AMERICAN COLLEGE of CARDIOLOGY

Point of Care Ultrasound: An Overview

Oct 31, 2017 | Sofia Melgarejo; Andrew Schaub, DO; Vicki E Noble

Expert Analysis

Introduction

With the ever-changing landscape of health care delivery in the United States, a greater proportion of patients are receiving their initial care and diagnostic testing in emergency departments (EDs). With this change, significant efforts have been made to improve the speed and accuracy of diagnostic testing, particularly by using point-of-care testing, to minimize the delay between onset of symptoms and initiation of definitive therapy. Expediting triage and time to diagnosis are crucial to decreasing morbidity and mortality in critically ill patients.[1] Point-of-care testing has been shown to achieve these goals, leading to improved operational efficiency and, ultimately, better patient outcomes.[2] Point-of-care ultrasound (PoCUS) in the ED is one of the point-of-care testing tools available to the emergency physician. It answers specific clinical questions that narrow differentials, guide clinical therapy, and direct consultations and disposition. This review is meant to highlight major clinical scenarios in which PoCUS can be used as a rapid, reliable, diagnostic tool. This list of scenarios is just an overview; there are many additional situations in which PoCUS can be crucial, but the presentations are often less acute (for example, musculoskeletal complaints, procedural guidance, and pregnancy evaluation).

Undifferentiated Shock

Broadly defined, shock is a state of tissue hypoxia due to reduced oxygen delivery, increased oxygen consumption, or inadequate oxygen utilization and most commonly occurs as a result of circulatory failure, resulting in hypotension. Identifying the cause of shock and rapidly intervening in patients experiencing it is

an essential step in improving patient outcomes. PoCUS in the undifferentiated shock patient allows for rapid and accurate differentiation between the major shock types: distributive (i.e., septic), cardiogenic, hypovolemic (i.e., bleeding or other volume loss), and obstructive. There are several scan protocols that standardize this assessment, and most involve ultrasound imaging of the heart, the lungs, the vena cava, and a focused assessment of the abdomen to look for free fluid. Previous research on the use of PoCUS in the undifferentiated hypotensive patient presenting to the ED showed that despite taking only a short period of time (average of 6 minutes), the use of PoCUS led clinicians to significantly narrow their differential diagnosis and increase overall diagnostic precision.[3] The sonographic footprint for each type of shock guides resuscitation efforts and interventions (see Table 1), such as fluid versus vasopressor support and therapeutic procedural interventions (for example, pericardiocentesis and laparotomy).

Table 1

	Distributive	**Cardiogenic**	**Hypovolemic**	**Obstructive**
Cardiac Findings	Spectrum from hyperdynamic to decreased left ventricular function	Decreased left ventricular function	Hyperdynamic	Dilated right ventricle or pericardial effusion
Inferior Vena Cava Findings	Range from collapsible to dilated	Non-collapsible	Collapsible	Non-collapsible
Lung Findings	Negative	B lines present	Negative	Focal or Negative
Abdominal Findings	Negative	Negative	Evaluate for hemorrhage	Negative

Cardiac Arrest

Despite the most recent international consensus on advanced cardiac life support conclusion that "there is insufficient evidence to support or refute the routine use of ultrasound or echocardiography to guide cardiac arrest resuscitation,"[4] PoCUS has become a common prognostic and diagnostic tool during cardiac resuscitation, particularly when combined with rhythm strip data. In patients with pulseless electrical activity (PEA) in particular, PoCUS can prove immensely helpful in revealing anatomic causes of PEA such as tension pneumothorax (see Video 1), cardiac tamponade, and pulmonary embolism. Presence of increased right ventricular strain, new tricuspid regurgitation, pericardial effusion, or absence of lung sliding can point in the direction of a reversible cause of PEA, thus rapidly directing the emergency physician to perform tube thoracostomy, pericardiocentesis, or thrombolysis, for example.

