EB MEDICINE

EMERGENCY MEDICINE PRACTICE

EBMEDICINE.NET

AN EVIDENCE-BASED APPROACH TO EMERGENCY MEDICINE

An Evidence-Based Approach To Emergency Ultrasound

Paramedics bring into the ED an elderly man who is complaining of right-sided chest and abdominal pain. Earlier this morning, a friend had arrived at the patient's home and found him on the floor at the bottom of the stairs. The patient is in pain, somewhat altered, and unable to provide further details about what happened. After numerous attempts, the paramedics were only able to place a 22-gauge peripheral line. On examination, his blood pressure is 98/55 mm Hg, heart rate is 118 beats per minute, respiratory rate is 32 breaths per minute, oxygen saturation is 94% on a nonrebreather, and temperature is 36.0°C (96.8°F). His Glasgow Coma Scale score is 12 (eyes 3, verbal 4, motor 5). Given the unclear events surrounding his presentation and the concern for trauma, the patient is boarded and collared. His chest is stable but tender, and because of noise in the resuscitation room, you have difficulty auscultating breath sounds. The abdominal examination is notable for marked tenderness over the right upper quadrant and right flank, with some guarding. There is also mild asymmetric swelling of his right lower extremity. The patient is critically ill, his history is limited, and at this point the differential is quite broad. You consider the possibility of a syncopal episode followed by a fall, with a closed head injury, blunt thoracic trauma, and blunt abdominal trauma. His hypotension could be secondary to hypovolemia (dehydration or blood loss due to a ruptured aortic aneurysm), heart failure (left- or right-sided dysfunction), cardiac tamponade, tension pneumothorax, or sepsis. Your ED recently purchased an ultrasound machine, you wonder whether bedside ultrasound can help narrow the differential and guide your resuscitation. You call over one of your new faculty members who just finished resident training; a fortunate decision for both you and the patient.

March 2011
Volume 13, Number 3

Authors

James Q. Hwang, MD, RDMS, RDCS, FACEP
Staff Physician, Kaiser Permanente, CA

Heidi Harbison Kimberly, MD
Director, Emergency Ultrasound Education, Brigham and Women's Hospital, Boston, MA; Instructor, Emergency Medicine, Harvard Medical School, Boston, MA

Andrew S. Liteplo, MD, RDMS, FACEP
Department of Emergency Medicine, Massachusetts General Hospital, Boston, MA; Assistant Director of Emergency Ultrasound, Emergency Ultrasound Fellowship Director, Instructor, Harvard Medical School, Boston, MA

Dana Sajed, MD
Clinical Instructor in Emergency Medicine, Department of Emergency Medicine, New York University School of Medicine, New York, NY

Peer Reviewers

Phillip Andrus, MD, FACEP
Assistant Professor of Emergency Medicine, Mount Sinai School of Medicine, New York, NY

Bret Nelson, MD, RDMS, FACEP
Associate Professor of Emergency Medicine, Director of Emergency Ultrasound, Department of Emergency Medicine, Mount Sinai School of Medicine, New York, NY

David D. Nguyen, MD, FACEP
Clinical Assistant Professor, Division of Emergency Medicine, The University of Texas Medical Branch, Galveston, TX; Baylor College of Medicine, Houston, TX

Prior to beginning this activity, please see "Physician CME Instructions" on page 28.

Accreditation: EB Medicine is accredited by the ACCME to provide continuing medical education for physicians. **Faculty Disclosure:** Dr. Hwang, Dr. Kimberly, Dr. Liteplo, Dr. Sajed, Dr. Andrus, Dr. Nelson, Dr. Nguyen, Dr. Jagoda, and their related parties report no significant financial interest or other relationship with the manufacturer(s) of any commercial product(s) discussed in this educational presentation. **Commercial Support:** This issue of *Emergency Medicine Practice* did not receive any commercial support.

