Goal Directed Echocardiography: 3 Simple Measurements That Will Change Your Practice

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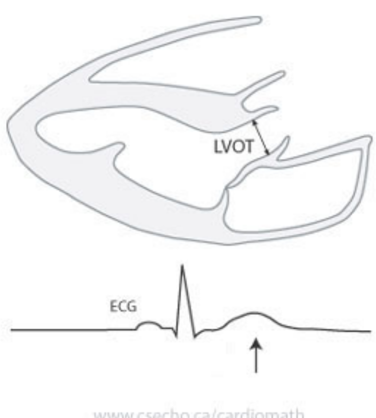
Objectives:

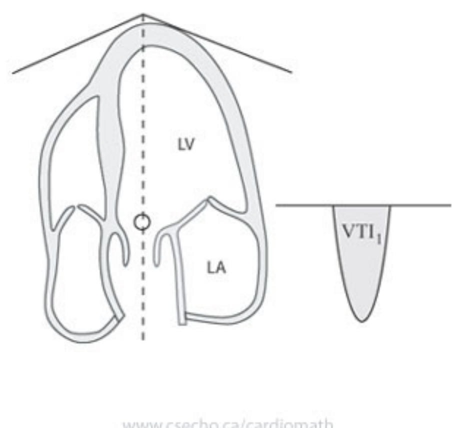
1. Review the proper technique to measure and calculate the left ventricular outflow tract velocity time integral (LVOT VTI), VTI variation, and tricuspid annular plane systolic excursion (TAPSE) with transthoracic echocardiography.
2. Understand the utility of LVOT VTI, VTI variation, and TAPSE to achieve macrocirculatory resuscitation endpoints in the shocked patient.

Left Ventricular Outflow Tract Velocity Time Integral (LVOT VTI)[1]

- **Clinical Utility:** Used to estimate cardiac output. In shocked patients, this can be used to determine the need for inotropic support.
- **Definition:** The LVOT *velocity time integral* (VTI) is measured with the pulsed wave Doppler function, and provides information regarding blood flow velocity across at a given point, measured during systole.
- Variables needed for calculation:
    - LVOT Diameter in parasternal long axis (Figure 1a)
        - Obtain clip of 3-5 cardiac cycles
        - Measure diameter 2-3 mm below aortic valve during systole, when leaflets are wide open.
        - Normal LVOT diameter in adult males is approximately 2 cm, females 1.75 cm.
    - VTI measurement using pulsed wave Doppler (Figure 1b)
        - After obtaining an apical 5-chamber (A5C) view, align the Doppler beam so that it travels directly through the aortic valve and proximal aorta.
        - Place the gate of the beam 2-3 mm below the aortic valve itself to accurately measure subvalvular blood flow.
        - Sometimes an adequate A5C view may not be obtainable. In such a case, an apical 3-chamber view can be tried.
        - Sometimes it may not be possible to get the beam to be perfectly aligned with the LVOT, it may be acceptable if the angle is kept to less than 20 degrees.



1a.



1b.

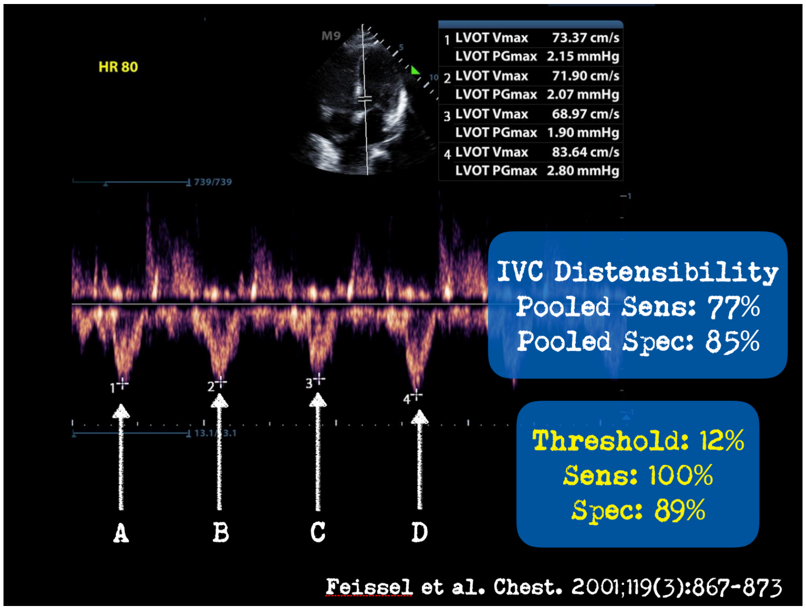
Figure 1a – Parasternal long axis view to obtain the diameter of the LVOT
Figure 1b – Apical 5-chamber view to obtain the LVOT VTI

Measurement	Formula	Units	Normal Value
Aortic Valve Area (AVA)	$\pi * \left\lvert \frac{\text{LVOT diameter}}{2} \right\rvert^2$	cm^2	2.5-4.5
Stroke Volume (SV)	AVA * LVOT VTI	mL	60 – 100
Cardiac Output (CO)	$\frac{SV * HR}{1000}$	L/min	4 - 8
Cardiac Index (CI)	$\frac{CO}{\text{Body Surface Area}}$	$L/min/m^2$	2.5 - 4

