Venue™ Family

Auto Tool for Measuring VTI

A white paper by

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Work Smarter, Not Harder

Key Points

1. The Auto-VTI tool calculates the velocity time integral (VTI) and cardiac output in a single step with a quality indicator to assist with image acquisition.

2. The VTI trending function helps clinicians quickly visualize the trend so the next course of action can be determined.

3. Auto VTI can provide up to 90% reduction in keystrokes and take up to 82% less time than manual method of calculations, as performed by experts. [1]

Accelerate Therapeutic Interventions

Auto Tool for measuring VTI

Shock, as defined by John Collins Warren, is a momentary pause in the act of death. Shock is the clinical term for circulatory failure, resulting in inadequate cellular oxygen utilization. [2] Augmentation of cardiac output (CO) with the goal of optimizing oxygen delivery to peripheral tissues is the key to shock survival. Supportive interventions targeting the optimization of CO include the administration of intravenous fluids and/or vasopressors and inotropes. However, each of these interventions is associated with significant side-effects: Unnecessary additional fluids may result in venous congestion and tissue edema, which are associated with poor outcomes in critically ill patients. [3]

Use of point-of-care ultrasound to assess patients in shock is becoming popular in emergency medicine and critical care settings worldwide. Use of ultrasound to aquire repeated assessments of the LVOT VTI enables monitoring of the stroke volume over time and the ability to evaluate changes related to therapy actions. The Venue™ Family Auto VTI tool aids clinicians in quickly determing the next course of action in shock treatment in order to achieve the best patient outcome.

What is VTI?

Velocity Time Integral (VTI) is a measurement that accompanies the assessment of the surface area of the left ventricle outflow tract (LVOT), and is used to calculate stroke volume (SV).

SV (Fig. 1, Fig. 2) is the volume of a cylinder that represents the column of blood traveling from the left ventricle to the aorta during systole.

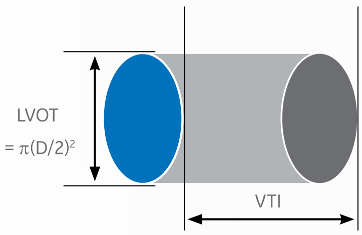


Figure 1: Illustration of the SV, presented as a cylinder.

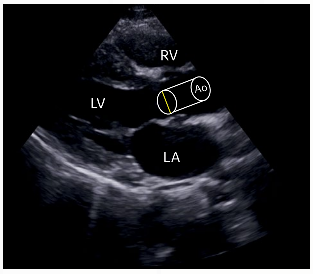


Figure 2: Parasternal long axis view, demonstrating the cylinder that represents the SV.

Two measurements are required to calculate Stroke Volume:

1. The LVOT surface area is calculated by measuring the LVOT diameter in the parasternal long axis view.
2. VTI, which represents the length of the cylinder at the LVOT is calculated by taking the integral (area under the curve) of the velocity of the blood flowing through the LVOT over time.

SV (ml/cycle) = LVOT Area (cm^2) x VTI/cycle (cm/cycle)
Where 1 L = 1000 cm^3
SV= Stroke Volume
LVOT Area = left ventricle outflow tract area
VTI/cycle = Velocity Time Integral of the blood flow through the LVOT per cycle (cycle represents each heart beat)

Equation 1: Left Ventricle Stroke Volume

Cardiac output is the blood volume that the heart pumps every minute. It is calculated by multiplying the LV stroke volume (blood volume the heart pumps every cycle) and the heart rate.

CO (L/min) = SV (L/cycle) x HR (cycle/min)[4]
CO= cardiac Output per minute
SV= Stroke Volume
HR= Heart Rate

Equation 2: Cardiac Output per minute

Although CO can be measured using the 2D Simpson's multidisc method, the use of pulsed-wave doppler across the LVOT is more accurate – often supplanting invasively acquired CO measurements.

Since the cross-sectional area of the left ventricular outflow tract (LVOT area) does not change over time for each individual, variation in LVOT VTI is equal to the variation in stroke volume. Therefore the LVOT VTI, as a single measure, can be used as a proxy for the stroke volume. Acquiring repeated assessments of the LVOT VTI enables monitoring of the stroke volume over time and the ability to evaluate changes related to therapy actions or passive leg raise.[3]

Why measure VTI?

The Velocity Time Integral (VTI) measurement plays a significant role in the management of critically ill patients. It allows the physician to monitor hemodynamic changes resulting from a disease or from the therapy actions that were required to achieve better patient outcome.[3]

Key questions that can be answered by measuring VTI:

1. Is the heart pumping enough blood to the end organs?
2. Did my intervention work? Is the patient's hemodynamic status changing?

