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Rapid Ultrasound for Shock and Hypotension (RUSH)

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It is now the standard of care to perform focused assessment using sonography for trauma (FAST) early in the evaluation of a sick trauma patient. There seems to be far less urgency to use ultrasound to evaluate the medical patient with hypotension or signs of shock. We believe that part of the reason for this discrepancy is the lack of an accepted way to refer to the exam and a standardized sequencing. In this paper, we outline the components and rationale for the rapid ultrasound for shock and hypotension (RUSH) exam.

In 2001, Rose et al. reviewed an ultrasound protocol they had created to evaluate the undifferentiated hypotension patient (1). In 2004, Jones et al. studied the effects of early goal-directed ultrasound for ED patients with hypotension (2). This study showed reduction in the number of conditions that needed to be ruled out, as well as a quicker time to final diagnosis. Recently, additional articles have discussed the use of focused ultrasound for cardiac arrest and shock patients without obvious etiology (3,4).

In an effort to conglomerate all of the various diagnostic ultrasound techniques applicable to these patients into a functional approach, we created the RUSH exam. The RUSH exam is designed to be rapid and easy to perform with the portable machines found in most emergency departments (EDs). The components of the exam are heart, inferior vena cava (IVC), Morison's/FAST abdominal views with thoracic windows, aorta, and pneumothorax scanning. These components can be recalled with the mnemonic: HI-MAP. This mnemonic also describes the sequencing of the exam. We will discuss each of the components in detail below.

Heart

The heart portion of the RUSH exam evaluates for pericardial effusion/tamponade; right ventricular failure, as a sign of pulmonary embolism; and a qualitative assessment of left ventricular function. The echocardiographic views used are the parasternal long axis and the four chamber view. For probe positioning and examples of normal exams, we recommend the *Yale Atlas of Echocardiography*:

Parasternal Long View

4-chamber View

Pericardial Tamponade

The parasternal long view is used to assess for pericardial fluid, which is best identified posterior to the left ventricle and anterior to the descending aorta. In the setting of shock and hypotension, more than trace pericardial fluid should increase your suspicion for pericardial tamponade. However, an experienced ultrasonographer can assess for this condition directly. In the same parasternal long view, if there is collapse of the right atrium during diastole (sensitive) and the right ventricle during early diastole (specific), the diagnosis is likely to be tamponade (5,6). Click here for an example of RV diastolic collapse in pericardial tamponade. If tamponade is diagnosed, the ultrasound exam can also aid in the performance of a pericardiocentesis. Ideally, a large pocket of fluid with a good amount of space between the pericardium and the heart, without interposed lung will be identified. This site may be sub-xiphoid, but more often it is on the anterior chest wall. Ultrasound-guided pericardiocentesis is safer than a blind sub-xiphoid procedure (7-9).

Apical 4 Chamber View of a pericardial effusion

Click on image to begin video

Video 1: Parasternal Long View (PLAX) of pericardial effusion

Sub-xiphoid View of pericardial effusion

Case I

A 45 year-old male with presents with chest pain and mild lower abdominal pain. His vital signs at triage are a blood pressure of 190/132 mm Hg, a pulse of 108 bpm, a respiratory rate of 20, and a 98% O2 saturation on room air. The patient states the chest pain is substernal and sharp. You elicit a social history of chronic cocaine use; the last use was 3 days ago. The patient's EKG shows sinus tachycardia with inferior T-wave inversions. You place the patient in a monitored bed and order labs, including cardiac enzymes and a D-dimer. You order aspirin, IV lorazepam, and a sublingual nitroglycerin tablet. You then go to see a few other patients.

Ten minutes later, the nurse urgently pulls you back to the bedside. The patient's blood pressure has dropped to 60/40 and he states the chest pain is worse. A repeat EKG shows no change. You grab the ultrasound machine and perform the RUSH exam. You see the following image during the heart portion of the exam:

Click on image to begin video

Video 2: Pericardial effusion with descending aorta; a dissection is seen in the aorta

Click on image to begin video

Video 3: Another view of the dissection within the descending aorta

Click on image to begin video

Video 4: A zoomed-in view of the descending aorta

You give the patient a rapid bolus of fluid and put in a stat page for cardiothoracic surgery. The patient is quickly taken to the OR, placed on bypass, and undergoes relief of his pericardial tamponade and repair of his aorta, which was found to have a dissection flap involving the entire arch.

Right Ventricular Enlargement

Rarely, actual clot can be visualized during transthoracic echocardiography (TTE), but massive pulmonary embolism is more likely to present with only indirect signs. A PE significant enough to cause shock will often be accompanied by signs of acute right ventricular failure. An enlarged right ventricle on the four chamber view points to right ventricular failure (RVF) as one of the contributors to the patient's shock state. RVF can be caused by many entities, but when it is acute in the setting of shock, the most likely diagnoses are massive pulmonary embolism and right ventricular infarction.
The right ventricle is normally less than 60% the size of the left ventricle. When the RV size equals or is larger than the LV, RV failure should be suspected.

