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Critical Care Echocardiography for Fluid Responsiveness

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Introduction

Fluid management is a crucial component of acute care in the intensive care unit. Early goal-directed therapy has shown better outcomes in patients with septic shock.[1] Increased end-diastolic volume and stroke volume depend on ventricular function. The accurate assessment of intravascular volume and adequate maintenance of cardiac preload can improve the outcomes of critically ill patients. Overresuscitation without fluid responsiveness may result in more harm by shifting fluid to the extravascular space and causing end-organ edema. To select patients who might benefit from volume expansion, many studies have sought bedside indicators of fluid responsiveness.

Current Limitations

Numerous hemodynamic variables have been proposed as predictors of fluid responsiveness. Static variables are based on a single observation in time, such as central venous pressure, but central venous pressure and other static measures are largely affected by intrathoracic pressures and ventricular compliance. Dynamic variables reflect the cardiovascular response to respiratory changes in pleural pressure. Respiratory changes in systolic pressure, pulse pressure, aortic blood flow peak velocity, superior vena cava diameter, and inferior vena cava (IVC) diameter have been proposed as more sensitive predictors of fluid responsiveness.[2]

Recent Developments

Bedside ultrasonography has emerged as a rapid, noninvasive tool for assessing and monitoring fluid status in the intensive care unit.[3] With positive-pressure ventilation, the vena cava blood flow is impeded during inspiration, causing a decrease in venous return and pulmonary artery blood flow. This effect on venous return can be quantified as variation in IVC diameter, which can be measured from the subcostal view at 1 cm caudal to the confluence of hepatic veins using M-mode or a 2-dimensional view. The inferior vena cava collapsibility index can be calculated by the difference between maximum and minimum IVC diameter over a single respiratory cycle divided by the maximum IVC diameter. Respiratory variation in IVC diameter better predicts fluid responsiveness in mechanically ventilated patients but has limited ability in spontaneously breathing patients.[4] Distention of the IVC to more than 12% to 18% in mechanically ventilated patients and IVC collapse of at least 40% to 50% in spontaneously breathing patients are considered predictive of fluid responsiveness.[5] The reliability of IVC diameter and collapsibility should be regarded with caution, however, and the underlying physiology assessed. Inferior vena cava dilation is expected in right ventricular failure or tamponade, and fluid administration should not be contraindicated when clinically appropriate. Compression of the IVC can occur with compression from abdominal pathology, as well. Issues of accuracy have also been raised in terms of whether measurement methods alter the reliability of the test.[6] Data

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suggest that superior vena cava imaging with transesophageal imaging may have a higher sensitivity for fluid responsiveness, which is an area for further exploration.[3]

Respiratory variation in aorta peak velocity is a better predictor of fluid responsiveness than systolic pressure or pulse pressure variation.[7-9] Unlike variables based on arterial blood pressure or plethysmographic measurements, flow measurements are not affected by arterial compliance or changes in arterial tone. Pulsed Doppler echocardiography at the aortic annulus from the apical 5-chamber view allows aortic flow velocity measurement (Fig. 1). The maximum and minimum peak aortic blood flow velocities can be measured over a single respiratory cycle. Respiratory variation in aorta velocity time integral (VTi) (Fig. 2) can be calculated by measuring the area under the Doppler envelope of blood flow in the left ventricular outflow tract in systole to estimate stroke volume, then calculating the difference between maximum and minimum aortic VTi observed over a single respiratory cycle divided by the maximum VTi. Greater than 15% variability is associated with fluid responsiveness in mechanically ventilated patients.[10]

Because metrics based on ultrasonography have had variable results in identifying fluid responsiveness depending on the physiological factors mentioned here, the same metrics used to evaluate the need for fluid administration may also be useful to measure fluid tolerance. Such metrics are useful in arenas where fluids may be considered, and unexpected ultrasonographic findings can help steer care.[10]

Abbreviations and Acronyms

IVC	inferior vena cava
VTi	velocity time integral

The passive leg raising test is a helpful tool to determine fluid responsiveness at bedside. Raising a patient's legs to at least 45 degrees for 2 to 3 minutes induces a gravitational transfer of venous blood from the legs into the central circulation, which results in a transient increase in cardiac preload. Passive leg raising is completely reversible; therefore, any detrimental effects of unnecessary fluid administration are minimal and temporary.

Summary

Bedside ultrasonography allows rapid and noninvasive assessment of volume status and can help predict fluid responsiveness in critically ill patients. Dynamic measurements are better predictors of fluid responsiveness than static variables. Extrinsic factors, such as intrathoracic pressure and intraabdominal pressure, can alter the anatomy. Underlying physiology should be taken into consideration for clinically appropriate interpretation of ultrasonographic findings.

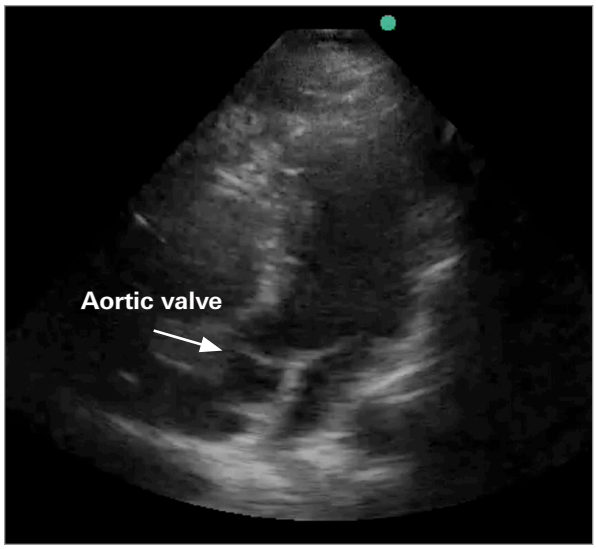

Fig. 1 Transthoracic echocardiogram with apical 5-chamber view identifying the aortic valve.

Supplemental motion image is available for Figure 1

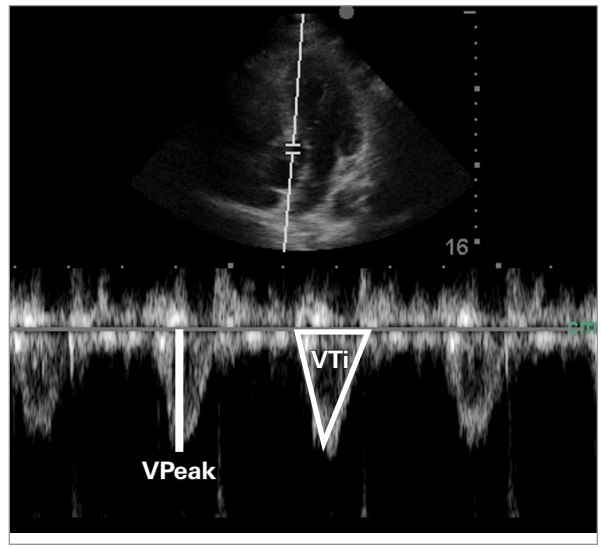

Fig. 2 Transthoracic echocardiogram with pulsed wave Doppler of the left ventricular outflow tract identifying peak velocity (VPeak) and velocity time integral of the Doppler tracing (VTi).

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