Calculating VTI using point-of-care ultrasound can provide quick objective information for guiding treatment regarding cardiac function to manage a specific shock state. This is particularly important because treatment in one shock state may have adverse effects in another. In addition, changes in cardiac output can reflect patient volume status and be used to assess their response to resuscitation over time.[4]

How VTI is used for patient management?

1. VTI trending can be used to assess response to therapy.
2. Assessing the absolute values of VTI may be useful to estimate cardiac output, assessing the relative change of VTI in shock management may be practically more useful to assess the response to therapy and help in decision making process about the next therapeutic steps.
3. If SV / VTI increases by 15% with fluid challenge fluid responsive may be considered.[6]
4. If SV / VTI increases by 20% with inotropes contractile reserve may be considered.[7]

Traditional method for measuring VTI with ultrasound

Steps for measuring VTI [4]

1. Obtain an apical 5-chamber view.
2. Select Doppler and place the gate in the LVOT (Fig. 3).
3. Orient the probe to align the Doppler beam parallel to the LVOT as closely as possible. Obtain PW Doppler waveform, and freeze the image.
4. Obtain PW Doppler waveform and freeze the image.
5. Trace the outline of 3 consecutive waveforms, if possible (if more than one waveform is traced, take the average of the measurements) (Fig. 4).

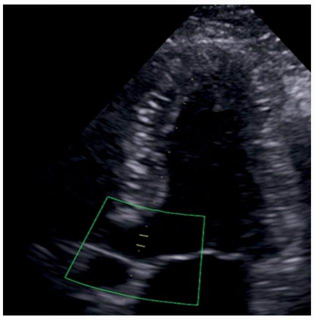


Figure 3: Apical 5-chamber view showing the Doppler gate in the LVOT

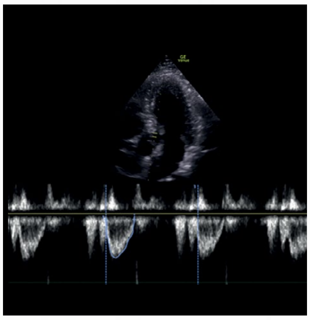


Figure 4: Tracing consecutive PW Doppler waveforms.

Limitations in the technical steps of manual VTI measurement:[4]

- Manually place the pulse-wave Doppler gate and align the Doppler beam parallel with LVOT blood flow. Inappropriate placement of the Doppler gate will result in either poor spectrum and underestimation of the VTI or if the sample gate is placed above the aortic flow, an overestimation of the VTI.
- Manually tracing the outline of >1 waveform to calculate the VTI is time consuming.
- Insonation angle may introduce inaccuracy and variability of VTI measurement, so acquiring adequate sonographic window is key to accurate measurement of this metric.
- Serial measurements can be done for tracking the patient's condition, but interobserver variability may also be an issue.

The limitations noted above can lead to inaccurate or incorrect assessments. This may interfere with appropriate care and therefore may deter users from integrating VTI measurement in their patient's workup. Additionally, placing the sample gate in the correct position requires skills that novice ultrasound users may lack and the multiple steps necessary to secure the VTI measurement takes time users may not have.

Our Solution | Automated VTI Measurement An AI-Enabled Auto Tool for Measuring VTI

The Venue™ Family of point of care ultrasound systems provide an Artificial Intelligence (AI) based tool that automatically calculates VTI. Auto VTI helps simplify patient assessments and obtain fast information that might affect therapeutic interventions and potentially improve confidence. In addition, it might be helpful in training medical students and residents by enabling them to secure and use this measurement easily and more independently. Using Auto VTI with the VTI trending function allows users to quickly track responses to interventions so they can determine the next course of action.

How does Auto VTI work?

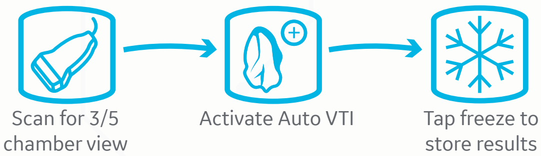
The Auto VTI tool is based on proprietary artificial intelligence. Using thousands of cardiac ultrasound images, we trained our algorithm to perform the actions required for placing the Doppler gate in the necessary position and auto trace the waveforms in order to calculate the VTI. The system calculates the VTI using pulsed Doppler with automatic tracing of the maximum velocity in the LVOT and integrating this measurement over time.

The Auto VTI tool can be used when scanning a patient with a phased array probe*, using a 3-chamber or 5-chamber view. After automatically locating and positioning the region of interest (ROI) over the LVOT, the tool places the gate at an optimal position on the image. The tool then calculates VTI and CO by averaging all Doppler waveforms during a period of 4 seconds.