Enlargement of the right ventricle can also occur from right ventricular infarction. This diagnosis will often present with signs of inferior wall infarction on electrocardiogram and may have associated left ventricular dysfunction. However cardiogenic shock can occur from isolated right ventricular failure without associated EKG or left ventricular abnormalities (11).

Click on image to begin video

Video 5: Apical 4-Chamber View demonstrating right ventricular enlargement

Hypodynamic Left Ventricle

In the setting of hypotension, the qualitative assessment of LV function can indicate a cardiogenic cause. The poor LV function can be the result of a primary problem, e.g. infarction or myopathy. Or it can be secondary to conditions such as sepsis or toxins. While more complicated procedures allow a numeric estimate of the ejection fraction, in the setting of hypotension, a visual estimate often suffices (12).

In the parasternal long view, at the level of the papillary muscles, a < 30% difference between the size of the LV in systole and diastole indicates a severely decreased LV function [(end diastolic size-end systolic size)/end diastolic size]. After a witnessing a reasonable number of normal and abnormal exams, this estimation can be made after a few seconds of seeing the heart's function (13).

Click on image to begin video

Video 6: Parasternal Long View (PLAX) of hypodynamic left ventricle

Hyperdynamic Left Ventricle

In the same echocardiographic view just mentioned, if the left ventricular walls change >90% between systole and diastole or if they actually touch at end systole, then the LV is hyperdynamic. This can be seen in hypovolemia, acute blood loss, and often in sepsis prior to the administration of vasopressors. These patients will usually benefit from volume loading.

Inferior Vena Cava

The evaluation of the IVC can give an estimate of the volume status of the patient. The exam outlined below is a dynamic evaluation of filling pressures based on respiration. The exam is conducted differently depending on whether the patient is spontaneously breathing or receiving mandatory breaths from a ventilator.

Spontaneously Breathing Patients

The IVC should first be located in longitudinal orientation in the sub-xiphoid area. By placing the probe just under the xiphoid and sliding 1-2 cm to the patient's right, the IVC should be easily located. The exam concentrates on the IVC superior to the influx of the hepatic veins. Both the diameter of the IVC and the response to patient inspiration are examined. The latter is often best assessed using M-mode ultrasonography.

The IVC portion of the exam allows both an estimation of the central venous pressure (CVP) and predicts a beneficial response to fluid bolus. An IVC diameter of <1.5 cm with complete inspiratory collapse is associated with a response to volume loading and these findings are associated with a low CVP (<5) (14-16). Conversely, an IVC diameter of >2.5 cm with no inspiratory collapse represents a high CVP (> 20) and the patient is unlikely to increase their cardiac output in response to fluid loading (14,16,17). Patients intravascularly depleted in this setting will need agents to increase their inotropy or decrease their afterload before fluids will be helpful.

The relationship of IVC size/collapsibility and CVP

Click on image to begin video

Video 7: IVC in a euvolemic patient

Click on image to begin video

Video 8: IVC in hypovolemia

IVC in fluid overload or right heart inflow obstruction (pericardial tamponade, tension pneumothorax or massive pulmonary embolism). The diameter of the IVC will change only insignificantly during respiration.

Mechanically Ventilated Patients

In contrast to spontaneously breathing patients, mechanical inspiration causes the IVC to enlarge. The difference between the inspiratory and expiratory size of the IVC can be used to gauge the need for fluid loading. In order to accurately assess the IVC in ventilated patients, they must be sedated enough to not be taking spontaneous breaths during the time of measurement. In addition, the ventilator should be adjusted to deliver 10 ml/kg of tidal volume. Even in patients with acute lung injury, placing a patient on this tidal volume for the ~20 seconds of measurement will cause no ill effects. The patient should be returned to their previous ventilatory settings after assessing the IVC.

Many studies have evaluated IVC diameter changes as a measurement of response to fluid loading (18,19). Unfortunately, these studies calculated their cut-off points using different formulae. The simpler formula is [(Insp size - Exp Size)/Exp size] (18). The result is expressed as a percentage; using this formula the cut-off is 18% change. Values greater than this predict an increase in cardiac output to a fluid challenge.

Morison's and the FAST Exam Views with Hemothorax Windows

Emergency physicians are familiar with the views of the FAST exam. Imaging for free fluid in the right upper quadrant, left upper quadrant, and suprapubic area can provide a clue to many diagnoses such as, ectopic pregnancy, massive ascites, ruptured viscus, spontaneous intraabdominal bleeding, intraperitoneal rupture of an AAA, etc. If there is not time to complete all of these views, an image of Morison's pouch with the patient in Trendelenberg position is sensitive for significant intraperitoneal blood or fluid (21).