Table 1: Equations used to calculate cardiac index using the LVOT VTI

- Pitfalls:
  - Non-alignment of Doppler beam: when there is an angle between the Doppler beam and the LVOT direction, the VTI will be underestimated.
  - Approximation in LVOT diameter measurement. It is important to have a good image with the true long axis of the LVOT (make sure that the walls of the LVOT and of the aortic root are parallel). Use the zoom to minimize the errors in the measurement.
  - Irregular heart rhythm or atrial fibrillation. It is important to average several measurements for each patient, and at least 10 average measurements in patients with irregular heart rhythm.
  - In patients who are taking deep breaths, the entire image/heart may move with respiration making it very difficult to ensure that the PWD sample volume stays at the same place in the LVOT through the respiratory cycle. This can lead to variations in the VTI with respiration, which is not due to hypovolemia.

Peak Aortic Flow Velocity Variation [2]
- **Clinical utility:** Volume responsiveness for patients in shock
- **View:** Apical 5-chamber view
- Measurements:
  - Technique: Pulsed-wave Doppler imaging
  - Marker Location: Sub-aortic flow, ~ 1cm from aortic valve
  - Measurement: Maximal velocity during respiratory cycle
  - Calculation: [VMax – Vmin] / VMax
  - Positive test: > 12% variation with fixed inspiration
- Important considerations:
  - Requires mechanical ventilation without spontaneous breathing (perfect to perform immediately after rapid sequence intubation).
  - In spontaneously breathing patients, can be used with passive leg raise to assess for improved CO with intrinsic fluid bolus from lower extremities.
  - Tidal volume requirements for validity: 8-10 mL/kg
  - Invalid if patient is not in sinus rhythm or has evidence of RV dilation or dysfunction.[3]



Tricuspid Annular Plane Systolic Excursion (TAPSE)

- TAPSE should be used routinely as a simple method of estimating RV function, with a lower reference value for impaired RV systolic function of 16 mm.[4]
- **Clinical Utility:** Right ventricular (RV) systolic dysfunction is an under recognized cause for shock in the critically ill patient.[5]
    - Acute RV dysfunction can be caused by many things, including left ventricular failure, acute pulmonary hypertension, pulmonary embolism, positive-pressure mechanical ventilation, acute hypoxemia/hypercapnea.
- **View:** Apical 4-chamber view
- **Measurements:**
    - Technique: M-mode
    - Marker location: Lateral annulus of the tricuspid valve, ideally ~ 20 °
    - Measurement: Vertical movement during cardiac cycle
    - Results:
        - Normal value: > 1.6 cm
        - Mild-moderate dysfunction: 1 – 1.6 cm
        - Severe dysfunction: < 1 cm

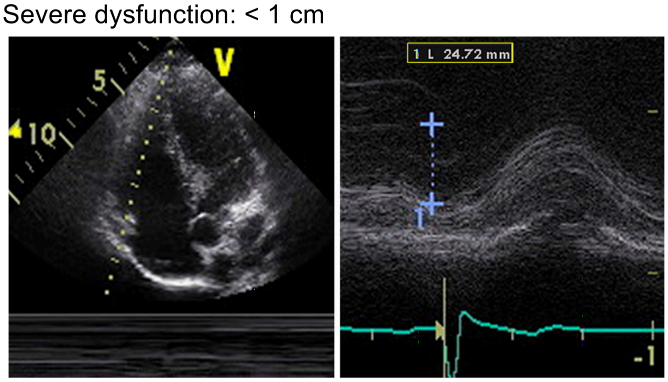
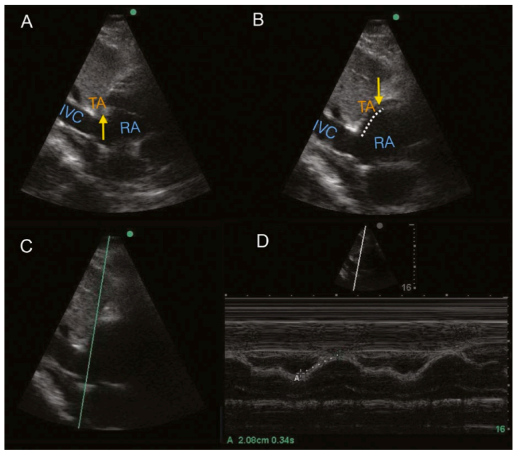


Figure 17 Measurement of tricuspid annular plane systolic excursion (TAPSE).

Alternative measure: Subcostal echo assessment of tricuspid annular kick (SEATAK)[6]

- **Clinical Utility:** if apical 4-chamber view cannot be obtained, subcostal view may be reasonable alternative.
- **View:** Subxiphoid or subcostal
- **Measurement:**
    - Technique: M-mode
    - Marker location: Through lateral annulus of tricuspid valve
    - Measurement: Vertical movement during cardiac cycle
    - Correlation with TAPSE: ρ coefficient of 0.86



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