Left Ventricular Outflow Tract Velocity Time Integral – Fluid Responsiveness

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Outline

- Definition
- Literature Review
- Experimental Design
- Results
- Conclusions

Introduction

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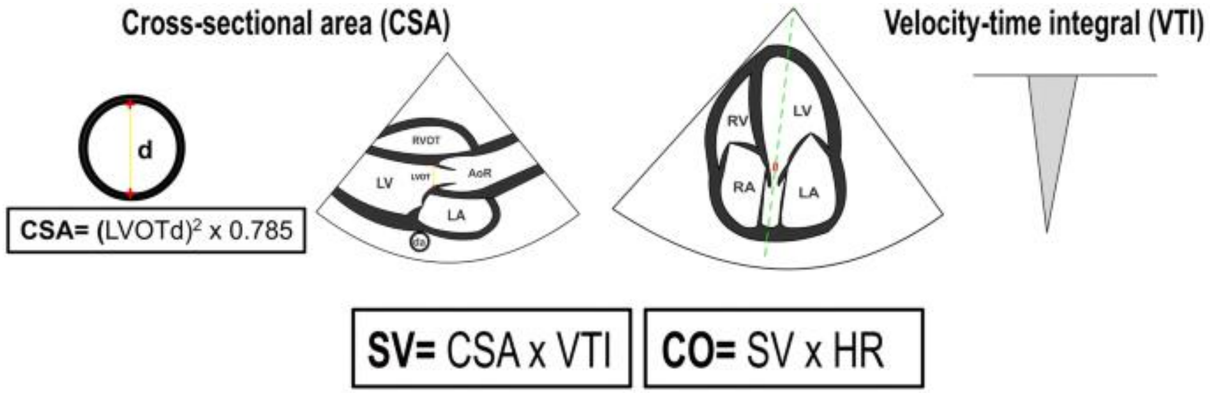
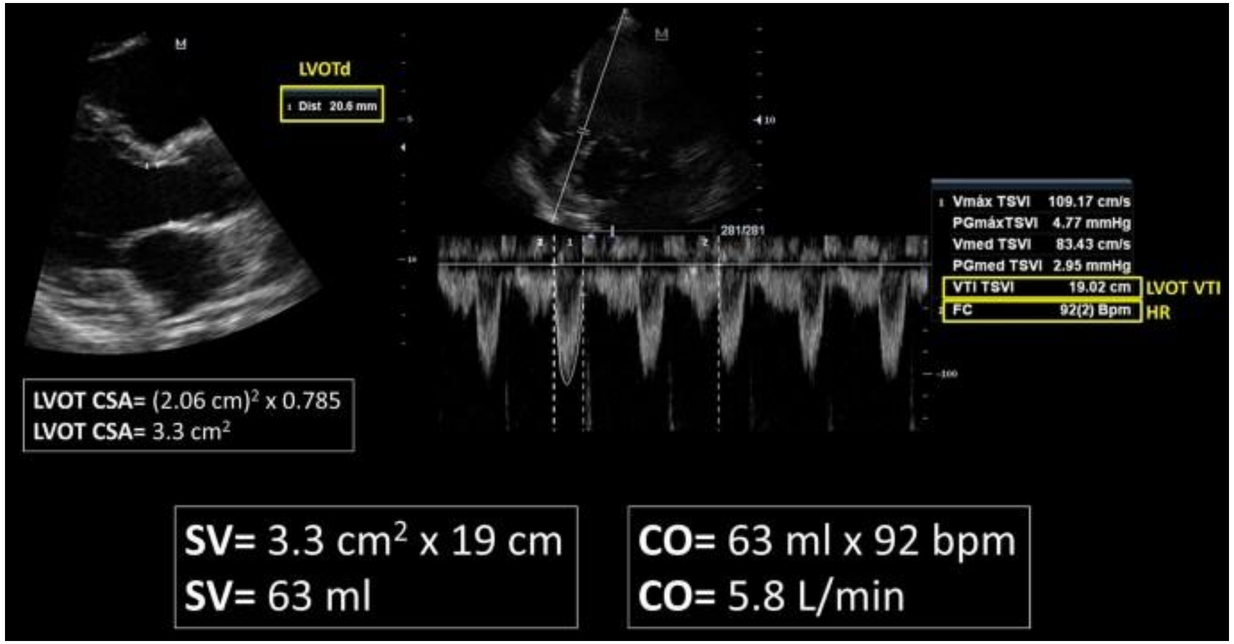
- Stroke Volume (SV) and Cardiac Output (CO) are crucial for hemodynamic monitoring but are difficult to estimate by clinical assessment alone.
- Pulmonary artery catheter is considered gold standard but has a high risk/benefit ratio.
- Transthoracic echocardiography (TTE) is non-invasive (also when 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.