Calculations are done in real time and the results are displayed in the Results Box. The Quality Indicator is represented by the color of the ROI placed by the system over the image. It varies between green/yellow/red to represent excellent/average/unacceptable image quality respectively.

Steps for activating the Auto VTI tool:

1. Scan to find a good 3/5 chamber view.
2. Activate Auto VTI tool (Fig. 5).
   *If you do not agree with the location of the ROI, you may manually reposition it to a preferred location.
3. Tap Freeze to store results.
   *If you do not agree with the location of the gate you may manually reposition it to a different location in the ROI while reviewing the loop.



*See UM for supporting probes.

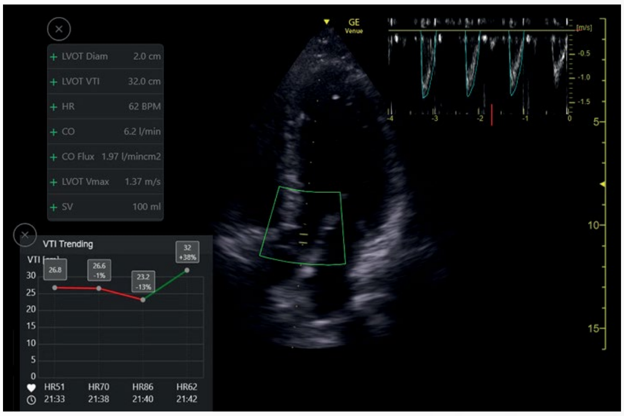


Figure 5: Auto VTI Tool with VTI Trending Function enabled.

VTI measurements can be repeatedly taken over time with the Auto VTI tool plotting results on the trending diagram (Fig. 5). VTI Trending helps clinicians quickly visualize the trend and determine a next course of action.

Calculations

To estimate total CO volume, based on VTI and HR (both calculated automatically by the tool), the system uses the following equation:

CO (Liter/Min) = VTI (cm) x LVOT CSA (cross section area in cm^2) x HR (beats/min) / 1000

Where 1L=1cm^3/1000

The LVOT CSA is calculated from the value of LVOT diameter:

LVOT CSA = (1/2 x LVOT diam (cm)$)^2$ x 3.14

The user has 3 options for inclusion of the LVOT diameter:

1. Leave the LVOT empty, in which case the CO is not calculated or displayed.
2. Measure the LVOT diameter directly from a PLAX cardiac view.
3. Enter a value for the LVOT diameter.

SV (Stroke Volume) calculation: SV [ml] = VTI x LVOT area
CI (Cardiac Index) calculation: CI [Liter/min./m^2] = CO/BSA (Body Surface Area)
CO Flux: CO Flux [liter/min/cm^2] = CO/LVOT area = VTI*HR*LVOT area/LVOT area = VTI * HR

CO Flux is a measurement characterizing cardiac output flow normalized to the patient size. It is similar to Cardiac Index but calculated in a much easier way without needing to know the patient's weight and height, nor measure the LVOT diameter.

Strategy for validating the Auto VTI tool

We utilized internal and external methods for evaluating the Auto VTI tool

How do we evaluate internally?

1. We conducted internal scanning sessions and simulated user testing at our internal sites. Here qualified healthcare professionals scan volunteers while providing feedback on the usability and quality of the tool they are testing. We utilize internal studies to further validate. The results of an internal study demonstrated the following: [1]
   a. The time to obtain results was shorter (by 82%) for measurements done using Auto VTI compared to manual measurements.
   b. The number of clicks required for obtaining these results was lower (by 90%), for measurements done using Auto VTI compared to manual measurements.
   c. The Auto VTI measurements were within 20% of an expert (Emergency Medicine physician >20 years of ultrasound experience) manual VTI measurements, in 90% of the time.

How do we evaluate externally?

1. We select external evaluation sites in which physicians use our systems in acute care settings and provide feedback based on their clinical expertise and experience with ultrasound studies.
2. We rely on external studies, conducted by PoCUS users, to further evaluate our findings.

For instance, in a recent study determined in an experimental model of hemorrhagic shock by Bobbia, et al.,[8] Venue™ Auto VTI tool was found to be better correlated with CO measured by thermodilution than manual echocardiographic measurements.

Conclusion

The evaluation of cardiac output is a time consuming and major challenge in acute care patients. During shock management, measurements of CO and stroke volume are recommended to evaluate the response to treatment, especially fluid resuscitation. The Venue™ Family Auto VTI tool calculates VTI and CO in one simple step. After running the Auto VTI tool, VTI Trending helps clinicians quickly visualize the trend and determine a next course of action in treatment. Auto VTI can provide up to 90% reduction in keystrokes and take up to 82% less time than a manual method of calculations, as performed by experts.[1]

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