Right Upper Quadrant View with free fluid

Click on image to begin video

Video 9: Right Upper Quadrant View with free fluid

When performing the upper quadrant views, tilting the probe towards the chest to image the diaphragm/lung interface reveals the presence of fluid or blood in either hemithorax (20).

Right Upper Quadrant View with pleural fluid

Click on image to begin video

Video 10: Pleural Effusion

Click on image to begin video

Video 11: Another view of pleural effusion

Case II

A 39 year-old woman presents with back pain for the past four hours. At triage, she has a BP of 70/40 mm Hg, a pulse rate of 60 bpm and a respiratory rate of 20. Her abdominal exam is benign. You quickly place the patient into an exam room and perform the RUSH exam while the nurse is placing large bore IV's.

The abdominal views are shown here:

Click on image to begin video

Video 12: Left Upper Quadrant View

Click on image to begin video

Video 13: Pelvic View

Click on image to begin video

Video 14: Right Upper Quadrant View

You confirm your suspicions with a bedside plasma pregnancy test, which returns positive. After 1 liter of fluids, the patient's blood pressure has improved to 90/60. OB GYN quickly takes the patient to the operating room.

Aorta

Scanning the abdominal aorta for aneurysm (AAA) is one of the key emergency ultrasound modalities. We prefer to scan the aorta in transverse orientation at four levels: just below the heart, suprarenal, infrarenal, and just before the iliac bifurcation (22,23). By sliding the probe down from the xiphoid to the umblicus, these four views can be obtained in a continuous and rapid fashion. If the Aorta is > 5 cm in any of these views and the patient is in shock, the diagnosis is a ruptured AAA until proven otherwise.

Abdominal Aortic Aneurysm in Transverse View

Click on image to begin video

Video 15: Same aneurysm in the infrarenal view

Click on image to begin video

Video 16: Same aneurysm with color-flow doppler, Note that most of the lumen is occupied by clot.

Pneumothorax

Though far more likely in trauma, tension pneumothorax can be a cause of shock in medical patients as well, especially if the patient recently had a procedure such as a central line, pacemaker placement, or thoracentesis. Scan longitudinally in the anterior 3rd intercostal space on both thoraces with a high frequency probe (20). We have found imaging in M-mode to make for the easiest interpretation. The ocean/beach or seashore sign reassures that there is no pneumothorax at the location of the probe (20). This pattern consists of the immobile soft tissue and muscle on the top of the image (ocean) and the lung, demonstrating movement on the bottom of the image (beach). If a continuous ocean pattern (stratosphere sign) is observed, then a pneumothorax is likely (20). One caution in intubated patients: a right mainstem bronchus intubation can lead to the false appearance of a pneumothorax over the left chest due to the lack of left lung motion (24).

Normal pleural interface with lung sliding and comet tail artifacts

Click on image to begin video

Video 17: A close-up of normal lung sliding

Pneumothorax underlying the probe; no lung sliding or comet tails

Seashore Sign: M-mode of normal lung; there is a clear interface between the static muscles and the pleural movement

Stratosphere Sign: M-mode of a pneumothorax

Case III

A 70 year-old man is sent from the clinic with a complaint of cough for 2 ½ weeks; the patient has no other complaints. When you take his vitals, his blood pressure is 95/60 mm Hg and he has distended neck veins. While performing the RUSH exam, you are surprised to find this view of the right upper lung:

Click on image to begin video

Video 18: Right lung demonstrating no lung sliding or comet tails

You do not believe the results of your ultrasound until a portable radiograph confirms the diagnosis of spontaneous tension pneumothorax. Insertion of a chest tube provides rapid improvement of the blood pressure.

Sequencing

This entire exam can be completed in less than 2 minutes using readily available portable machines. We go in the order of the **HI-MAP** acronym:

1. Heart: **Parasternal long** and then **4 chamber cardiac views**, with the general purpose or cardiac probe

2. **IVC view** with the same probe

3. If not already using it, switch to general purpose abdominal probe and scan **Morison's and splenorenal views** with **thorax** images and then examine the **bladder window**

4. Increase your depth and find the **aorta** above and below the renal artery with four views

5. Scan both sides of the chest for **pneumothorax**. It may be beneficial to switch to a small-parts, high frequency transducer, but the general purpose probe will often supply sufficient views of the pleural interface

The HIMAP Sequence

Probe Positioning for HIMAP

In conclusion, the RUSH exam provides a sequenced approach to ultrasound in the medical shock patient. Using the HI-MAP components, we can evaluate for the causes and potential responses to treatments of hypotension and tissue malperfusion. Hopefully, it will inspire the same alacrity to perform ultrasound in sick non-trauma patients as the FAST exam has in traumatic instability.

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