Physics!

- 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 = π r^2
- LV-OT x VTI = SV
- SV x HR = CO





Additional Sources of CO

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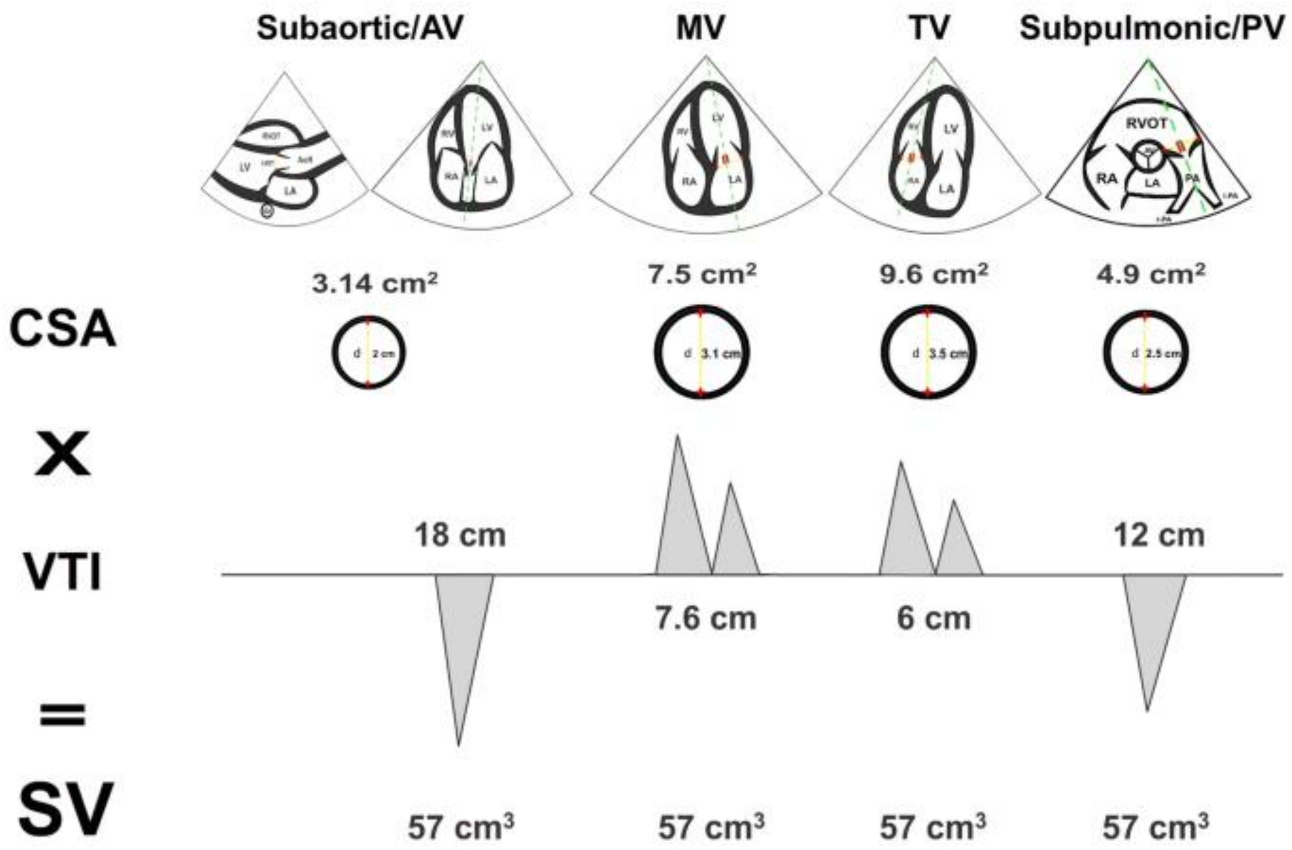
- Assuming normal flow throughout the heart without valvular flow abnormalities or shunting, flow across various valves can be used to calculate CO.
- VTI x Outflow tract area = SV, SV x HR = CO



