>>EMERGENCY ULTRASOUND

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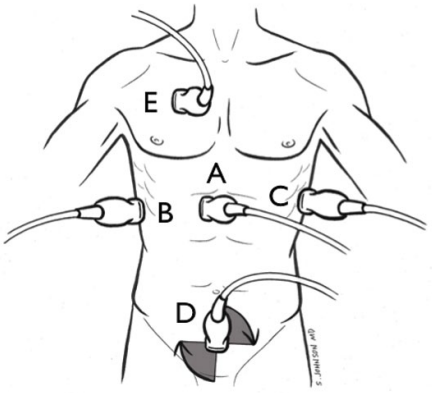
Rapid Ultrasound in SHock: The RUSH Protocol

Figure 1. Evaluation of the Tank



A. Inferior vena cava

B. FAST (right upper quadrant, add pleural view)

C. FAST (left upper quadrant, add pleural view)

D. FAST (pelvis)

E. Lung views

FAST = focused assessment with sonography in trauma

CASE

A 52-year-old man arrives at the ED with acute shortness of breath. He appears ill, with a blood pressure of 100/60 mm Hg; heart rate, 100 beats/min; respiratory rate, 28 beats/min; temperature, 37.8°C. His pulse oximetry reading is 82% on room air, increasing to 98% on face-mask oxygen. He has a history of hypertension, chronic obstructive pulmonary disease (COPD), and congestive heart failure. He reports a cough productive of yellow-green sputum, as well as fevers and chills. You determine that the patient may be in early shock, based on his relative hypotension. However, his myriad medical problems make it difficult to determine the optimal course of therapy. Do you treat for congestive heart failure, COPD, or pneumonia? To determine an answer, you perform the RUSH exam, using bedside ultrasound.

Evaluation of the "pump" (part 1 of RUSH; see discussion in September–November 2009 issues) shows that the patient's left ventricle is contracting well and there is no pericardial effusion and no evidence of acute right heart strain. Thus, the next step is to continue to part 2 of the RUSH protocol: evaluation of the "tank," or core vascular volume. This, together with examination of the pump, provides crucial data on the patient's shock state.

DISCUSSION

There are three parts to the evaluation of the "tank" in the RUSH protocol (Figure 1). The first is to assess "tank fullness" through sonography of the inferior vena cava and jugular veins. The second is to look for "leakiness of the tank" using the extended FAST (focused assessment with sonography in trauma) examination for free fluid within the abdominal/pelvic or thoracic cavity. The final part is to evaluate for "compromise of the tank," using pulmonary ultrasound techniques to assess for pneumothorax. A tension pneumothorax can compress the vena cava and cause hemodynamic compromise through underfilling of the "tank." Additionally, the use of ultrasound to look for B-lines (indicating pulmonary edema) can be very helpful in the evaluation of the "tank." This finding demonstrates "tank overfilling" and corroborates cardiogenic shock. This month, we will concentrate on the RUSH evaluation of the inferior vena cava and jugular veins to determine "fullness of the tank."

"Emergency Ultrasound" presents clinical cases involving the diagnostic use of bedside ultrasound in the emergency department. Cases can be explored in more detail on the Web in the SoundBytes section of CMEDownload.com, which can be accessed directly at www.sound-bytes.tv. Instructional videos detailing the components of the RUSH exam are available for download.

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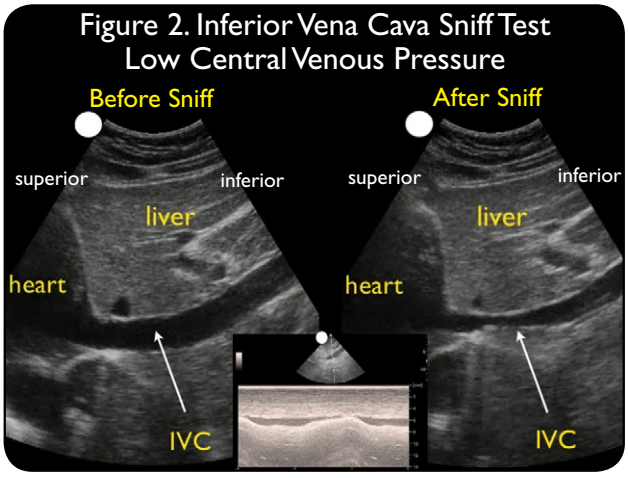

