

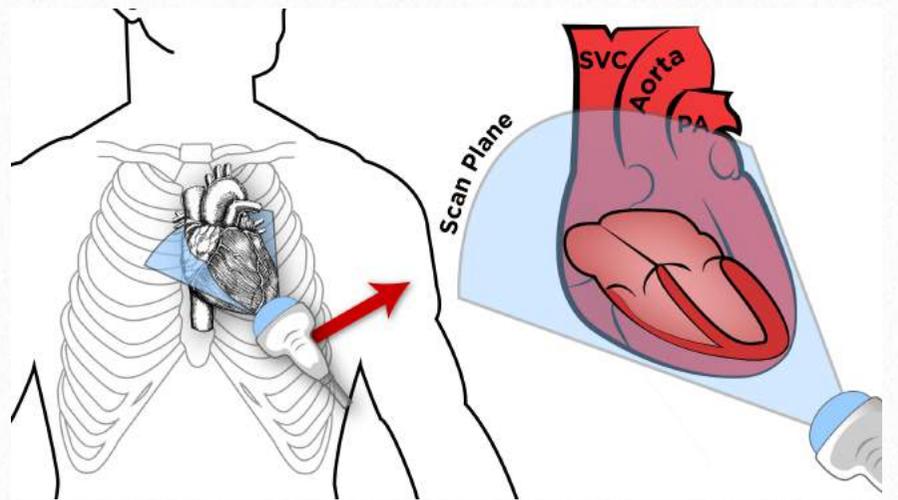
C. RESPIRATORY VARIATION ON VELOCITY TIME INTEGRAL (VTI) OF THE LEFT VENTRICULAR OUTFLOW TRACT

Pulsatile blood flow across a cardiac valve or artery can be measured by a Doppler waveform that quantifies the velocities for each pulse. This waveform (shown below), generated by pulse waveform (PW) or continuous waveform (CW) Doppler ultrasound, is called the **velocity time integral (VTI)**. In other words, VTI is the collection of velocities from red blood cells as they get ejected with each cardiac cycle, therefore representing the stroke volume generated with each cardiac cycle. Since VTI represents stroke volume one can monitor the effects of the respiratory cycle on the generation of stroke volume. This change, or *variation*, in the VTI can be used to predict volume responsiveness. Briefly, a patient who is fluid responsive will have a significant (>15%) increase in stroke volume in response to a fluid challenge. This indicates that the heart is on the steep portion of the Frank-Starling Curve. Positive Pressure Ventilation (PPV) causes negative changes in venous return, which is accentuated in hypovolemic patients. By monitoring the variation in VTI secondary to this effect of positive pressure ventilation, one can determine which patients are fluid responsive. Specifically, a variation of VTI greater than 12% suggests that one is fluid responsive.

There are many locations that one can sample a VTI waveform to assess for this variation. The most validated is across the *left ventricular outflow tract (LVOT)*. This location is relatively easy to identify and is less predisposed to pathologic diseases than other cardiac valves or locations. However, new literature also shows that one may obtain VTI waveforms with Doppler ultrasound imaging of the radial, brachial, carotid, and femoral arteries as well. The benefit of these locations is that they are technically easier to obtain.