Emergency ultrasound (EUS) continues to develop and expand and is now a core skill in the clinical practice of emergency medicine. The Accreditation Council for Graduate Medical Education (ACGME) training programs now require residents to demonstrate competency in the use of EUS prior to completing their residency training. Thus, graduating emergency medicine residents are now expected to perform and interpret focused EUS studies as well as they are able to read electrocardiograms and manage emergent airways. With increased focus on patient safety and emergency department (ED) crowding, more and more EDs have purchased ultrasound machines in hopes of improving patient safety and quality of care and decreasing lengths of stay in the ED. Anecdotal stories of the benefits of bedside ultrasound (BUS) abound, yet many emergency clinicians are not familiar with its numerous applications or the body of literature regarding its use.

To date, there are 11 core EUS applications, and the clinical usefulness of each application is covered in the literature to varying degrees. The 6 initially established applications include: 1) the Focused Assessment with Sonography for Trauma (FAST) examination, 2) abdominal aortic aneurysm, 3) emergency echocardiography, 4) pregnancy, 5) hepatobiliary ultrasound, and 6) renal ultrasound. The 5 recently added applications include: 1) deep venous thrombosis, 2) thoracic ultrasound, 3) musculoskeletal ultrasound, 4) ocular ultrasound, and 5) procedural ultrasound.

The American College of Emergency Physicians (ACEP) 2008 revision of their Emergency Ultrasound Guidelines Policy Statement updates the original 2001 policy statement and details how EUS has expanded and where it stands today.[1] Appendix 1 of the 2008 ultrasound policy statement briefly reviews the evidence for the 11 core applications of EUS. This ACEP policy statement is the most current, comprehensive, specialty-specific guideline in the field of EUS. This issue of *Emergency Medicine Practice* expands on this review and summarizes the existing and best available literature concerning these EUS applications.

Table Of Contents

Available Online At No Charge To Subscribers

EM Practice Guidelines Update: "Current Guidelines on CPR, Emergency Cardiovascular Care, And Adult Cardiac Arrest," www.ebmedicine.net/ACLS

Critical Appraisal Of The Literature

For some applications of EUS, the existing literature is vast; for others, it is limited. In the more established applications, research has moved beyond the assessment of technical and diagnostic accuracy toward diagnostic decision-making and patient outcomes research. A few general statements can be made regarding much of the research on EUS. First, ultrasound is operator-dependent. Results are conditional and based on the sonographer's skill level, making generalizability a concern. Second, EUS is a diagnostic and resuscitative imaging modality, and its impact on patient outcomes is more challenging to study than that of other interventions. Third, many ultrasound studies are convenience samples, since emergency medicine providers who are sufficiently trained in sonography are not always available to enroll patients in a consecutive manner. Fourth, chart reviews with EUS — like all chart reviews — depend on the availability and accuracy of bedside ultrasound data, and the quality of these data is highly variable.

The 2008 ACEP Emergency Ultrasound Guidelines effectively summarizes the quality of clinical ultrasound research by defining classes of evidence[1]:

- *Class I Evidence:* Randomized controlled trials (RCTs) are the gold standard
- *Class II Evidence:*
  - A. Data collected prospectively
  - B. Retrospective analyses from clearly reliable data
- *Class III Evidence:* Most studies based on retrospectively collected data

Based on this system of ranking, some Class I evidence exists for ultrasound-assisted central venous cannulation and the FAST examination, but most publications offer Class II (both A and B) evidence. Published literature for clinical sonographic evaluation of other established applications, including abdominal aortic aneurysm, cardiac tamponade and global inotropy, early intrauterine pregnancy confirmation, and shock states, represent Class II (both A and B) and Class III evidence. Some Class II data exist for the newer applications of EUS, but the majority of the literature remains Class III evidence.

In general, the EUS literature continues to grow and the quality of the studies continues to improve. As data collection becomes standardized and as more widespread data networks are established, larger multicenter studies are on the horizon.

Trauma: Abdominal And Thoracic Ultrasound

The Focused Assessment with Sonography for Trauma, or the FAST examination, is a well-established diagnostic and resuscitative modality for patients who present with trauma. New-found understanding of pulmonary ultrasound in addition to the FAST scan has allowed for more complete bedside analysis of the acutely injured patient.

