Emergency Ultrasound: Point-of-care Ultrasound in Emergency Medicine

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INTRODUCTION & DEFINITIONS

Ultrasound is a safe and effective form of imaging that utilizes sound waves to examine internal human anatomy for diagnostic purposes and procedure guidance. With the advent of smaller, high quality machines in the 1990s there has been a growth of point-of-care ultrasound – ultrasound that is performed and interpreted by a provider at the patient's bedside in real time – in many medical specialties.[1,2] Many terms in the medical literature are used to describe this unique application of ultrasound (US); these include "bedside," "limited," "focused," and "goal-directed." The favored terminology is clinician-performed *point-of-care ultrasound* often abbreviated as POCUS.

Point-of-care ultrasound has been a part of the specialty of emergency medicine for two decades and is referred to within the specialty as Emergency Ultrasound (EUS). Emergency physicians are confronted with critically ill patients with undifferentiated complaints and must make time-sensitive diagnostic decisions or perform therapeutic interventions based on limited available information. Ultrasound can be performed directly at the time of the physical examination in a matter of minutes and can help to greatly reduce the number active differential diagnoses. These ultrasound examinations are integrated into Emergency Medicine diagnostic and treatment pathways at the point-of-care and seek to answer a specific clinical question. In this manner emergency physician-performed point-of-care ultrasound refines and accelerates bedside diagnosis, clinical decision-making, management, and disposition by providing limited, but directly relevant, clinical information.

History

Since its inception decades ago, EUS has developed into an essential component of emergency medicine practice. EUS competency is a core content requirement for all emergency medicine residents and part of the American Board of Emergency Medicine written and oral board examinations. EUS fellowships provide advanced training and are prevalent throughout the country with over 90 national programs.[3] Comprehensive specialty-specific guidelines for emergency ultrasound were first published over ten years ago by the American College of Emergency Physicians.[4]

Rationale

The emergency department provides a unique physical and clinical environment in which to apply point-of-care ultrasound. Variable ED volume and flow, critically ill patients, and patients with undifferentiated complaints all present unique challenges.

Because of this diversity of illness and illness severity, emergency ultrasound is conceptually divided into five functional categories: Resuscitative (e.g. acute cardiopulmonary resuscitation), Diagnostic (any emergent diagnostic capacity), Symptom/Sign-based (e.g. undifferentiated shock, dyspnea, chest pain), Procedure Guidance (e.g. central venous access, nerve block, peripheral IV, pericardiocentesis) and Monitoring (e.g. inferior vena cava measurements for volume resuscitation). Within each category Emergency Ultrasound can provide rapid assessment at the bedside.

Two brief clinical scenarios reflect challenges present in emergency medicine and highlight the rationale and categories outlined above. In the first clinical scenario, a patient with undifferentiated hypotension (e.g., an elderly patient found down at the side of road with loss of consciousness, mild back pain, but without obvious trauma) has bedside point-of-care cardiac, inferior vena cava, E-FAST (see below), and aorta exams which indicate hypovolemic or distributive shock (not obstructive or cardiogenic) and reveal the presence of a large abdominal aortic aneurysm (AAA). During the initial resuscitation, AAA is the presumed etiology of the patient's hemodynamic instability until proven otherwise, while several other etiologies are lower on the differential diagnosis. This case exemplifies a sign or symptom-based approach to undifferentiated hypotension, the utility of which is well described in the emergency medicine literature (**Table 1**).[5,6]

In a second clinical scenario, a patient with history and exam findings consistent with acute cholecystitis has a bedside point-of-care ultrasound which demonstrates

Table 1. Use of Ultrasound in Undifferentiated Hypotension

	Ultrasound Examination	
Etiology of Shock	**Inferior Vena Cava Findings**	**Cardiac Findings**
Hemorrhagic/ Distributive	Collapsing	Normal to hyperdynamic ejection fraction*
Cardiogenic	Non-collapsing	Decreased ejection fraction
Obstructive	Non-collapsing	Pericardial effusion, right heart strain

* May be decreased in late stage septic cardiomyopathy

gallstones and gallbladder wall thickening. The focused biliary ultrasound confirms the clinical suspicion as well as the diagnosis. A comprehensive right upper quadrant ultrasound performed by a radiology technician in the radiology suite, and interpreted by the radiologist, may include evaluation of the liver parenchyma, measurement of gallbladder width, measurement of intra-hepatic ducts, and often renal evaluation. This additional information may not be immediately relevant in the above mentioned clinical scenario. In the emergency department this is an example of emergency ultrasound as a functionally diagnostic exam. Diagnostic point-of-care ultrasound has also been shown to improve patient flow through the department, a valuable feature for any busy hospital center.[7] In both cases the treating emergency physician correlates the EUS imaging results with the patient's clinical picture within minutes of the patient encounter. If they do not correlate then alternate diagnoses and additional diagnostic studies will be indicated.

