Duplex in HD

- Vein mapping
- Arterial inflow
- Predicting maturation?
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