Abdominal Ultrasound: Focused Assessment With Sonography In Trauma (FAST)

As early as 1971, the utility of ultrasound scanning for patients with splenic injuries was documented.[2] It was not until the early 1990s, however, that ultrasound became widely advocated and studied in patients with blunt abdominal trauma.[3-6] Since then, ultrasound has been included in the Advanced Trauma Life Support protocol of the American College of Surgeons[6] and in the Eastern Association for the Surgery of Trauma (EAST) guidelines for the management of blunt abdominal trauma.[8] The American College of Radiology also recommends the use of ultrasonography — and specifically, the FAST scan — to evaluate for free or localized intra-abdominal fluid collections.[9] **(See Figures 1 and 2, page 4.)**

Ultrasound evaluation of patients with trauma has numerous benefits. The test can be rapidly performed at the bedside, accurately predicts the presence of hemoperitoneum, is noninvasive, can be repeated, and does not involve ionizing radiation or intravenous contrast media. Unfortunately, the number of RCTs assessing the FAST examination is limited. In 2005, The Cochrane Collaboration reviewed the efficiency and effectiveness of trauma algorithms that include ultrasound in the evaluation of patients suspected of having blunt abdominal trauma. Their initial conclusion, which remains unchanged in 2008 (after correction of their first review), is that there is still insufficient evidence from RCTs to justify promoting ultrasound-based clinical pathways in the diagnosis of patients with blunt injury to the abdomen.[10] Although the mortality data reviewed by The Cochrane Collaboration do not favor the FAST examination, the use of ultrasound in this setting has been shown to decrease the time to recognition of intraabdominal trauma, the time to operative therapy, hospital costs and resource use, and the number of CT scans and diagnostic peritoneal lavages performed.[11-13]

In a retrospective review of patients with penetrating cardiac injury, Plummer et al found that 2-dimensional echocardiography in the ED decreased the time to diagnosis and improved both survival and neurologic outcomes of survivors.[14] Although the value of the FAST examination in hemodynamically unstable trauma patients is accepted, its role in the management of those who are hemodynamically stable is unclear and often questioned.

Moylan et al found that the FAST examination can indeed assist in the risk stratification of normotensive patients with blunt abdominal trauma.[15] In a retrospective cohort analysis of consecutive normotensive blunt abdominal trauma patients at 2 different level I trauma centers, they tested the association between a positive result on FAST and the need for therapeutic laparotomy. They found that the odds ratio for an unadjusted association between a positive FAST result and laparotomy was 116 and that this association persisted after adjusting for confounding variables, with an odds ratio of 44. This study showed a strong association between a positive FAST and the need for therapeutic laparotomy and noted that very few normotensive patients with a negative FAST required therapeutic laparotomy. The sensitivity of the FAST examination as a diagnostic test for therapeutic laparotomy, however, was found to be only 75.8%; similarly, its positive predictive value was found to be only 37.3%.[15]

Thoracic Ultrasound

The traditional FAST examination involves 4-quadrant scanning with views of the hepatorenal space, the perisplenic and splenorenal interface, the pelvis, and the pericardium through a subxiphoid or parasternal approach. Recently, authors have studied an extended version of the FAST examination, referred to as the Extended Focused Assessment with Sonography for Trauma (E-FAST). In addition to the 4-quadrant views of the FAST, the E-FAST includes views of both hemithoraces at the levels of the diaphragm-abdominal interface and over bilateral anterior chest walls. **(See Figure 3, page 4.)** It is designed to assess for pneumothorax in the anterior views and for pleural effusion or hemothorax in the supradiaphragmatic views.