While EUS can be an invaluable tool for the emergency physician, it is nevertheless a user-dependent technology requiring technical expertise, image acquisition and interpretation, as well as clinical correlation in real-time at the patient's bedside. As with all such procedures and practices, it is imperative that the caring provider complete training, maintain skills, and understand its specific applications, strengths, and limitation

Specific Core Applications

Selected specific applications from **Table 2** will be discussed here briefly. Relevant clinical application, ultrasound findings, and limitations will be highlighted. Discussion of the technical performance of these exams is beyond the scope of this article.

Trauma

The Extended Focused Assessment with Sonography in Trauma (E-FAST) is an essential tool of the management of unstable trauma patients. The E-FAST evaluates the patient for pneumothorax, hemothorax, free intra-abdominal as well as pericardial fluid (***Image 1, Image 2***). When positive, this exam may dictate management; it has been shown to reduce mortality and time to operative care in critically ill patients.[8,9] It is imperative to understand the limitations of the FAST exam. It is designed to detect free fluid but does not differentiate blood from ascites or urine. Clinical correlation is necessary, especially in cases of patients with liver disease or pelvic trauma. In addition, the test characteristics of the exam are such that it may not detect amounts of free fluid less than 500 milliliters.[10] If clinical suspicion is high in the unstable patient, serial FAST exams have been shown to increase sensitivity. Fortunately, the FAST exam is most accurate in patients with hypotension where the rapid bedside information is most essential.[11] Lung ultrasound, the "Extended" component of the E-FAST, accurately detects traumatic pneumothorax and hemothorax (***Image 3***).[12,13]

Table 2. Emergency Ultrasound Modalities and their Core Applications

Examination	Selected Clinical Scenarios
E-FAST	Trauma (blunt & penetrating)
Biliary	Right upper quadrant abdominal pain
Pelvic	Suspected ectopic, intrauterine pregnancy
Cardiac	Shock, dyspnea, arrest
Abdominal Aortic Aneurysm	Shock, back pain, abdominal pain
Deep Venous Thrombosis	Suspected deep venous thrombosis
Bladder/Renal	Renal colic
Soft Tissue/Musculoskeletal	Abscess, joint effusion, dislocation
Pulmonary	Dyspnea, shock
Ocular	Retinal detachment
Monitoring	Shock
Procedural	(See Table 3)

E-FAST = Extended Focused Assessment with Sonography in Trauma

Image 1.

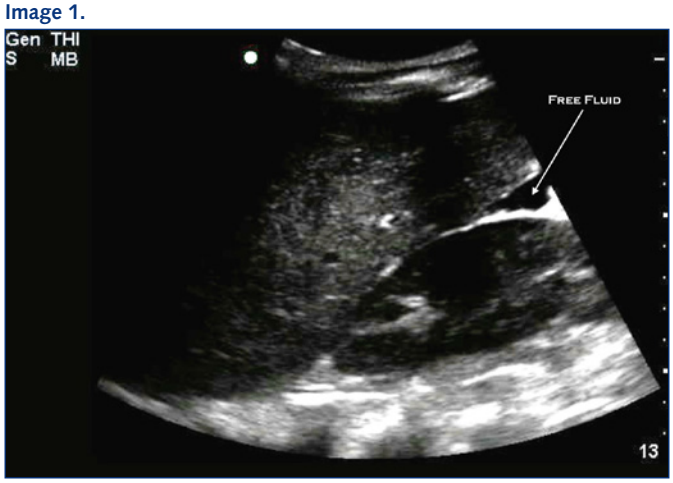
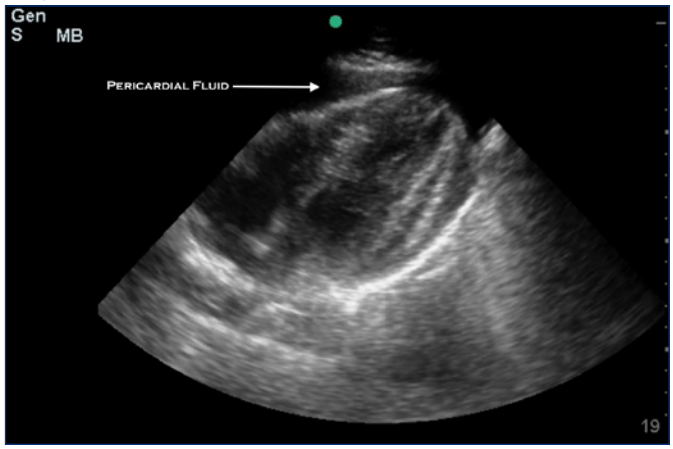


Image 2.



