Ultrasonography Use in Resuscitation

Michael Herndon, DO, and Catherine Erickson, MD

Objectives
On completion of this lesson, you should be able to:

1. Explain how bedside ultrasonography can aid in the evaluation of a cardiac arrest patient.
2. Identify and treat cardiac tamponade.
3. Describe the important uses of bedside ultrasonography in the assessment of the undifferentiated hypotensive patient.

From the EM Model
19.0 Procedures and Skills Integral to the Practice of Emergency Medicine
19.5 Other Diagnostic and Therapeutic Procedures

Initial diagnosis and therapies in critically ill patients can be challenging. A hypotensive medical patient may need rapid administration of large quantities of crystalloid or have his condition potentially worsened by the infusion of fluids. A trauma patient might be assumed to be in hemorrhagic shock but could actually be suffering from an expanding tension pneumothorax or another obstructive process. In many of these situations, the use of bedside ultrasonography can aid in the diagnosis and guide therapeutic interventions.

From the focused assessment with sonography for trauma (FAST) examination to a rapid bedside echocardiogram, ultrasonography has become a vital tool for emergency physicians. Bedside ultrasonography allows the practitioner to monitor ongoing hemodynamic parameters and effectiveness of treatments and has been rapidly integrated into the care of emergency department patients over the past decade. Bedside point-of-care ultrasonography training is now fully included in the residency training of emergency physicians across the United States.¹ The American College of Emergency Physicians' guidelines have identified a new category of “resuscitative” ultrasonography and support its role in the care of critically ill patients. Numerous studies encourage the use of goal-directed ultrasonography and confirm its ability to inform a more accurate diagnosis and improve patient care plans. This lesson will focus on two areas in which resuscitative ultrasonography can have a significant impact—the evaluation and management of cardiac arrest patients and the diagnosis and treatment of patients with undifferentiated hypotension.

Case Presentations

Case One
A 58-year-old man with a past medical history of coronary artery disease presents by ambulance with acute onset of severe respiratory distress and hypotension. He told paramedics he had been having severe chest pain for the past three days. Continuous positive-pressure ventilation (CPAP) was started by paramedics. As the patient is wheeled into the emergency department, he becomes unresponsive. His blood pressure is 60/20.

Physical examination reveals a man in moderate distress, moaning with agonal respirations. His remaining vital signs are heart rate 120, respiratory rate 4, and pulse oximetry 85% on CPAP; a temperature was not obtained. His pupils are symmetric, his eyes open to voice, and he attempts to withdraw from pain. His neck is supple, and his neck veins are moderately distended. His pulmonary examination is unremarkable, and his central pulses are weakly palpable.

Further examination reveals a well-healed sternotomy scar, a nontender abdomen with present bowel sounds, no lower extremity edema, and skin that is cool and clammy to the touch. While intravenous access is being
established, the patient becomes apneic and has an undetectable oxygen saturation with an end-tidal carbon dioxide of 10. The monitor shows a narrow complex rhythm with a rate of 70, but the physician is unable to palpate a carotid pulse, and CPR is started immediately.

Case Two
A 68-year-old man presents after a witnessed syncopal event at a restaurant. The patient has a history of hypertension, hyperlipidemia, and mild heart failure that are well controlled. After eating dinner, the patient complained of abdominal pain and suddenly lost consciousness. When paramedics arrived, the patient was minimally responsive, and he was intubated.

Physical examination reveals an intubated patient with spontaneous respirations. Medics are assisting with bag-valve-mask ventilation. Vital signs are blood pressure 70/30, heart rate 110, respiratory rate 20, and pulse oximetry 95% on room air. His pupils are symmetric, although he does not open his eyes spontaneously, and he attempts to withdraw from pain. Breath sounds are symmetric and clear, and his distal pulses are weak. His abdomen is distended, and bowel sounds are present. There is 1+ pitting edema in his lower extremities, and his skin is cool to the touch.

Cardiac Arrest
Some of the most challenging cases in emergency medicine involve caring for patients with life-threatening cardiac conditions. Emergency physicians act as resuscitation specialists and are routinely called to the bedside of patients in septic shock, severe heart failure, or even pulseless electrical activity (PEA) arrest. Regardless of the disease process, the information that the clinician ascertains from a brief history and physical examination can be limited. Patients in shock have high mortality rates, and these rates are correlated to the amount and duration of hypotension. Diagnosis and initial care must be accurate and prompt to optimize patient outcomes.