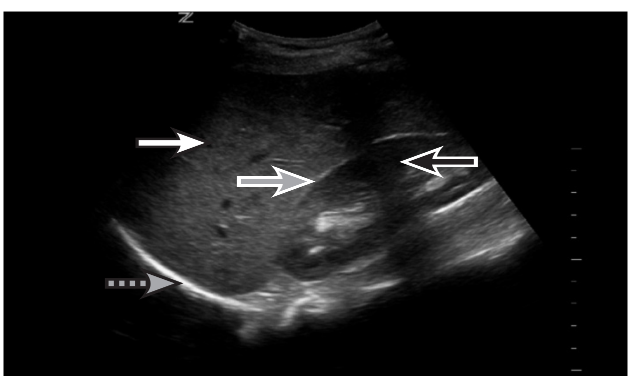
Evaluation of the patient with thoracic trauma begins with an examination for external injuries and auscultation of lung sounds, usually followed by radiographic evaluation with a portable supine anteroposterior chest x-ray. Unfortunately, the physical examination is frequently insufficient and carried out in a loud environment where diminished breath sounds are not easily appreciated. In addition, portable chest radiographs are not sensitive enough to rule out lung injury and have been estimated to miss traumatic pneumothoraces up to 50% of the time.[16-21]

The use of ultrasound to detect pneumothorax has been well established. Lichtenstein and Menu showed that in patients in the intensive care unit (ICU), bedside ultrasound has a sensitivity of 95.3%, a specificity of 91.1%, and a negative predictive value of 100% when compared with CT scanning as the reference standard for the detection of pneumothorax.[22] In ICU patients with radio-occult pneumothoraces, the same group showed that ultrasound was superior to plain radiography for the detection of pneumothorax, with a specificity approaching 100%.[23] Both of these studies were conducted in ICU patients in whom disease processes such as fibrotic lung disease and acute respiratory distress syndrome may affect the quality of the sonogram, resulting in both false-positive and false-negative studies.

In a prospective study of blunt trauma patients, Blaivas et al found that the sensitivity of ultrasound in detecting pneumothorax was 98.1% and the specificity was 99.2%, while chest radiography had a sensitivity of 75.5% and a specificity of 100%.[16] An article by Rowan et al also compared the accuracy of sonography with supine chest radiography for the detection of traumatic pneumothorax. In 27 patients who sustained blunt thoracic injury, the radiographic and ultrasound findings were compared with CT scan results as the gold standard for diagnosis. Eleven of the 27 patients had pneumothoraces on CT and all 11 cases were detected with sonography. There was, however, 1 false-positive with ultrasound, resulting in a sensitivity of 100% and a specificity of 94%. Supine chest radiography had a specificity of 100% but a sensitivity of only 36%.[17]

Two studies by Soldati and colleagues also found highly superior sensitivity and comparable specificity for ultrasound when compared with chest x-ray, again using CT as the gold standard.[18,19] In a prospective study of patients with blunt trauma, Zhang et al found a sensitivity of 86% and a specificity of 97% with sonography, while plain film had a sensitivity of 27.6% and a specificity of 100%. Of note, they found that the mean time needed to diagnose pneumothorax was significantly shorter with ultrasound than with chest x-ray (2.3 ± 2.9 vs 19.9 ± 10.3 min, $P < 0.001$).[20] Kirkpatrick et al compared the value of supine chest radiography versus a handheld ultrasound device in 208 patients with blunt or penetrating trauma to detect pneumothorax during their initial resuscitation. The methods in this study differed slightly from those in previous studies in that they used both a composite standard (which included CT, chest x-ray, and the escape of air with tube thoracostomy) and CT as the gold standard in the comparison with the sonograms and chest

Figure 1. Normal Right Upper Quadrant View



White arrow points to liver.
Black arrow points to right kidney.
Gray arrow points to Morison's pouch.
Dashed arrow points to diaphragm.

The normal right upper quadrant in the longitudinal view, showing the kidney, liver, and no fluid in the Morison's pouch.