Video 1: Lung Point

The point where the visceral pleura separates from the parietal pleura is called the lung point. The lung sliding or shimmering is where the two pleura are still opposed; the static parietal pleura

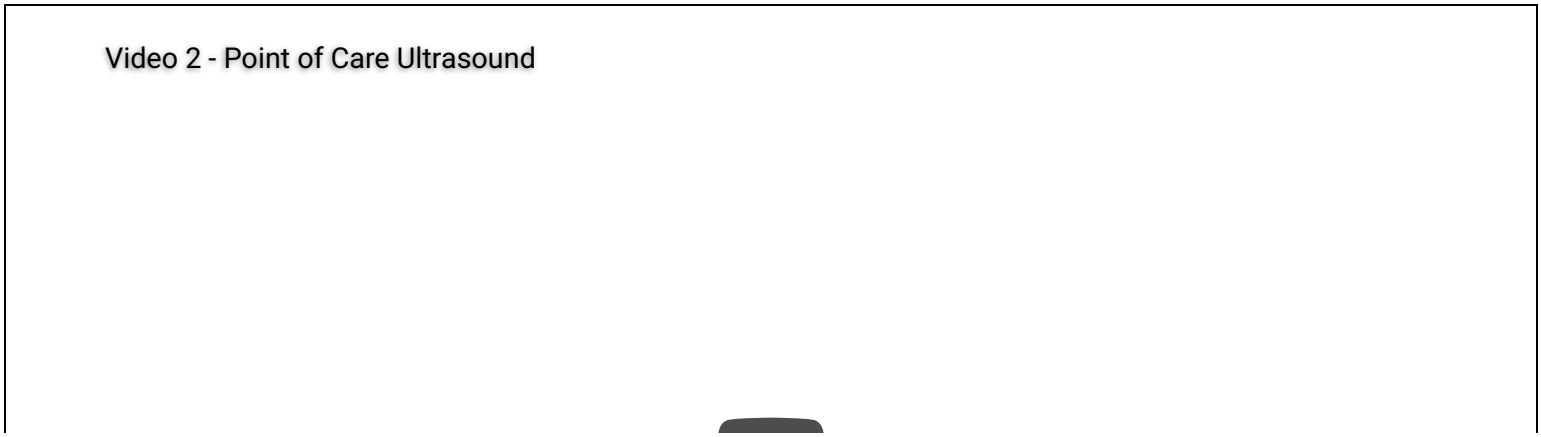
line is where there is air separating the two.

Additional use of PoCUS during cardiac arrest relates primarily to prognosis. Numerous articles have demonstrated that the absence of any organized systolic contractions after three rounds of advanced cardiac life support medications suggests a minimal likelihood of return of spontaneous circulation.[5-7] Such intra-arrest knowledge can help guide the resuscitation timeline and direct resource utilization appropriately away from heroic measures. Moreover, it can provide some comfort to family and loved ones knowing that there are truly no signs of life, thus facilitating an appropriate withdrawal of care.

Trauma

The role of PoCUS for trauma patients has been a topic of considerable change and debate over the last 30 years. Using ultrasound as a diagnostic tool for traumatic abdominal/thoracic injuries started in Europe and spread to North America in the 1990s.[8] Currently, ultrasound in trauma is primarily used for detection of intraperitoneal hemorrhage, pericardial tamponade, and hemothorax/pneumothorax. This constellation of applications is commonly referred to as the "extended focused assessment with sonography for trauma" (FAST).[9] The most basic six-view trauma ultrasound exam includes the hepatorenal space ("Morrison's pouch"), perisplenic space, subcostal space, pelvis, and views of each hemi-thorax (see Videos 2-5; these images are the footprint of a negative FAST). Although abdominal ultrasound views are often unable to isolate the source bleed, such diagnostic information can expedite trauma patients to the operating room for exploratory laparotomy when they are hemodynamically unstable.[10-13]

Video 2: The Standard FAST Views: Right Upper Quadrant



Video 3: The Standard FAST Views: Left Upper Quadrant

Video 3 - Point of Care Ultrasound

Video 4: The Standard FAST Views: The Pelvis

Video 4 - Point of Care Ultrasound

Video 5: The Standard FAST Views: Abdominal Spine and Diaphragm Coming Together at a Point (Indicating the Chest Is Full of Air and Not Fluid)

The introduction of ultrasound into the standard trauma algorithm work-up has allowed for a more accelerated, definitive surgical approach and, in the right clinical context, a process designed to forgo computed tomography scans.

Chest Pain

Although acute coronary syndrome is a "must not miss" diagnosis, the initial evaluation of chest pain in the ED includes alternative diagnoses such as aortic dissection, pulmonary embolism, pericardial effusion, and several primary pulmonary processes.[14,15] PoCUS can be used to improve diagnostic specificity in such settings. A focused ultrasound of the symptomatic patient with chest pain can address focused questions such as the following:

- Is there pericardial fluid?
- Is there a discrepancy in right versus left chamber size?
- Are there signs of global cardiac dysfunction?
- Is there an absence of pleural sliding?
- Is the aortic root dilated? Or is there a flap seen in the aortic root?