Methods of VTI Acquisition

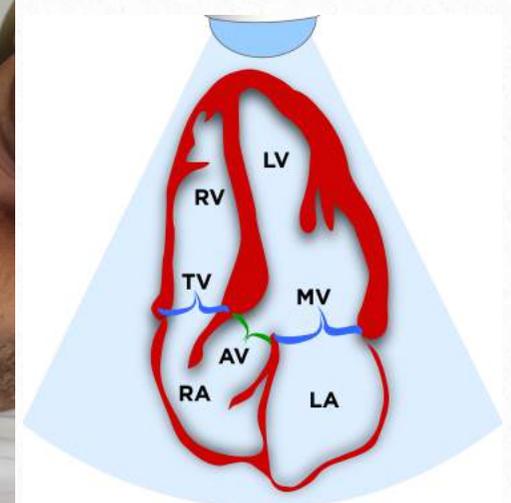
1) VTI using LVOT



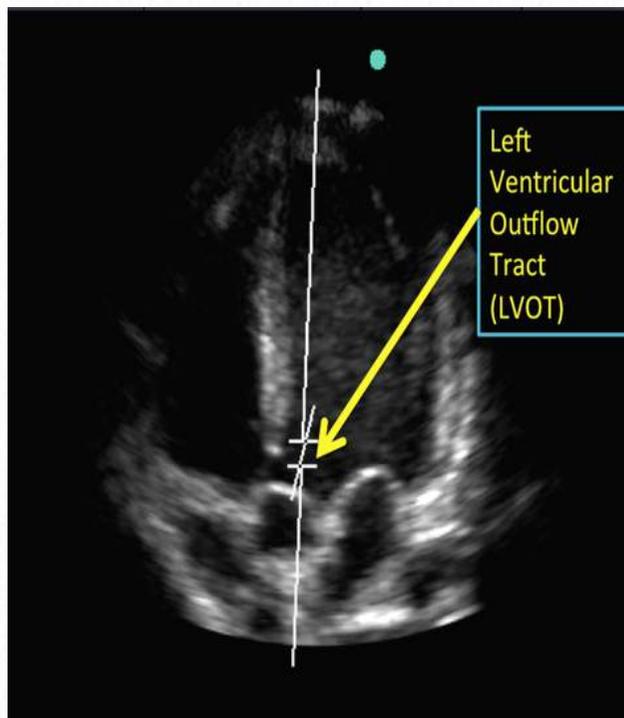
Patient Position: Left-Lateral with L arm Extended

Probe Type: Phased array cardiac probe (small footprint/low frequency)

Probe Position: Left lateral point of maximal impulse (one or two ribs spaces below the nipple), the probe is placed approximately at the 2-3 o'clock position. In the apical 5-chamber view, place a PW or CW sample volume in the middle of the LVOT just adjacent to the aortic valve. The sample cursor should not overlie the valve if one is using PW Doppler. PW Doppler provides a more precise measurement and should be used when possible. Make sure there is no valve opening artifact in front of the systolic flow waveform that is shown on PW waveform. This means that the cursor is placed over the aortic valve and needs to be moved into the LVOT by a few millimeters.



Example Image of LVOT and PW Doppler Placement



If you don't see the mitral and tricuspid valves of the atria, your probe is aimed too deep. To fix this, angle the probe more anteriorly by decreasing the angle between the probe and the skin to visualize the atria.

If you don't see the LV apex or if the apex is foreshortened, you are not at the apical window. Try scanning one or two intercostal spaces lower for a better view.

If you see a big and round-shaped right ventricle, you are probably too medial and too high.

2) VTI using Arterial source

Probe Position: Ultrasound probe is placed over a major artery such that *blood flow is the most parallel to the ultrasound plane as possible*.

VTI Waveform

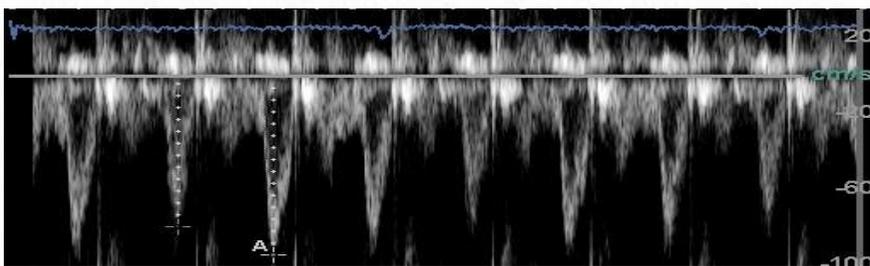


Image Quality Criteria

When using the LVOT method, the apex of the left ventricle should be close to the probe with the LVOT being as close to parallel to the ultrasound plane as possible.

You should visualize the mitral and tricuspid valves fully opening and closing, as well as the atria. Be careful not to shorten the apex of the left ventricle, which would appear round-shaped and hyperkinetic.

Troubleshooting LVOT Method

If the apex of the heart is tilted toward the right of the screen, you are too medial and should move or tilt your probe laterally. If the apex of the heart is tilted toward the left of the screen, you are too lateral, and you should move or tilt your probe medially.