Math Minimization

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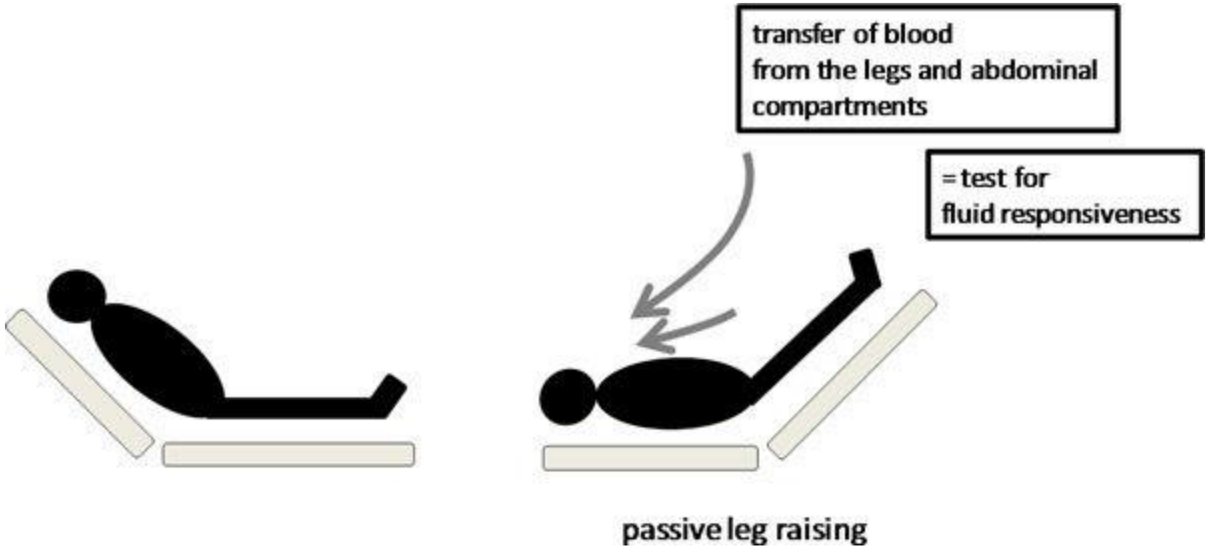
- Given that the area calculation for outflow tract area is a circle, $A = \pi r^2$, any variation in r will drastically alter results.
- Luckily, the outflow area generally can be considered constant and can be measured once to estimate CO without repeat measurements.
- Without significant variation 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

