Left Ventricular Outflow Tract Velocity Time Integral – Fluid Responsiveness

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Outline

- Definition
- Literature Review
- Experimental Design
- Results
- Conclusions
• Stroke Volume (SV) and Cardiac Output (CO) are crucial for hemodynamic monitoring but are difficult to estimate by clinical assessment alone.
• Pulmonary artery catheter is considered gold standard but has a high risk/benefit ratio.
• Transthoracic echocardiography (TTE) is non-invasive (also when compared to transesophageal echo), repeatable, and has low costs for assessing SV.
• Using TTE, measurement of the flow across aortic outflow tract in the left ventricle can estimate SV and CO.
Velocity Time Integral (VTI) – Measure of “length” of a hypothetical column of blood which passes via Doppler ultrasonography

VTI – length, LV outflow tract (OT) – area

LVOT area = \( \pi r^2 \)

LV-OT \( \times \) VTI = SV

SV \( \times \) HR = CO
Additional Sources of CO

- Assuming normal flow throughout the heart without valvular flow abnormalities or shunting, flow across various valves can be used to calculate CO.
- VTI x Outflow tract area = SV, SV x HR = CO
• Given that the area calculation for outflow tract area is a circle, \( A = \pi r^2 \), any variation in \( r \) will drastically alter results.

• Luckily, the outflow area generally can be considered constant and can be measured once to estimate CO without repeat measurements.

• Without significant variation in HR, the VTI alone can be used as a surrogate for CO.

• VTI alone is known as the minute distance – and can be used to track CO.
Fluid Responsiveness

- Fluid responsiveness has been defined as an increase in SV of 15% or more with a fluid challenge.
- LVOT-VTI has been examined in the context of fluid responsiveness and shown to be a reliable indicator of this increase in SV.
- This fluid responsiveness can be measured by passive leg raise or Trendelenburg positioning.
- For passive leg raise as a test of fluid responsiveness, a target of 12% increase in SV can be used as a cutoff point with a sensitivity of 87.5% and a specificity of 95%.
Test of Concept Experimental Design

- 2 subjects, 2-3 samples
- Each sample with 4 scans of LVOT-VTI, hydrated and dehydrated
  - Measurement of mitral view or 5 chamber view LVOT-VTI, HR
  - Scan while subject seated and head elevated at 30 ° (Low Fowler's)
  - Scan during passive leg raise, with legs elevated to 30 °, head flat
- Samples compared for increase of at least 12% for fluid responsiveness
- Hypothesis: Subjects will have increased fluid responsiveness while dehydrated
- Dehydration was achieved through vigorous outdoor exercise for at least 30 minutes without intake of water
Obtaining the View

- 5 Chamber View: Obtain the Apical 4-chamber view and fan anteriorly.
- Place the VTI window over the LVOT with the Doppler indicator inferior to the aortic valve.
5 Chamber View

5 Chamber View Video

![5 Chamber View Image]
Findings – Hydrated Example

Low Fowler's

Passive Leg Raise

VTI 15.4 cm

VTI 20.5 cm

Δ = 5.1 cm

~33%
Findings – Dehydrated Example

Low Fowler's

Passive Leg Raise

VTI 12.4 cm

VTI 18.9 cm

$\Delta = 6.5$ cm

$\sim 52\%$
## Auto-Derivation of VTI

<table>
<thead>
<tr>
<th></th>
<th>Low Fowler's</th>
<th>Passive Leg Raise</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrated</td>
<td>17.7</td>
<td>22.5</td>
<td>4.8 (27%)</td>
</tr>
<tr>
<td>Dehydrated</td>
<td>14.4</td>
<td>19.3</td>
<td>4.9 (34%)</td>
</tr>
<tr>
<td><strong>Day 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrated</td>
<td>15.4</td>
<td>20.5</td>
<td>5.1 (33%)</td>
</tr>
<tr>
<td>Dehydrated</td>
<td>12.4</td>
<td>18.9</td>
<td>6.5 (52%)</td>
</tr>
<tr>
<td><strong>AVERAGE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrated</td>
<td>16.6</td>
<td>21.5</td>
<td>4.9 (30%)</td>
</tr>
<tr>
<td>Dehydrated</td>
<td>13.4</td>
<td>19.1</td>
<td>5.7 (43%)</td>
</tr>
</tbody>
</table>
Manual Derivation of VTI

• To derive the VTI manually, the waveforms must be individually traced on the US interface for calculation of the underlying area.

• With the probe in the appropriate position, this tracing outputs an individual VTI as compared to the automatic average VTI via device alone.

• Once the waveforms are outlined, the area under the figure is calculated to give the VTI.

• As seen here, the manual method is susceptible to variation based on user tracings of the waveform.
## Manual VTI Data

<table>
<thead>
<tr>
<th></th>
<th>Low Fowler's</th>
<th>Passive Leg Raise</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1, Hydrated</td>
<td>17.5</td>
<td>18.9</td>
<td>1.4 (8%)</td>
</tr>
<tr>
<td>Trial 1, Dehydrated</td>
<td>16.6</td>
<td>19.7</td>
<td>3.1 (19%)</td>
</tr>
<tr>
<td>Trial 2, Hydrated</td>
<td>19.8</td>
<td>22.5</td>
<td>2.7 (14%)</td>
</tr>
<tr>
<td>Trial 2, Dehydrated</td>
<td>19.6</td>
<td>19.8</td>
<td>0.2 (1%)</td>
</tr>
<tr>
<td>Trial 3, Hydrated</td>
<td>17.4</td>
<td>17.3</td>
<td>0.1 (0.5%)</td>
</tr>
<tr>
<td>Trial 3, Dehydrated</td>
<td>17.7</td>
<td>18.9</td>
<td>1.2 (7%)</td>
</tr>
<tr>
<td><strong>Average Hydrated</strong></td>
<td><strong>18.2</strong></td>
<td><strong>19.6</strong></td>
<td><strong>1.4 (8%)</strong></td>
</tr>
<tr>
<td><strong>Average Dehydrated</strong></td>
<td><strong>18.0</strong></td>
<td><strong>19.5</strong></td>
<td><strong>1.5 (8%)</strong></td>
</tr>
</tbody>
</table>
50th percentile LVOT-VTI values for 24-year-old males was found to be 20.5, with a range from 13.9-29.7 from 1st to 99th percentiles.

Experimental findings of average VTIs (hydrated) of 18.2 (~25th percentile) and 16.6 (10th percentile) were within the normal distribution of LVOT-VTI for 24-year-old males.
• Transthoracic echocardiogram is a reliable method of obtaining LVOT-VTI.

• LVOT-VTI is a reliable surrogate measure of cardiac output.

• LVOT-VTI is a reliable measure of fluid responsiveness.

• Auto-derivation of VTI is generally a more precise and accurate manner of measuring fluid responsiveness.

• Limitations to LVOT-VTI use in practice mainly stem from user proficiency in bedside ultrasound.

• Next steps would include comparison of IVC collapsibility to LVOT-VTI as a measure of fluid responsiveness.

Conclusions
References