In a medical cardiac arrest, a patient in asystole or PEA arrest will have a very poor prognosis if the etiology is not found and a perfusing rhythm is not restored promptly.

Focused transthoracic echocardiography is an ideal diagnostic tool for detecting life-threatening cardiac conditions in the emergency department. It allows the practitioner to obtain real-time information that would otherwise only be obtainable from invasive hemodynamic monitoring techniques. The dynamic nature of bedside ultrasonography to elucidate cardiopulmonary pathology is an excellent adjunct to static tests such as ECG, chest radiograph, and laboratory values.

In cardiac arrest with PEA, it is helpful to determine whether the patient has true electromechanical dissociation (EMD) with cardiac standstill or pseudo-EMD with mechanical contractions too weak to generate a palpable blood pressure. It has been reported that 85% of patients with PEA have mechanical cardiac contractions. Other studies have shown that the palpation of pulses in the resuscitation bay is both unreliable and difficult, making ultrasonography a more attractive option. Some patients thought to be in PEA arrest may actually have an organized rhythm with extreme hypotension and central pulses that are not detectable. Patients in PEA may suffer from a number of other life-threatening conditions such as a tension pneumothorax, cardiac tamponade, massive pulmonary embolism, or severe left ventricular failure following a myocardial infarction. Bedside ultrasonography can provide clues to the underlying etiology of cardiac arrest and direct distinct life-saving interventions.

CRITICAL DECISION
What is the best method for performing focused bedside echocardiography on a cardiac arrest patient?

To perform a focused bedside echocardiogram, the practitioner must first understand the various axes of the heart and probe orientation. The long axis of the heart is drawn from the right shoulder to the left hip, and the short axis is at 90° from the long axis. The orientation of the probe indicator for these axes will depend on whether the ultrasound machine is in the cardiac mode (screen indicator on the right) or the abdominal/pelvic mode (screen indicator on the left). Most ultrasound machines in emergency departments, by convention, will default to the abdominal/pelvic mode with the screen indicator on the left. Regardless of the indicator position, the sonographer can check...
orientation by sliding a finger under one end of the probe and visualizing the resulting anechoic stripe on the monitor. The practitioner may choose to view the heart in long axis with the left ventricle on the left side or right side of the screen.

The subxiphoid view is useful because it can be obtained while CPR and critical interventions are in progress. This view should be obtained with the patient supine and with the probe placed below the xiphoid, using the liver as an acoustic window. In patients with emphysema or asthma, the heart is pushed downward, and it is usually visualized more clearly with the subxiphoid approach. The probe should be aimed at the left shoulder and be held at a 15° angle to the chest wall. The probe indicator should be aimed at the patient’s right flank. The optimal time to perform this focused bedside echocardiogram is during interruptions in CPR when the team traditionally is checking for a pulse, changing compressors, and analyzing the rhythm on the monitor. Limitations occur if a patient is obese or has a distended abdomen. In the event that the heart cannot be viewed in the subxiphoid region, the clinician should quickly attempt visualization in the other cardiac windows.

The parasternal long and short-axis windows are ideal for evaluating the left atrium, left ventricular cavity, and aortic outflow tract. In patients with increased abdominal pressure, the heart is pushed upward into the chest, making this approach ideal in, for example, pregnant and obese patients and those with ascites. Remember that the parasternal long axis is roughly from the right shoulder to the left hip. The transducer should be placed in the third or fourth intercostal space (at the nipple line) immediately adjacent to the sternum with the probe indicator directed at the left hip. The following structures can be visualized on the monitor: right ventricular free wall, right ventricular cavity, interventricular septum, left ventricular cavity, posterior left ventricle, aortic outflow tract, mitral valve, and left atrium. The parasternal short-axis view will be less helpful in the cardiac arrest patient, but with regular echocardiography it is ideal for evaluating the overall “squeeze” or contractility of the left ventricle. This window is obtained by rotating the probe 90° from the long axis.

The apical four-chamber view is a coronal view of the heart in which the probe is placed at the apex and all four chambers of the heart can be visualized. Similar to the subxiphoid view, this window allows for excellent evaluation of global cardiac function, pericardial effusions, wall motion abnormalities, and chamber dilation. The physician may compare both right and left side function and size, as well as obtain a general sense of tricuspid and mitral valve problems if Doppler is used. During a standard bedside echocardiogram, it can help to have the patient turn on the left side in this probe position to bring the heart closer to the chest wall.