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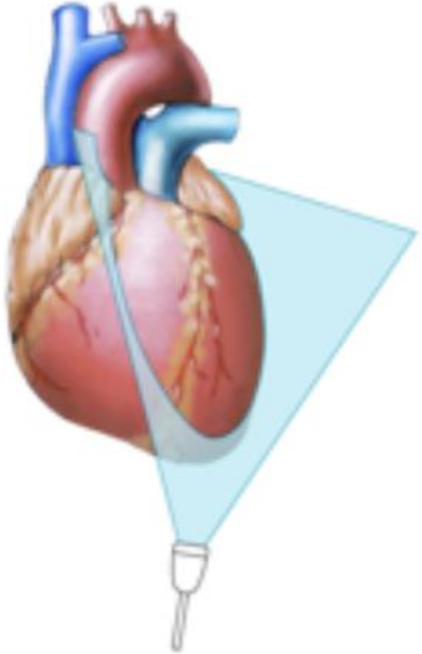
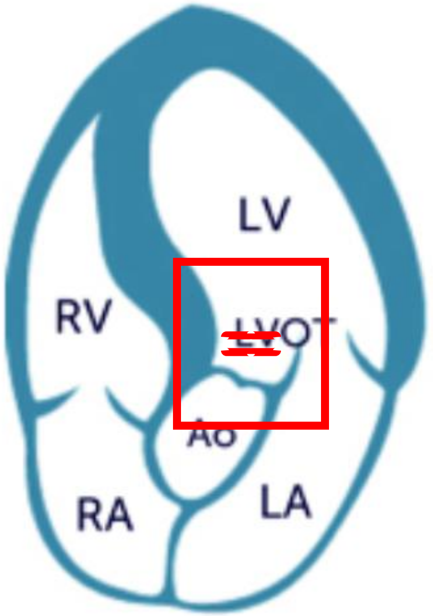
- 2 subjects, 2-3 samples
- Each sample with 4 scans of LVOT-VTI, hydrated and dehydrated
  - Measurement of mitral view or 5 chamber view LVOT-VTI, HR
  - Scan while subject seated and head elevated at 30 ° (Low Fowler's)
  - Scan during passive leg raise, with legs elevated to 30 ° , head flat
- Samples 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.



