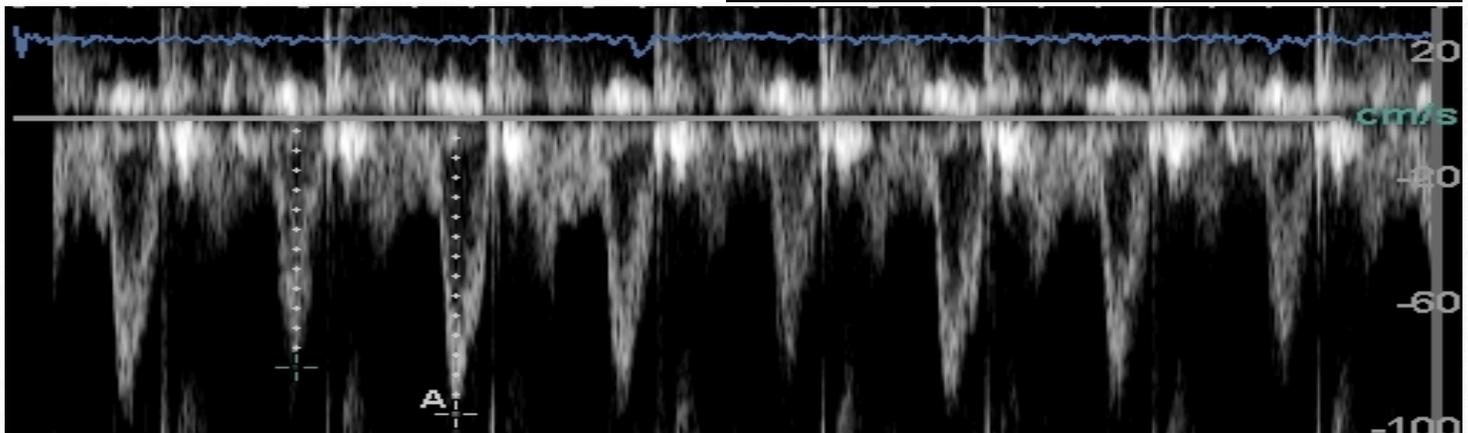
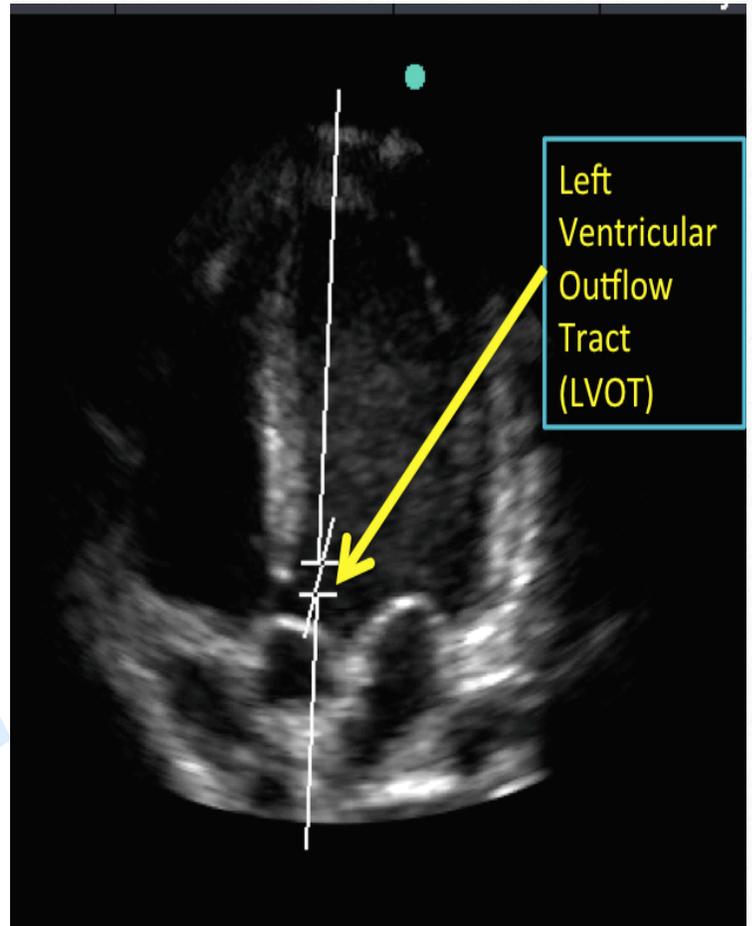