In cardiac arrest, bedside ultrasonography allows emergency physicians to gain valuable information. If true “cardiac standstill” or true EMD is noted during the pulse check, compressions can be restarted and the clinician can move towards finding other potentially treatable conditions. The practitioner can evaluate, with high accuracy, for a tension pneumothorax, pericardial tamponade, right-sided heart strain from a large pulmonary embolus, and hemoperitoneum from a ruptured abdominal aortic aneurysm. Numerous studies have validated the use of bedside ultrasonography in the evaluation of cardiac arrest.7,8

CRITICAL DECISION
How can cardiac tamponade be diagnosed and treated using bedside ultrasonography?

The rapid diagnosis and treatment of cardiac tamponade can be lifesaving. For tamponade to occur, there must first be a pericardial effusion, which is characterized by an anechoic fluid collection between the parietal and visceral pericardium. In the long-axis parasternal view, the descending aorta is used as a landmark to differentiate between pericardial and pleural fluid. The pericardium is superior to the descending aorta in this view. Free fluid adjacent to the descending aorta will be pleural fluid and not amenable to removal by pericardiocentesis. Small amounts of pericardial fluid may be physiologic, and the presence of a large effusion does not equate to cardiac tamponade in and of itself. In actuality, the rate of fluid accumulation within the pericardial sac is directly proportional to the rate of developing tamponade physiology. Emergent echocardiographic findings of cardiac tamponade include a pericardial effusion, right atrial collapse during ventricular systole, right ventricular collapse during diastole, and the lack of respiratory variation in the inferior vena cava (IVC) and hepatic veins.9 The traditional physical examination findings of cardiac tamponade (hypotension, jugular venous distention, and muffled heart sounds) are often difficult to appreciate (Video 1; apical four-chamber views of an echocardiogram demonstrating a pleural effusion and cardiac tamponade; http://www.acep.org/CDEM_2013_Lesson_23/).

If tamponade is suspected, the clinician can use bedside ultrasonography to evaluate the heart. The subxiphoid and apical four-chamber windows are the most useful in evaluating for tamponade. These views allow for visualization of the pericardial sac and the right side of the heart that will be the most affected by increasing external pressures from the filling pericardium.

The indications for emergent pericardiocentesis include the following: evidence of cardiac tamponade diagnosed by bedside ultrasonography; cardiac arrest with a pericardial effusion; and hypotension with rapid decompensation in a
patient with a large pericardial effusion. The two most common entry locations for pericardiocentesis are the subxiphoid and parasternal/apical approaches. The subxiphoid approach has long been the preferred method for blind pericardiocentesis. However, with the use of ultrasonography, the anterior thoracic or parasternal approach is considered the preferred route because of the often superficial location of the fluid and the lack of key structures in the path of the needle.

In the parasternal approach, the area of maximal fluid should be identified and usually is best appreciated somewhere between placement for the traditional parasternal long and apical windows. In the long-axis orientation and during real-time guidance, a 14- to 18-gauge angiocatheter may be inserted in the same longitudinal plane adjacent to the transducer. A larger catheter will be more readily visualized, and the path of the needle should be tracked in long axis until it is seen penetrating the pericardium.

Although it is important to continue high-quality CPR during cardiac arrest, it is inherently difficult to perform any procedure, whether it is endotracheal intubation, central line placement, or an ultrasound-guided pericardiocentesis, when CPR is in progress. The subxiphoid approach may be the preferred method during a resuscitation to minimize interruptions in compressions. Regardless of the procedure being performed, remember to protect the members of the team, plan ahead, and coordinate resuscitative measures.

**CRITICAL DECISION**

**What are the sonographic findings associated with the presence of a pneumothorax?**

Bedside ultrasonography is not only effective in detecting a hemotorax, but it is sensitive and specific for identifying a pneumothorax. It is reported that up to 76% of pneumothoraces are occult when interpreted by the trauma team. A limitation of the chest radiograph is that it is often performed with the patient supine, and, if a pneumothorax is present, the air usually lies anteriorly. Ultrasonography can be performed quickly prior to obtaining a portable chest radiograph. Pulmonary ultrasonography for detecting pneumothorax is based on the principle that air between the parietal and visceral pleura will obscure the normal artifacts seen in lung ultrasonography.