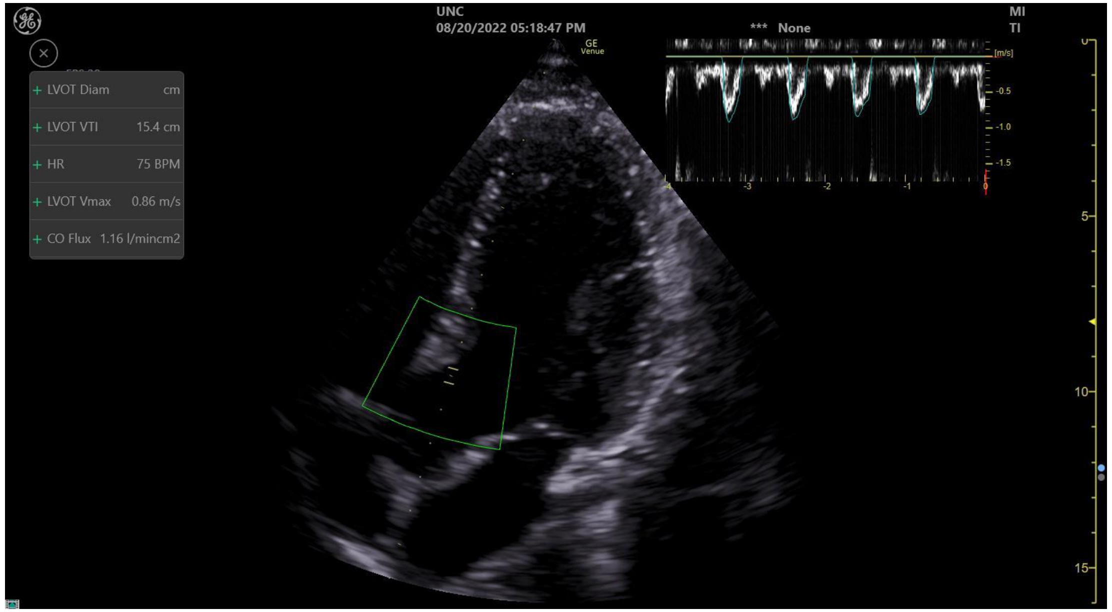


5 Chamber View

5 Chamber View Video

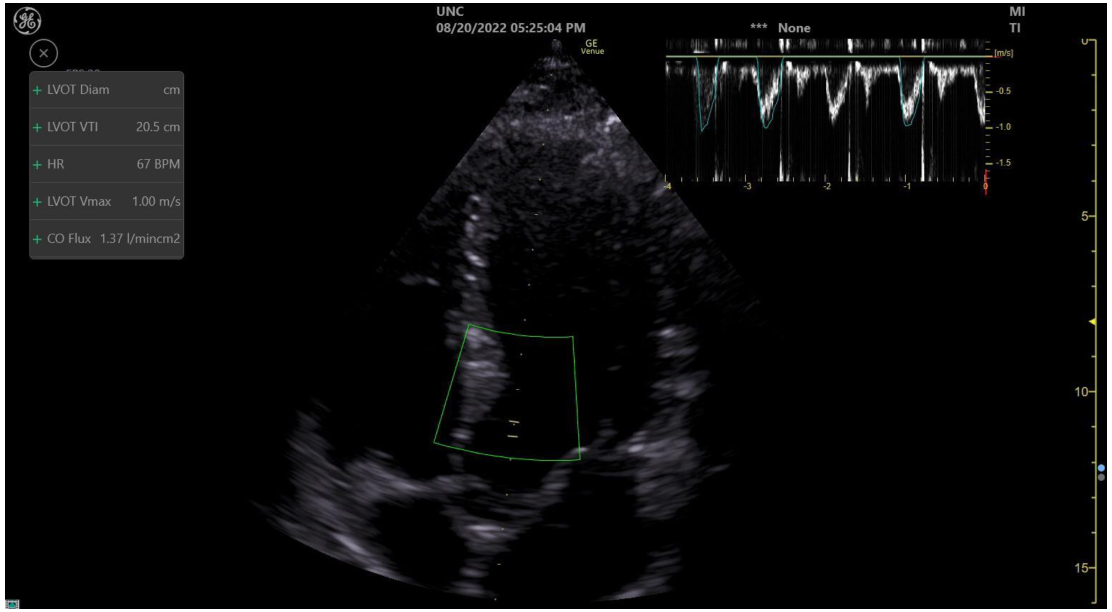
Findings – Hydrated Example

Low Fowler's



VTI 15.4 cm

Passive Leg Raise