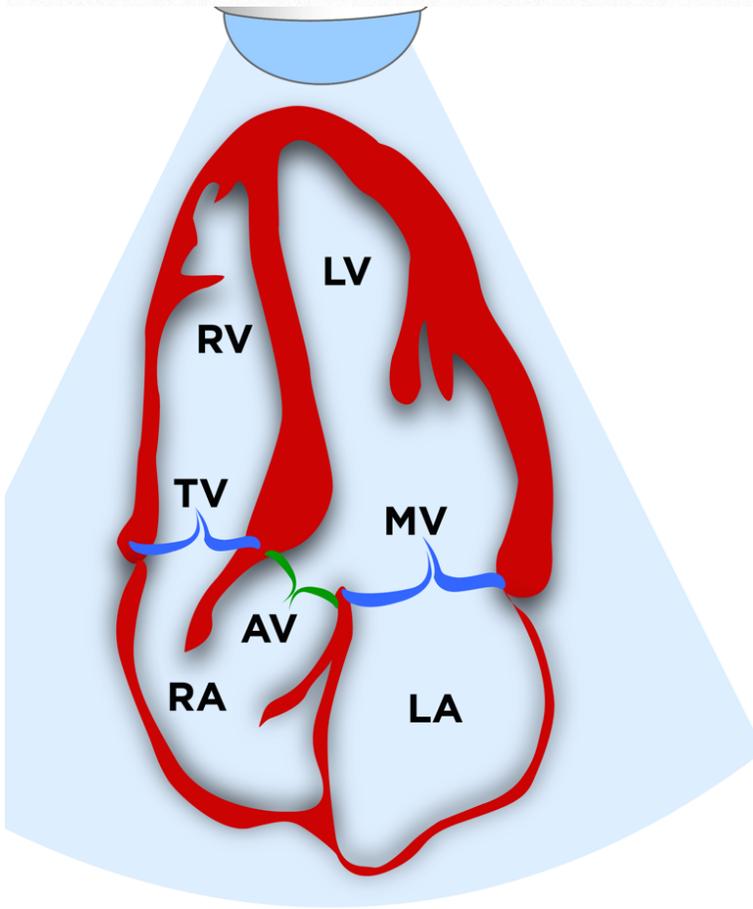