Respiration is associated with physiologic sliding of the two pleural surfaces. This pleural interface is seen as sliding on ultrasonography and is one sign that a pneumothorax is not present. This movement is best visualized at the lung bases and less so at the apices. There are two different modalities that ultrasound can use to further confirm physiologic lung sliding. One is the color power Doppler mode, which can enhance the depiction of sliding movement due to power Doppler’s ability to detect motion. The second modality is the use of M-mode imaging, which sends sound waves in quick succession. This allows you to see a quick video that displays movements of different structures. When lung sliding is present we see what is called the “seashore sign,” and when it is absent we see the “stratosphere sign,” which is representative of a pneumothorax.

Another normal sign is known as comet tail artifact or B-lines. These lines represent reverberation artifact that arise from physiologic water located under the visceral pleura. Comet tails can only be seen when the visceral and parietal pleura are in apposition. Under normal physiology, there are usually fewer than three comet tails that can be seen at any time. An abundance of B-lines represents a fluid overload state such as pulmonary edema.

A key finding that corresponds with a pneumothorax is the “lung point.” Lung point is seen when an area of normal lung and sliding appears during respiration when a pneumothorax is present. It represents the “edge” of the pneumothorax (Video 2; lung sonogram with the linear transducer showing lung point, where normal sliding is visualized adjacent to an area of pneumothorax; http://www.acep.org/CDEM_2013_Lesson_23/).

Additional sonographic findings of pneumothorax on the lung sonogram are A-lines. A-lines are horizontal, brightly echogenic lines seen below the pleural interface at a distance that replicates the interval between the skin and the pleural space and represents the horizontal reverberation artifact generated by the parietal pleura. A-lines can be a normal physiologic finding. However, if A-lines are visible in the absence of lung sliding and B-lines on chest ultrasonography, then the diagnosis of pneumothorax can be made. In a study of 200 consecutive undifferentiated ICU patients who went on to CT scanning, Lichenstein and coworkers were able to note absent lung sliding in all patients with occult pneumothoraces; 41 of 43 patients had an A-line sign. The absence of lung sliding alone had 100% sensitivity, but only 78% specificity for diagnosing an occult pneumothorax. When an A-line was seen with absent lung sliding, there was 95% sensitivity and 94% specificity for diagnosing an occult pneumothorax (Video 3; an area of abnormal sliding is seen here between two ribs with posterior acoustic shadowing. Only the horizontal A-lines can be seen; http://www.acep.org/CDEM_2013_Lesson_23/). A final sign of normal pulmonary physiology identified by ultrasound is the “lung pulse.” This pulsation represents the rhythmic movement of the viscera on the parietal pleura generated by each cardiac oscillation. If the pleura are not in apposition, as occurs in the presence of a pneumothorax, the lung pulse will be absent.

In 2012, the European Society of Intensive Care Medicine published
an international consensus report on evidence-based recommendations for point-of-care lung ultrasonography, confirming that the sonographic signs of pneumothorax include presence of lung point(s), absence of lung sliding, absence of B-lines, and the absence of a lung pulse. The paper identified that M-mode and color Doppler may be used as effective adjuncts to the diagnosis. In summary, the report recommends that lung ultrasonography be used when pneumothorax is part of a differential diagnosis and reports that lung ultrasonography more accurately rules out the diagnosis of pneumothorax than supine anterior chest radiography.

The Undifferentiated Hypotensive Patient

A patient with undifferentiated hypotension can present diagnostic and treatment challenges for emergency physicians. In a nontrauma patient, emergency physicians determine the cause of undifferentiated hypotension in only 24% of cases. Patient survival often depends on the physician's making a rapid diagnosis to direct specific therapy because sustained hypotension is the greatest predictor of adverse outcomes. A number of groups have recently developed protocols for undifferentiated hypotension, and all these protocols involve systematically evaluating the heart, vasculature, and lungs with bedside ultrasonography.