It is of greatest utility in unstable patients where chest radiography is indeterminate and CT imaging is not feasible. Ultimately the E-FAST can accelerate and optimize the emergency physician's care of critically ill trauma patients (e.g., tube thoracostomy, hospital transfer, laparotomy) and save lives by augmenting limited initial information.

Image 3.

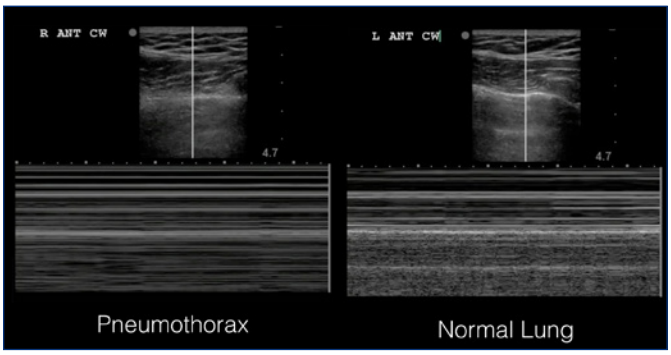


Image 4.

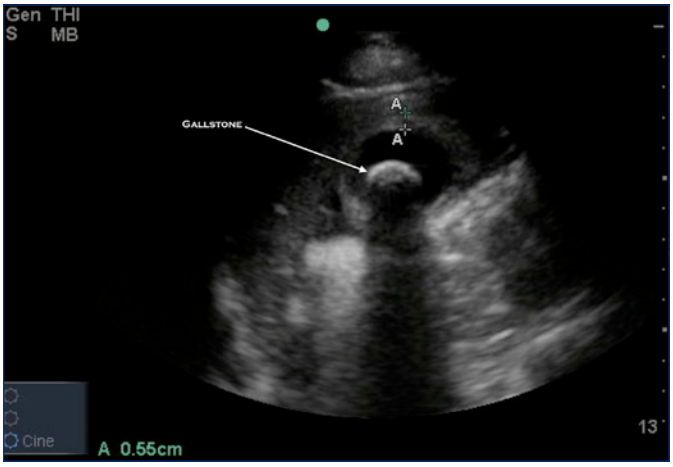
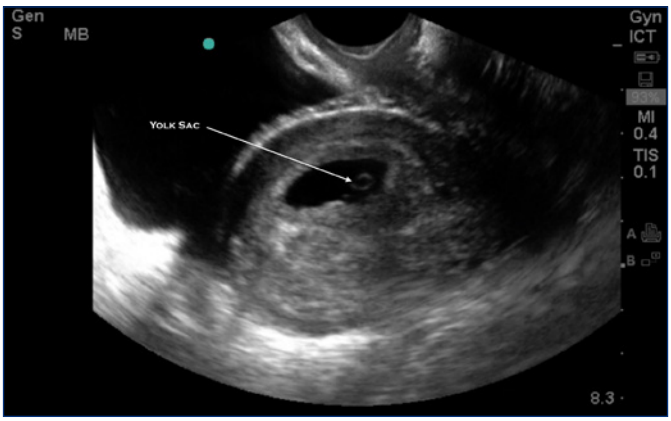


Image 5.



Gallbladder

The gallbladder exam, unlike the E-FAST, is rarely indicated in resuscitation but is particularly useful as a diagnostic exam in patients with suspected cholelithiasis or cholecystitis. The limited gallbladder exam includes evaluation for gallstones, gallbladder wall width, pericholecystic fluid, sonographic Murphy's sign and common bile duct width (***Image 4***). Several features of a comprehensive right upper quadrant ultrasound are omitted from the limited exam (e.g., gallbladder body width, liver parenchyma, intra-hepatic biliary tract). However, in coordination with a clinical evaluation, the limited right upper quadrant exam is well suited to diagnose cholelithiasis and acute cholecystitis.[14] The limited exam can also help determine which subsequent imaging modalities might be required (e.g. abdominal CT, comprehensive right upper quadrant US, or renal ultrasound) especially in the context of a normal point-of-care exam.