Figure 2. Positive Right Upper Quadrant View

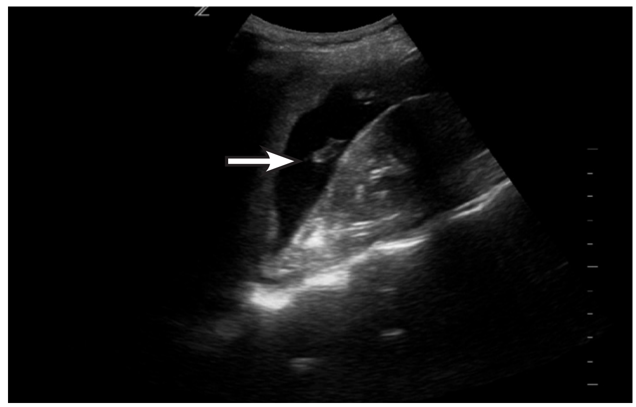
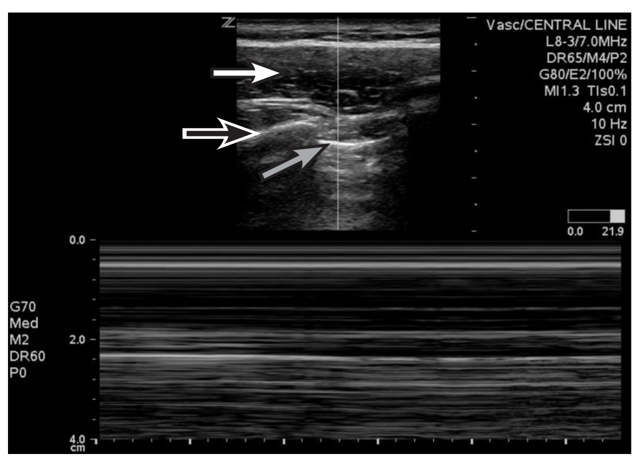


Image shows positive free fluid in the hepatorenal space. White arrow points to fluid in Morison's pouch.

Figure 3. Pneumothorax On Motion Mode Imaging



White arrow points to chest wall. Black arrow points to rib. Gray arrow points to pleural line.

Motion mode imaging can be performed to assess for a pneumothorax. In the presence of a pneumothorax, lung sliding is absent and repeating horizontal lines are seen across the entire screen (referred to as the "bar code" or "stratosphere" sign).

radiographs. Ultrasound had a sensitivity of 58.9% and a specificity of 99.1% when compared with the composite standard and a sensitivity of 48.8% and a specificity of 98.7% when compared with CT alone; chest x-ray had a sensitivity of 20.9% and a specificity of 99.6% when compared with CT alone.[21] Again, these results demonstrate the superiority of ultrasound over supine chest radiography for the detection of pneumothorax, although the sensitivity reported in this study is much lower than that described previously. As a possible explanation for the decreased sensitivity, the authors cite the technical limitations related to using a hand-held ultrasound device for trauma resuscitations.

The ability of ultrasound to detect hemothorax and pleural effusions has also been well-documented. There are advantages to the use of BUS, as with the E-FAST examination, when compared with traditional methods of assessing for blood or other fluid in the pleural space. Ma et al were among the first to show that emergency clinicians can use BUS to rapidly assess trauma patients with a time-to-completion of approximately 4 minutes for a thoracoabdominal sonographic study.[24] In a follow-up retrospective study of the same patient sample, these authors showed that both thoracic ultrasound and chest x-ray were 96.2% sensitive, 100% specific, and 99.6% accurate for the detection of hemothorax, using chest CT and tube thoracostomy as criterion standards.[25] Sisley and colleagues showed that the performance time for ultrasound was significantly shorter than that for a portable chest radiograph and had superior sensitivity, with both techniques offering comparable specificity.[26] Other authors have confirmed these findings.[27,28] In addition, ultrasound has been reported to be able to detect smaller quantities of fluid than chest radiography. Ultrasound can detect as little as 20 mL of pleural fluid,[29] while approximately 175 mL is required before findings are noted on supine chest radiography.[30]

Conclusions

By adding thoracic views to the standard 4 views of the FAST examination, the emergency clinician can rapidly assess the trauma patient for hemothorax and pneumothorax, and this technique is a valuable tool in initial management. Although CT remains the mainstay for detecting parenchymal injuries and other intraperitoneal trauma, the use of clinician-performed ultrasound has many advantages, including lower cost, time-sensitive bedside assessments, ease of repetition for reevaluation, and lack of ionizing radiation. The last advantage is of particular importance, given recent evidence that ionizing radiation from CT does, in fact, increase a patient's lifetime risk of cancer.[31-33] Since many trauma patients are young, the use of a nonionizing diagnostic test is ideal. Repeat assessment is often necessary in trauma patients if there is a change in vital signs or patient status or after interventions are carried out. In these scenarios, repeat evaluation with BUS can be performed rapidly and can guide the clinician in terms of further interventions.