Classically, shock is categorized into four subtypes. The first is hypovolemic shock that generally results from traumatic and nontraumatic hemorrhage or extensive loss of body fluids. The second subtype is cardiogenic shock. As the name implies, this shock state is the result of left ventricular failure and the heart's inability to pump oxygenated blood to vital organs. The third major form of shock is distributive shock, which produces a state of massive vasodilation and relative core hypotension that is insufficient for end organ perfusion. The classic examples of this subtype are septic and neurogenic shock. The final subtype is obstructive shock. Examples include cardiac tamponade, tension pneumothorax, and massive pulmonary embolus. Each of these pathologic states will obstruct cardiac output.

In 2004, a study looked at incorporating a goal-directed ultrasonography protocol into the evaluation of undifferentiated hypotension. The authors found that those patients who underwent immediate ultrasound examinations had significantly fewer viable diagnoses at fifteen minutes, and more often the correct one, than those patients who had a delay in ultrasonography.

Many groups have subsequently established resuscitative protocols to include the use of bedside ultrasound. In 2001, Rose and colleagues described the combination of an abdominal evaluation, a qualitative cardiac assessment, and an abdominal aorta scan to assess for hemoperitoneum, pericardial effusion, and ruptured abdominal aortic aneurysm, respectively. Additionally, it has been suggested that a patient's intravascular volume can be assessed by evaluating the degree of respiratory collapse of the inferior vena cava and by a qualitative estimation of left ventricular function. Estimation of volume status will be discussed in further detail in a following section.

In 2010, Perera and colleagues developed the RUSH examination (Rapid Ultrasound in SHock). The protocol involves a 3-part bedside physiologic assessment simplified, as follows: the pump, the tank, and the pipes. The “pump” refers to a cardiac examination. The “tank” involves a look at the inferior vena cava, jugular veins, and an eFAST examination to look for any thoracoabdominal pathology. Finally, the “pipes” are the abdominal aorta with or without evaluation for deep venous thrombosis in the lower extremities. No matter which protocol is chosen, bedside sonography has proved valuable in the diagnosis and treatment of the critically ill hypotensive patient.

In the hypotensive patient, cardiac ultrasonography will provide clues as to how well the heart is functioning. Global left ventricular function can be qualitatively measured by estimating function to be normal, moderately depressed, or severely depressed. Additionally, ejection fraction can be characterized as poor, moderate, or normal depending on the change that occurs in left ventricular size between diastole and systole. Studies show that physician estimates are accurate after a brief training period (Video 4, parasemporal long axis of the heart shows depressed cardiac function. Note the poor contractility of the left ventricle and a mitral valve that does not meet the septum during diastole; http://www.acep.org/CDEM_2013_Lesson_23/). The American Society of Echocardiography and ACEP in 2010 defined the role of focused cardiac ultrasound (FOCUS) in patient care and treatment. This also includes estimating global function, ejection fraction, and central venous pressure.

CRITICAL DECISION
What are the key sonographic findings to look for when evaluating a patient for a possible ruptured abdominal aortic aneurysm?

An aneurysm is defined as a focal dilation in an artery of at least 50% more than the normal diameter. An enlargement of at least 3 cm of the abdominal aorta fits the definition of an aneurysm. Abdominal aortic aneurysm (AAA) is a relatively common disease in patients over 50 years of age. Rupture of an AAA has a high mortality rate, and patients are often asymptomatic until actual rupture occurs. Emergency physicians with limited training can diagnose AAA with a sensitivity and specificity approaching 100%. The risk of AAA rupture is directly related to the largest diameter of the aneurysm and...
An examination of the abdominal aorta should be performed in any patient with undifferentiated hypotension or a clinical presentation consistent with an AAA. For example, back pain in elderly patients, with or without hematuria, is a primary indication for a bedside aortic ultrasound. Most patients will be examined in the supine position, but the patient may be placed in the lateral decubitus position if excessive bowel gas is present. The curvilinear probe gives the largest footprint coupled with the best resolution of the retroperitoneal structures and is the transducer of choice. The entire length of the aorta from the epigastrium to the bifurcation must be examined in order to exclude a ruptured AAA.