Pelvic

Pelvic ultrasound for intrauterine pregnancy (IUP) is used primarily in cases where ectopic pregnancy is suspected. Definitive IUP on limited pelvic ultrasound examination is defined as the presence of a yolk sac, fetal pole, or embryo (***Image 5***). In the unstable patient without definitive IUP the patient is presumed to have an ectopic pregnancy until proven otherwise.[15] The FAST exam, specifically the evaluation of Morrison's pouch in the right upper quadrant, is indicated in this scenario as the presence of free fluid predicts the need for operative management.[16] In the unstable patient with definitive IUP alternate etiologies should be sought for clinical presentation. Naturally, physicians must correlate with historical features (e.g. *In-vitro* fertilization) to determine if comprehensive pelvic ultrasound is indicated for detection of heterotopic pregnancy. In stable patients, point-of-care pelvic ultrasound is used to confirm IUP and to calculate fetal heart rate.

Cardiac

Focused cardiac ultrasound (FOCUS) is used for the rapid assessment of critically ill patients and includes assessment for pericardial effusion, global cardiac systolic function, right and left ventricular enlargement, and intravascular volume.[17] It is used in a variety of diagnostic and symptom and sign-based clinical presentations including undifferentiated hypotension, dyspnea, chest pain, suspected pericardial effusion, trauma and cardiopulmonary arrest. While FOCUS is an integral part of the initial time-sensitive evaluation and management of a critically ill patient, it does not replace the need for a comprehensive echocardiographic evaluation as indicated by the patient's presentation, physical exam findings, or initial diagnostic work-up.

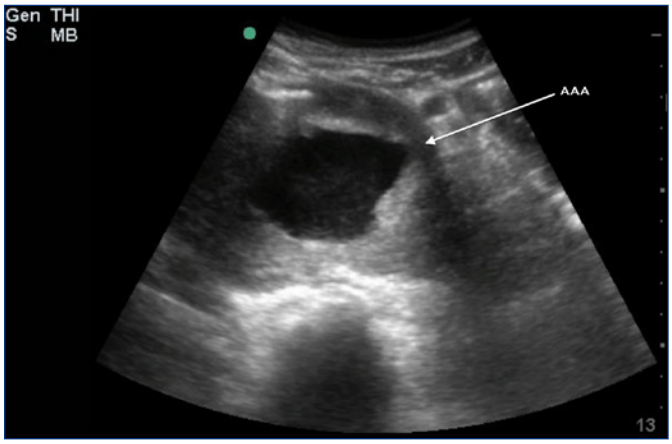
Aorta

Emergency ultrasound accurately detects abdominal aortic aneurysm.[18] Rapid diagnosis of abdominal aortic aneurysm can save lives by shortening time to definitive management (***Image 6***). When the abdominal aorta is normal, alternate diagnoses must be considered based on the patient's chief complaint (e.g. new non-traumatic back pain) or clinical presentation. Ultrasound as a modality does not reliably detect whether or not there is *rupture* of the abdominal aorta, so correlation with the entire clinical picture is essential, and additional imaging is sought if the patient is stable.

Pulmonary

In addition to detection of traumatic pneumothorax and hemothorax (discussed in the E-FAST section), point-of-care

Image 6.



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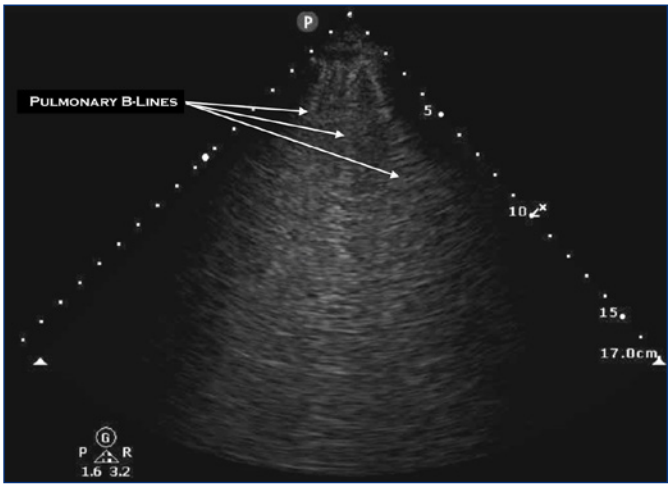


Image 8.