Figure 2. Inferior Vena Cava Sniff Test
Low Central Venous Pressure

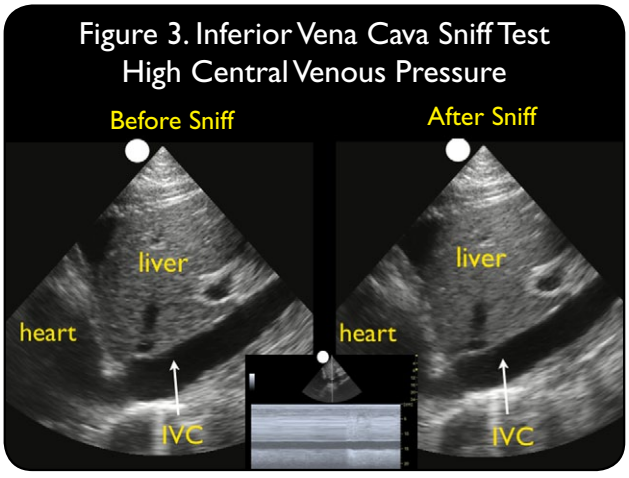

Figure 3. Inferior Vena Cava Sniff Test
High Central Venous Pressure

To perform the ultrasound evaluation of the inferior vena cava, first the probe is placed in the subxiphoid two-chamber position. The probe marker dot will point upward. In this plane, the heart will be seen superiorly and the liver anteriorly in a midsagittal configuration. If the probe is positioned to the midline, the aorta will usually come immediately into view in a long-axis configuration. The aorta can be identified by its thick wall, failure to compress with pressure from the probe, and pulsatile activity, which can be documented on Doppler sonography. Moving the probe from the aorta toward the patient's right will allow visualization of the inferior vena cava in a long-axis orientation. The inferior vena cava will be identified by the thinner walls and compressibility with the probe. It may be noted to have pulsations, although these are actually the waves associated with the physiology of the heart and lung. Doppler sonography of the inferior vena cava will distinguish these waves from the pulsatile blood flow in the aorta. Once the inferior vena cava is identified in long axis, the sonographer should specifically examine the part that is 2 cm distal to the right atrium. It is also useful to analyze the inferior vena cava in the short-axis view by moving the probe transversely, with the marker oriented to the right. The inferior vena cava will appear as a circular structure to the right of the aorta and superior to the spine. The probe can be aimed superiorly for visualization of the confluence of the hepatic veins with the inferior vena cava, which will provide further information about the "tank." Using both the short- and long-axis views ensures that the examiner will not underestimate the size of the inferior vena cava. By investigating only in long axis, it is possible to "slice" the ultrasound beam through the smaller side of the vessel, as can be seen in a cylinder-type effect.

The evaluation of the inferior vena cava should include an assessment of its size. In general, a diameter greater than 2 cm correlates with a high central venous pressure (CVP), ie, greater than 10 cm H_2O, while a diameter less than 2 cm correlates with a low CVP, ie, less than 10 cm H_2O. In the short-axis view, the patient with a high CVP will have both a distended inferior vena cava as well as dilated hepatic veins joining the inferior vena cava. Important additional information is obtained both by looking at the absolute dimensions of the inferior vena cava as well as by analyzing its variation in size with respirations. In