The examination should start with the transducer in the transverse plane with the indicator to the right of the patient and the probe placed just caudal to the xiphoid process. With light compression, the examiner should be able to visualize the uppermost portion of the abdominal aorta, with the liver acting as an acoustic window. At this level, it is helpful to identify the spine posteriorly, which appears as a hyperechoic structure that casts a shadow. The aorta will be pulsatile, thick walled, and round. The IVC will also be visible adjacent to the aorta, but should be easily differentiated with its thin wall, respiratory variation, tear-drop shape, and compressibility. The probe is then moved inferiorly to visualize the next portion of the aorta. Branches such as the celiac trunk and superior mesenteric artery can be visualized, along with various branches of the venous or portal system. If, at any point, bowel gas begins to obscure images, the examiner can move the patient to the lateral decubitus position or use increased pressure to displace intestinal air. The distal, infrarenal, abdominal aorta is the most common site for an AAA. Care should be taken to sweep inferiorly to the bifurcation of the iliac arteries which occurs near the level of the umbilicus.

Correct measurement of the anterior-posterior outer wall to outer wall of the aorta is important. A common pitfall is to measure only the inner lumen of the vessel which could give a false negative result. The abdominal aorta should also be viewed in the longitudinal axis (probe indicator pointing cephalad), but all measurements should be made in the short-axis orientation.

When an AAA is identified, an intraluminal thrombus, formed when laminar flow rates decrease and blood stagnates, may also be seen. It is also possible to see hemoperitoneum on the FAST examination if rupture into the peritoneal cavity has occurred; however, this is not likely given the retroperitoneal location of the aorta. Other less common findings include contained aortic rupture, hydronephrosis, acute abdominal aortic dissection, and aortovenous fistula. If an AAA is found on bedside ultrasound in a stable patient, a CT scan with intravenous contrast should be performed to further characterize the lesion and look for leakage. Hypotensive patients with sonographic evidence of an AAA should be considered to have an acute rupture, and emergent operative intervention must be arranged.

### Critical Decision

**How can bedside ultrasonography be used to evaluate volume status?**

Traditionally, the measurement of intravascular blood volume and responsiveness to fluids was dependent on the measurement of central venous pressure (CVP). Recent literature shows that there is a poor relationship between CVP and blood volume, and that the change in CVP is not predictive of hemodynamic response to a fluid challenge. An estimate of the intravascular volume can be determined noninvasively by visualizing collapse of the IVC. The sonographer should look at the absolute diameter of the IVC and the degree of collapse with respiration to qualitatively estimate the CVP. As previously stated, a limited cardiac ultrasound to evaluate left ventricular size and function should be part of the volume assessment.

The IVC is a thin-walled, compliant vessel that changes in diameter in response to intravascular fluid status. Normally, the IVC expands and contracts during respiration. The diameter will decrease during inspiration, when negative pressure is created in the thoracic cavity, and then expand during exhalation. This phenomenon is called respiratory variation and can be represented as the caval index. The caval index is a measurement of the percentage of the collapse of the IVC. The caval index is calculated by dividing the IVC expiratory diameter by the IVC inspiratory diameter and multiplying this by 100. A caval index closer to 100% is indicative of increased collapse and relative volume depletion. An index that is closer to 0% is therefore representative.
of minimal collapse and a state of volume overload. With intravascular volume depletion, the diameter of the IVC will likely be decreased and the percentage collapse will be greater than 50%.\(^\text{28}\) In volume-overloaded states, the IVC will be plethoric with a large diameter and minimal collapse on inspiration.

Most patients will be fluid responsive if the IVC collapse is greater than 50%. After fluid resuscitation, repeat imaging of the IVC can demonstrate whether additional volume should be given. An important exception to this rule is the presence of a plethoric IVC in a patient with cardiac tamponade. In this situation, the patient may be normovolemic or even hypovolemic despite a suggestion of volume overload by IVC ultrasonography. A plethoric IVC can also be visualized during heart failure. This pitfall highlights the importance of performing a bedside echocardiogram in conjunction with IVC measurements.\(^\text{29}\)

To perform a scan of the IVC, the patient should be in the supine position. The sonographer may choose to do this immediately following a focused echocardiogram. The phased array and curvilinear probes should be used. The transducer is placed longitudinally just right of midline in the subxiphoid region and oriented with the indicator directed cephalad. At this point, the IVC will be visualized in the longitudinal plane as it enters the right atrium. On the screen, the edge of the right atrium and adjacent IVC will be visualized. The diameter of the IVC should be measured 2 to 3 cm from where it enters the right atrium. This will also be about 1 cm away from where the hepatic vein empties into the IVC. In 2D mode, the caval index can be grossly measured. Alternatively, the IVC diameter can be measured using the M-mode setting. The M-mode beam should be placed at the smallest and largest locations, respectively (Video 5; the IVC is visualized during respiration and does not collapse more than 50% during respiration. This patient is on the spectrum of volume overload and would be unlikely to respond to intravenous fluids; [http://www.acep.org/CDEM_2013_Lesson_23/](http://www.acep.org/CDEM_2013_Lesson_23/)).