# 4

## Volume Responsiveness via Assessment of Velocity Time Integral Variation



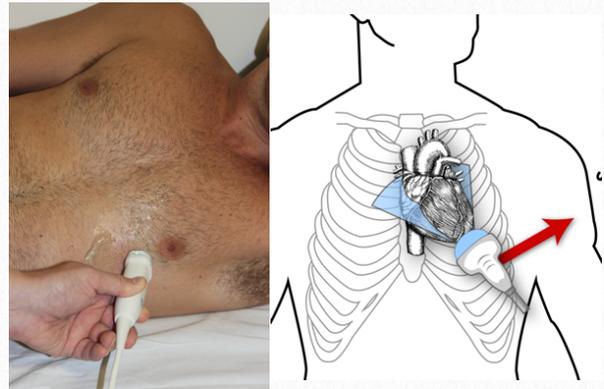
**I. Volume Status:** Ultrasound provides a variety of techniques to assess the patient's volume status, and, often more importantly, whether or not the patient is fluid responsive. Each subsection (below is part 3 of 5) will cover one ultrasound technique used to answer these questions.

**C. Respiratory Variation on Velocity Time Integral (VTI) of the Left Ventricular Outflow Tract:**

Pulsatile blood flow across an 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.

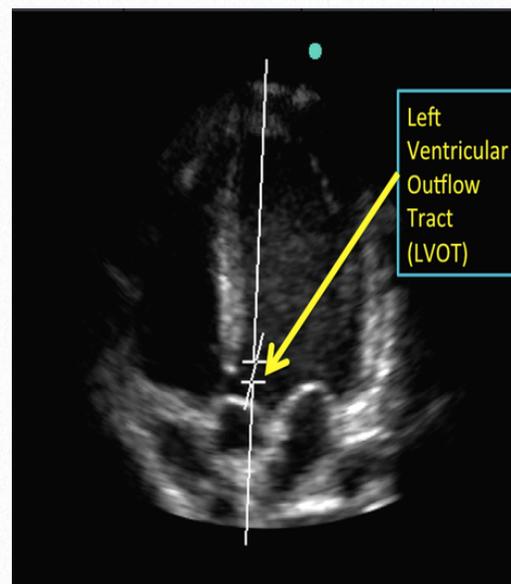
There are many locations that one can sample a VTI waveform to assess for this variation. The most validated is across the left ventricular outflow tract (LVOT). This location is relatively easy to identify and is less predisposed to pathologic diseases than other cardiac valves or locations. However,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

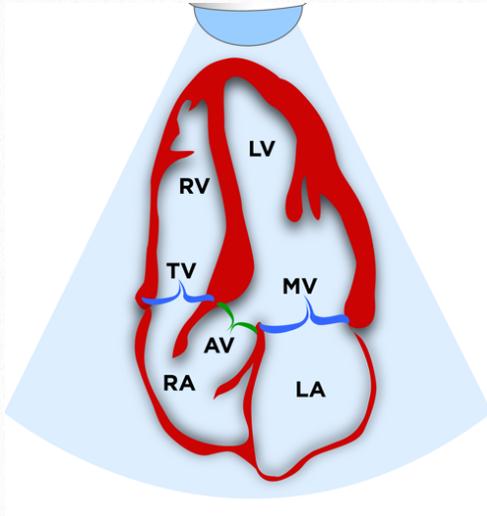
**Patient Position VTI of LVOT: Left-Lateral with L arm Extended.**



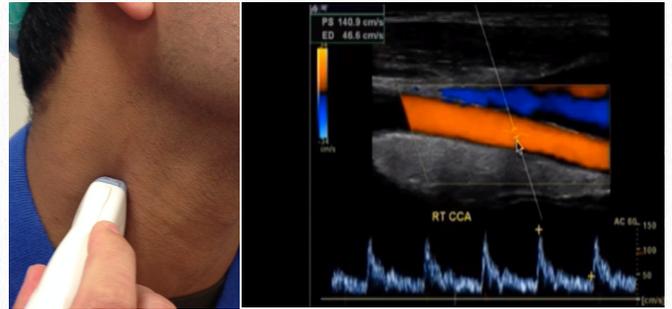
**Probe type:** phased array cardiac probe (small footprint/low frequency)

**Probe position: LVOT VTI.** 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

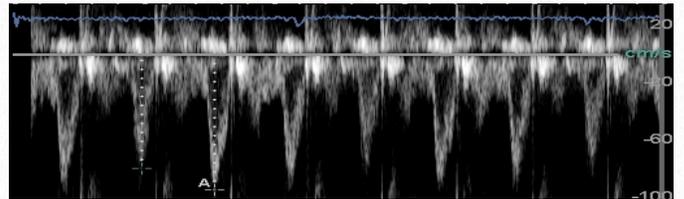
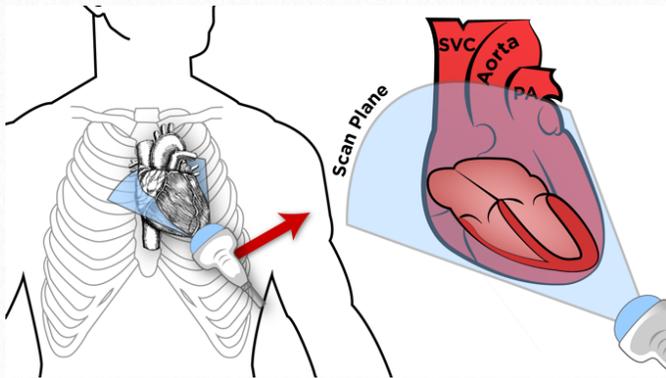




**Probe position: Arterial VTI:** Ultrasound probe is placed over a major artery such that blood flow the most **parallel** to the ultrasound plane as possible.



**VTI Waveform:**



### **Image Quality Criteria**

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, and the atria.

Be careful not to shorten the apex of the left ventricle, which would appear round-shaped and hyperkinetic.

### **Troubleshooting**

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

If you don't see the mitral and tricuspid valves of the atria, your probe is aimed too deep. You should 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. You should try to scan one or two intercostal spaces lower.

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