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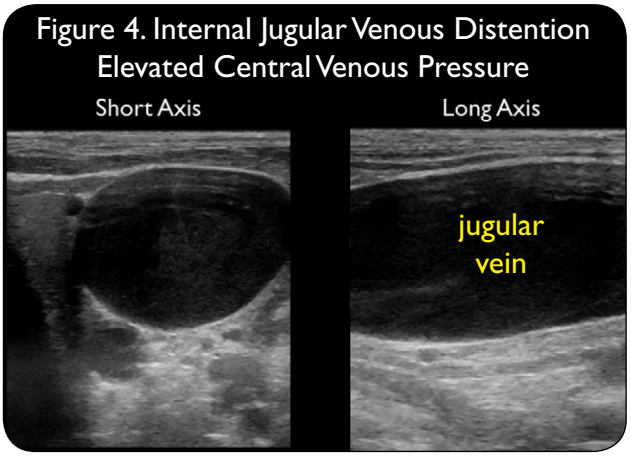

the spontaneously breathing individual, the inferior vena cava will collapse with inspiration. This occurs as negative pressure within the chest (resulting from inspiration) causes blood to move up from the abdomen into the heart. In variance, with expiration, the inferior vena cava will have its widest dimensions.

It is possible to maximize these physiologic changes within the inferior vena cava to better investigate the CVP by means of the sniff test, ie, having the patient forcefully inspire while the inferior vena cava is visualized. The inferior vena cava correlating with a CVP less than 10 cm H_2O will collapse more than 50% with the sniff test (Figure 2, page 23). Conversely, a distended inferior vena cava that does not collapse more than 50% correlates with a CVP greater than 10 cm H_2O (Figure 3, page 23). M-mode Doppler sonography can be used to graphically depict the changes in size of the inferior vena cava as they occur with the respiratory phases.

There are two caveats to this general rule on inferior vena cava size. The first is in the intubated patient who is receiving positive pressure ventilation. In this state, the changes in size will be opposite because it is in expiration that the chest cavity pressure becomes negative and the inferior vena cava is smaller. In most intubated patients, the inferior vena cava will be more distended and stiff. However, a gradual increase in size with fluid loading has been correlated with fluid responsiveness in these patients.

The second caveat is in the patient who has received diuretics and/or nitroglycerin prior to arrival in the ED. The inferior vena cava in these patients may have become smaller with such treatment, and it may be necessary to look for pulmonary edema, as indicated by ultrasound B-lines, to make the correct diagnosis.

Evaluation of the inferior vena cava can be supplemented by evaluation of the jugular veins. For this exam, the head of the bed is inclined upright at a 30° angle. The high-frequency linear array probe is placed gently over the anterior neck, so as not to artificially collapse the vein. First, the jugular vein is examined in short axis low in the neck; then, the vein is followed superiorly to the angle of the jaw. A jugular vein that is distended (usually greater in size than the paired carotid artery) and lacks variation in size with respiration, as described with the inferior vena cava, correlates with a high CVP. By following the jugular vein superiorly, one can look sonographically for jugular venous distention, which can be difficult to assess by traditional physical exam in patients who have a thick neck. Swiveling the probe on the jugular vein into a long-axis orientation with the probe marker pointed toward the head can allow excellent determination of the closing level, or meniscus, of the jugular vein. In a patient with a high CVP, the jugular vein will resemble a distended pipe without a closing level (Figure 4). Conversely, in a patient with a low CVP, the jugular vein will appear smaller in size. In addition, the closing meniscus level (the location where the two areas of vessel meet) may be seen low in the neck.

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CASE ANALYSIS

Employing the RUSH exam at the bedside—specifically, evaluation of "tank fullness" by examining the inferior vena cava and jugular veins (part 2 of RUSH)—will give a good estimate of the patient's core vascular volume.

In the case patient described above, analysis of the patient's inferior vena cava and jugular veins showed distended vessels without respiratory collapse, indicating a high CVP. Interestingly, this patient had good contraction of the left ventricle on bedside echocardiography. Thus, he was found to have primary diastolic heart failure, consistent with his elevated blood pressure and chronic hypertension, leading to a thickened ventricle with poor relaxation. He was treated with nitroglycerin, diuretics, and bilevel positive pressure ventilation. He also received antibiotics for presumed respiratory infection, given his history of copious sputum and fevers/chills. There was dramatic improvement in his condition, and he was subsequently admitted to the medical unit, where he did well.


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>>Look for discussion of the RUSH evaluation for "leakiness of the tank" in an upcoming issue.

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