Studies have shown a high degree of sensitivity and specificity in the detection of pericardial effusions in medical and trauma patients using PoCUS.[16,17] Multiple sonographic signs suggesting cardiac tamponade have been described, but the most sensitive of these findings is the presence of a circumferential pericardial effusion with a hyperdynamic heart and "scalloping" of the right ventricle (i.e., diastolic collapse of the right ventricle).[18]

Dyspnea

The primary question confronting the emergency physician when a patient presents with shortness of breath is whether the etiology is primarily cardiac or pulmonary. PoCUS is a great tool for making this distinction. The range of pulmonary findings on PoCUS includes the following:

- A-lines or horizontally oriented reverberation artifacts
- B-lines or vertically oriented bright lines extending to the sonographic window edge, which indicate loss of normal alveolar aeration (often secondary to pulmonary edema, infection, or contusion) (see Video 6)
- Consolidation: the hepatization of lung tissue as it starts to collapse secondary to decreased aeration (see Video 7)
- Pleural line abnormalities: a thin, homogenous pleural line (normal or hydrostatic pressure) versus a thick, irregular pleural line (inflammatory and/or infectious process)
- Pleural sliding: Its presence indicates opposition of visceral and parietal pleura, whereas its absence indicates pleural non-adherence (such as seen with a

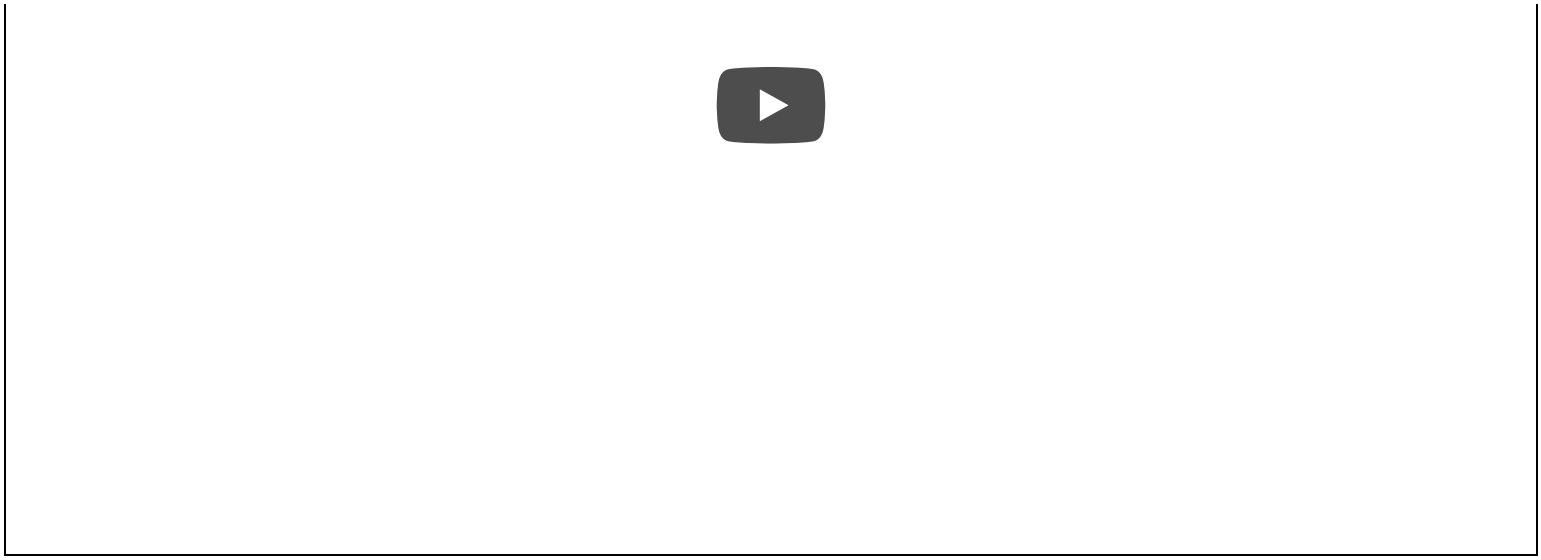
pneumothorax)
- Pleural fluid: anechoic, clear fluid (transudative process) versus hypoechoic, debris-filled fluid (exudative process)

Different etiologies of shortness of breath have different sonographic footprints. The presence or absence of the above-mentioned findings on ultrasound aid providers in making quick, often life-saving, clinical decisions at the bedside.