VTI 20.5 cm

Δ = 5.1 cm
~33%

Findings – Dehydrated Example

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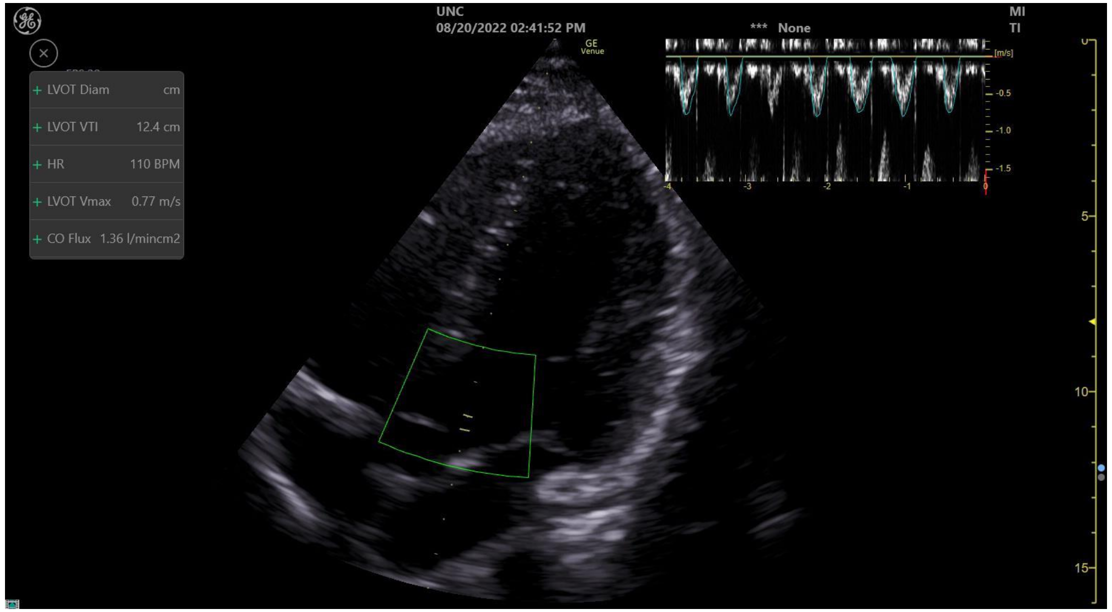
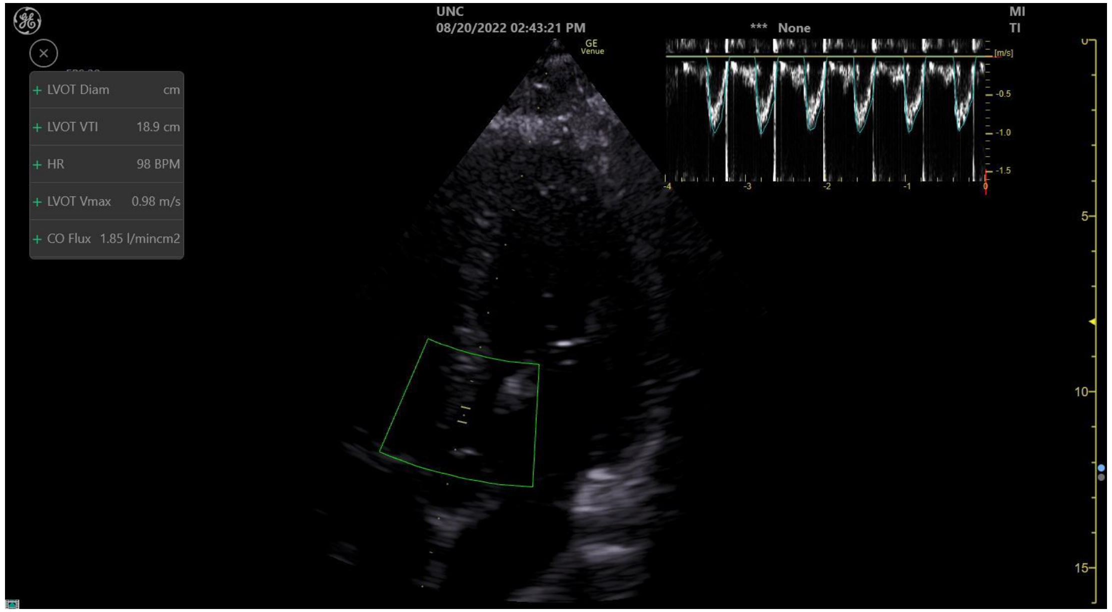
Low Fowler's