In summary, evaluation of fluid status should be thought of as an extension of the cardiac examination and be used to guide fluid therapy. Including IVC measurements can help to estimate central venous pressure and volume status in critically ill patients.

### Case Resolutions

#### Case One

In the case of the unresponsive patient with severe hypotension, the team continued to perform high-quality CPR and advanced cardiovascular life support measures. The patient received a dose of epinephrine and vasopressin, but PEA persisted. While CPR was held for a pulse check, the emergency physician placed the ultrasound transducer in the subxiphoid region to evaluate the heart. On the monitor, a large thick anechoic strip of fluid was seen surrounding the heart. The right ventricular free wall appeared to be bowed in during diastole, and the right atrium contracted during systole. Using ultrasonography in the parasternal long approach, the emergency physician performed an emergent pericardiocentesis, leaving a 14-gauge angiocatheter sheath in place for drainage. The patient

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**Pearls**

- Focused bedside echocardiography has proved helpful in the resuscitation of patients in PEA. Most PEA patients (85%) have mechanical cardiac contractions on echocardiography examination, making successful resuscitation possible if a reversible cause can be identified in a timely manner.
- The presence of a lung point on thoracic ultrasonography is pathognomonic for a pneumothorax.
- Emergency physicians can narrow the differential diagnosis for undifferentiated hypotension with the use of bedside ultrasonography by performing focused pulmonary, cardiac, and abdominal sonographic examinations.
- Intravascular volume can be estimated by evaluating the dynamic changes of the IVC using bedside ultrasonography.

**Pitfalls**

- Failing to use bedside ultrasonography in a cardiac arrest patient to evaluate for reversible causes.
- Using palpation of the femoral pulses rather than echocardiography to determine cardiac contraction during resuscitation.
- If there is a high degree of suspicion for intraabdominal injury, relying on bedside ultrasonography to exclude disease.
- Failing to measure the outer lumen of the aorta, this can yield a false-negative result.
- Failing to perform bedside echocardiography when evaluating the IVC to assess fluid status.
vascular access.

a vascular ultrasound, either for a pulmonary evaluation, and finally, an assessment for abdominal free fluid. Resuscitations include performing a focused bedside echocardiogram, in resuscitations. Key studies to focus on department in traumatic and medical conditions. An article of interest is the discussion on how to use bedside ultrasound in trauma patients.

Summary

Bedside ultrasonography is widely used in the emergency department in traumatic and medical resuscitations. Key studies to focus on in resuscitations include performing a focused bedside echocardiogram, an assessment for abdominal free fluid or aortic dilation and rupture, a pulmonary evaluation, and finally, a vascular ultrasound, either for assessing volume status or obtaining vascular access.

References


Case Two

In the case of the 68-year-old man who presented with syncope and undifferentiated hypotension, bedside ultrasonography was performed as part of his secondary survey. Examination of his heart revealed a slightly hyperdynamic function despite the patient’s history of heart failure. There was no pericardial effusion, and his right heart did not appear dilated. His IVC was evaluated and appeared to be more than 50% collapsed. Next, pulmonary ultrasonography was quickly performed and showed no pneumothorax or concern for fluid overload. This was followed by a FAST examination that revealed a small strip of fluid in the hepatorenal space (Morison pouch). On evaluation of the abdominal aorta, ultrasonography showed a large fusiform infrarenal aortic aneurysm (>7.5 cm) with associated intramural thrombus. Vascular surgery was consulted, and the patient was transferred to the operating room. He experienced cardiac arrest during surgery and died despite aggressive resuscitation efforts.

Summary

Bedside ultrasonography is widely used in the emergency department in traumatic and medical resuscitations. Key studies to focus on in resuscitations include performing a focused bedside echocardiogram, an assessment for abdominal free fluid or aortic dilation and rupture, a pulmonary evaluation, and finally, a vascular ultrasound, either for assessing volume status or obtaining vascular access.