Video 6: B Lines

Using the abdominal probe with the depth set to 18 cm, the vertical laser-like bright lines that move back and forth with the pleura with respiration indicate the presence of interstitial edema.

Video 7: Consolidation



The tissue density seen here is the hepatized lung, or the collapse of the aerated lung around the bright air-filled bronchioles.

Abdominal Pain

PoCUS has been described as the "third hand of emergency physicians and surgeons."[19] Ill-appearing patients with abdominal pain require immediate evaluation, particularly if they are elderly, because mortality rates in this population can be as high as 14%.[20] The "acute abdomen" in the emergent patient is a challenging diagnosis due to the wide differential the emergency physician must consider, which in turn causes a considerable amount of difficulty with regard to prompt initiation of treatment.

Fortunately, among the numerous pathologies that present as abdominal pain, many are amenable to PoCUS evaluation. Acute renal colic should demonstrate unilateral hydronephrosis and, on occasion, an obstructing stone at the ureterovesicular junction or within the urinary bladder.[21] Cholelithiasis is characterized by the presence of rounded, acoustically enhanced structures with distal shadowing artifacts; presence of common bile duct dilatation (diameter >6 mm) indicates biliary obstruction. Acute cholecystitis will show gallbladder wall thickening and pericholecystic fluid.[22] An abdominal aortic aneurysm can be identified on ultrasound with a rapid longitudinal evaluation of the abdominal aorta, looking for a diameter measuring >3 cm.[23] Finally, an acute intestinal obstruction can be diagnosed by identifying multiple loops of bowel measuring >3 cm in diameter when performing an abdominal sweep (see Video 8). The severity of the obstruction can be further categorized by determining the presence or absence of peristalsis, extra-luminal fluid, bowel wall thickening, and luminal air.[24]

Video 8

Small bowel obstructions show fluid-filled bowel loops greater than 3 cm in diameter with back-and-forth peristalsis.

Conclusion

PoCUS has been a practice-changing technology for the care of the emergent and critically ill patient. The ability to look inside the human body in real time without the risk of radiation helps physicians narrow the differential diagnoses early on in a patient's evaluation and helps guide decisions regarding further testing (if any is indicated). Furthermore, findings seen on PoCUS engage consultants early on in workup, ultimately improving initial diagnostic accuracy, initiation of proper management, and thus overall patient care. As the technology becomes more accessible, we can expect it to diffuse throughout the broader institution of medicine.

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Clinical Topics: **Acute Coronary Syndromes, Arrhythmias and Clinical EP, Cardiac Surgery, Heart Failure and Cardiomyopathies, Invasive Cardiovascular Angiography and Intervention, Noninvasive Imaging, Pericardial Disease, Vascular Medicine, Implantable Devices, SCD/Ventricular Arrhythmias, Aortic Surgery, Cardiac Surgery and Arrhythmias, Cardiac Surgery and Heart Failure,**

Acute Heart Failure, Interventions and ACS, Interventions and Imaging, Interventions and Structural Heart Disease, Interventions and Vascular Medicine, Echocardiography/Ultrasound

Keywords: *Diagnostic Imaging, Abdomen, Abdomen, Acute, Abdominal Pain, Acute Coronary Syndrome, Advanced Cardiac Life Support, Algorithms, Aorta, Abdominal, Aortic Aneurysm, Abdominal, Cardiac Tamponade, Chest Pain, Cholecystitis, Acute, Cholelithiasis, Cholestasis, Colonic Pouches, Common Bile Duct, Contusions, Critical Illness, Diagnosis, Differential, Diaphragm, Dilatation, Dyspnea, Edema, Echocardiography, Emergency Service, Hospital, Heart Arrest, Heart Ventricles, Hemothorax, Hydronephrosis, Hydrostatic Pressure, Hypotension, Hypovolemia, Intestinal Obstruction, Laparotomy, Operating Rooms, Oxygen, Oxygen Consumption, Pelvis, Pericardial Effusion, Pericardiocentesis, Peristalsis, Pleura, Pneumothorax, Point-of-Care Systems, Point-of-Care Systems, Pregnancy, Prognosis, Pulmonary Edema, Pulmonary Embolism, Referral and Consultation, Renal Colic, Shock, Surgeons, Thoracic Injuries, Thoracostomy, Thorax, Tomography, Triage, Tricuspid Valve Insufficiency, Ultrasonography, Urinary Bladder*