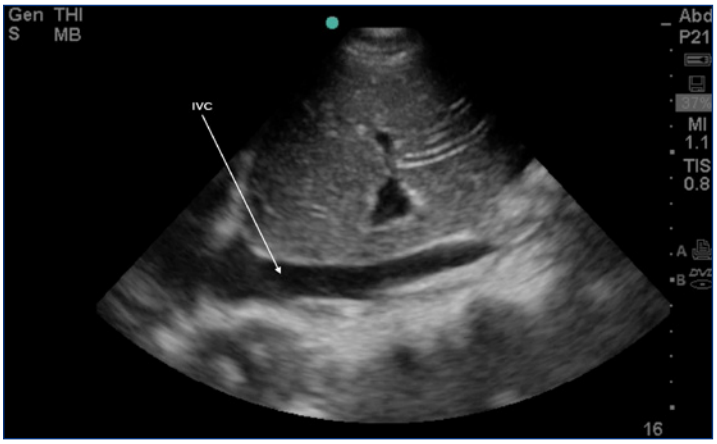
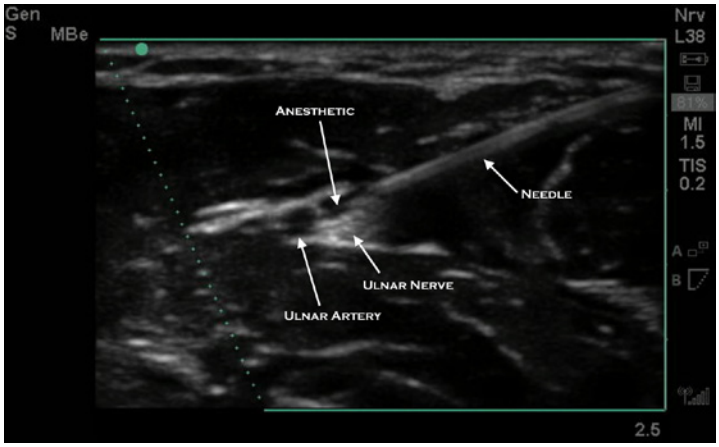


Image 9.



pulmonary ultrasound has a variety of diagnostic and symptom-based applications. It is most frequently applied in the patient presenting with dyspnea, where it can help differentiate COPD exacerbations from acute pulmonary edema as the etiology of the presenting complaint.[19] Specifically, the presence of *ultrasonographic* B-lines on pleural ultrasound reliably detects alveolar interstital edema and adds valuable information to the total clinical assessment (***Image 7***). Point-of-care pulmonary ultrasound and cardiac ultrasound are often combined at the bedside in patients with this chief complaint. Pulmonary ultrasound also aids in the diagnosis and management of non-traumatic pleural effusions.[20]

Monitoring & Resuscitation

The inferior vena cava (IVC) is an easily visualized structure that provides valuable information in the hemodynamically unstable patient (***Image 8***). The amount of collapsibility of the IVC is also associated with specific central venous pressure measurements, and a change in the IVC measurements with fluid boluses predicts hemodynamic fluid responsiveness.[21] Patients with undifferentiated hypotension can be more easily classified as being in cardiogenic/obstructive or distributive/hypovolemic shock. A flat or significantly collapsing IVC is indicative of the latter types of shock and effectively eliminates many cardiogenic and obstructive etiologies of hypotension. In addition, integration of IVC and cardiac ultrasound into the management of sepsis is associated with management changes and improved outcomes.[22]

Procedural

Ultrasound guidance for emergency department procedures directly and significantly improves patient care. In 1999 Agency for Healthcare Research and Quality listed "real-time ultrasound guidance during central line insertion to prevent complications" as one of the twelve most highly rated patient safety practices to decrease medical errors.[23] This recommendation is based on multiple studies that have demonstrated reduced failure rate, reduced number of attempts, and reduced complications as compared with the landmark technique, most profoundly with cannulation of the internal jugular vein and in patients with complex medical conditions.[24] Ultrasound guidance is used in the emergency department to improve success rates and decrease complications in many other procedures (**Table 3**) (***Image 9***).

CONCLUSION

Emergency ultrasound is an essential component of emergency medicine practice and has been integrated into the training and board certification of all emergency physicians. It is performed at the bedside, directly at the time of the physical examination, in a matter of minutes. It has broad utility and serves, in its many functional categories, to aid in the diagnosis, management, and disposition of emergency department patients.

Table 3. Ultrasound Guidance for Procedures

Procedure	Benefits of Ultrasound-Guidance
Central venous catheterization	Improves success rate; reduces complications
Peripheral venous catheterization	Reduces central lines; reduces attempts
Arterial access	Improves success rate
Lumbar puncture	Improves success rate (primarily with increased BMI)
Paracentesis	Improves success rate; reduces complications
Thoracentesis	Improves success rate; reduces complications
Arthrocentesis	Improves success rate; reduces attempts
Regional anaesthesia	Reduces pain; reduces time to completion of procedure
Incision and drainage	Improves success rate; avoids unnecessary procedure
Identification and removal of foreign body	Improves localization
Bladder volume	Reduces unnecessary catheterization

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