VTI 12.4 cm

Passive Leg Raise



VTI 18.9 cm

Δ = 6.5 cm
~52%

Auto-Derivation of VTI

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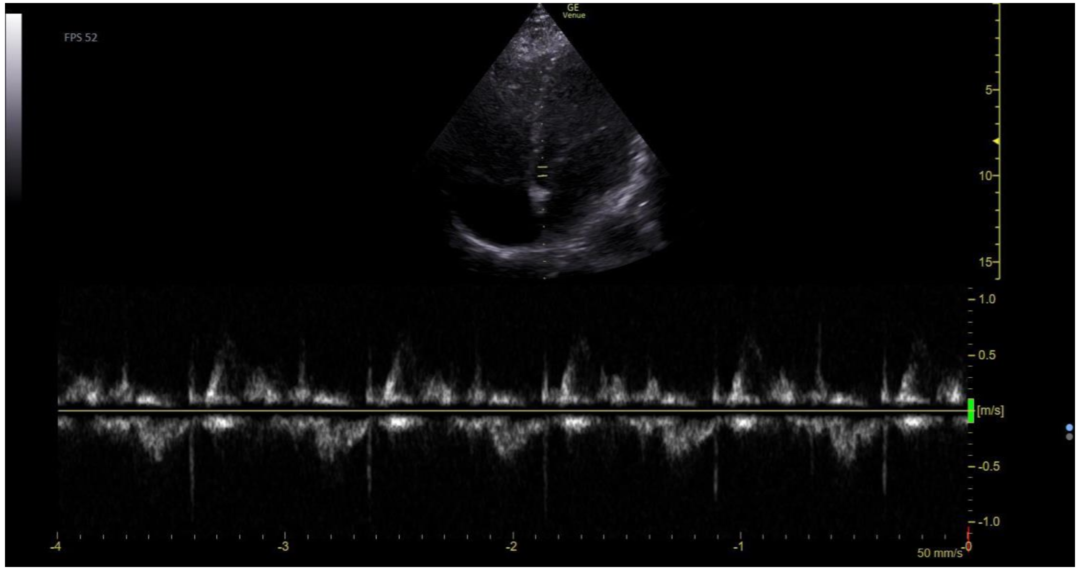
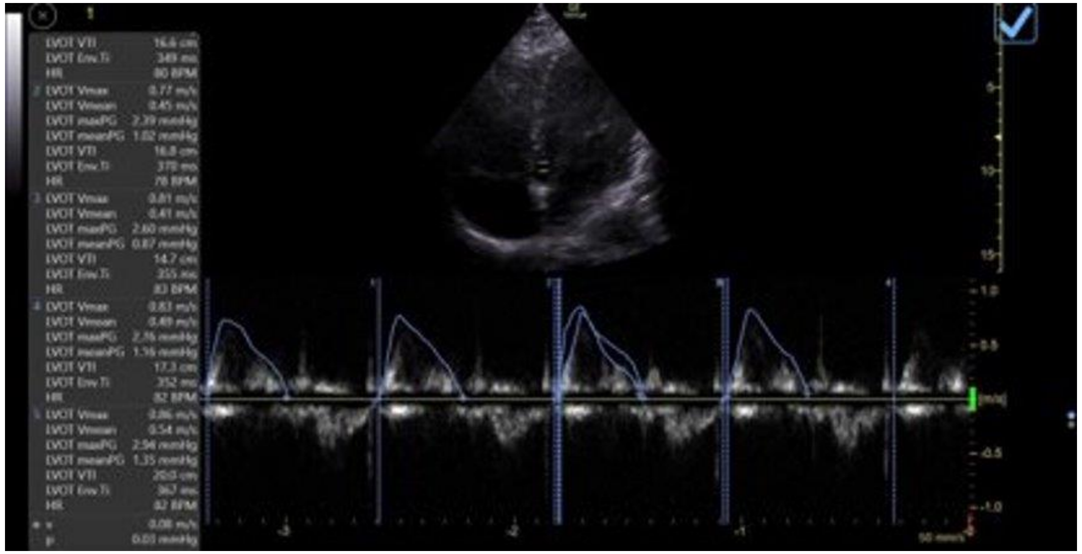
Day 1	Low Fowler's	Passive Leg Raise	Delta
Hydrated	17.7	22.5	4.8 (27%)
Dehydrated	14.4	19.3	4.9 (34%)
Day 2			
Hydrated	15.4	20.5	5.1 (33%)
Dehydrated	12.4	18.9	6.5 (52%)
AVERAGE			
Hydrated	16.6	21.5	4.9 (30%)
Dehydrated	13.4	19.1	5.7 (43%)

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

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	Low Fowler's	Passive Leg Raise	Delta
Trial 1, Hydrated	17.5	18.9	1.4 (8%)
Trial 1, Dehydrated	16.6	19.7	3.1 (19%)
Trial 2, Hydrated	19.8	22.5	2.7 (14%)
Trial 2, Dehydrated	19.6	19.8	0.2 (1%)
Trial 3, Hydrated	17.4	17.3	0.1 (0.5%)
Trial 3, Dehydrated	17.7	18.9	1.2 (7%)
Average Hydrated	**18.2**	**19.6**	**1.4 (8%)**
Average Dehydrated	**18.0**	**19.5**	**1.5 (8%)**

Reference Values

- 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.

Conclusions

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- 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.

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