Ultrasound In Pregnancy

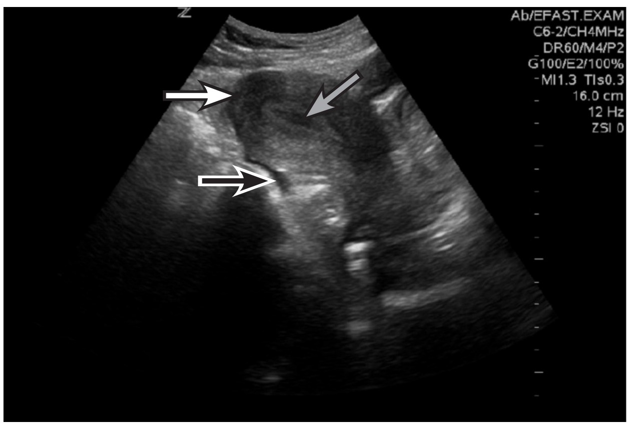
Transabdominal ultrasound (TAUS) and transvaginal ultrasound (TVUS) in the first-trimester pregnant patient is one of the primary applications of emergency ultrasound.[1] Ectopic pregnancy has a prevalence of 8% in pregnant patients presenting to the ED[34] and remains a top cause of maternal mortality.[35] Unfortunately, approximately half of symptomatic ectopic pregnancies have no identifiable risk factors.[36] Pelvic ultrasound performed by the emergency clinician can be both life-saving and time-saving in these patients.[37-40] Emergency pelvic ultrasound can identify a definite diagnosis in the majority of symptomatic first-trimester pregnant patients and focuses on detection of an intrauterine pregnancy (IUP). Multiple studies have demonstrated pelvic ultrasound to be diagnostic of IUP or ectopic in approximately 70% to 75% of symptomatic first-trimester pregnant patients.[40-42] In a study by Durham et al, pelvic ultrasound results obtained by emergency physicians were consistent with radiology department findings in 96% of cases (95% confidence interval [CI], 91% to 97%).[41] A recent meta-analysis of emergency physician ultrasonography as a diagnostic test for ectopic pregnancy found that emergency physician-performed bedside ultrasonography demonstrated a sensitivity of 99.3% (95% CI, 96.6% to 100%) and a negative predictive value of 99.96% (95% CI, 99.6% to 100%) for detecting an intrauterine pregnancy.[43]

Focused Pelvic Ultrasound

Transabdominal ultrasound can identify an IUP in most women at 6 or 7 weeks' gestation, while TVUS can identify an IUP 7 to 14 days earlier, at 5 to 6 weeks' gestation.[44] While TVUS scanning provides superior imaging of the uterus (ie, retroverted uterus) and adnexa, TAUS ultrasound offers a more global view of the pelvis, is easier to learn, and requires less maintenance from an infection-control perspective.[34] **(See Figure 4, page 6.)** For emergency clinicians, sonographic findings consistent with an IUP include a yolk sac, fetal pole, or fetal heart activity within the uterus, surrounded by an 8-mm rim of myometrium. **(See Figure 5, page 6.)** Visualization of a yolk sac, whether by TAUS or TVUS, is the first definitive evidence of an IUP. Once an IUP has been confirmed, fetal viability (fetal heart rate) and gestational age can also be determined. Although visualization of an IUP does not completely exclude ectopic or heterotopic pregnancy, its presence — in patients without risk factors — decreases the chances sufficiently to allow for further outpatient management.[34,38]

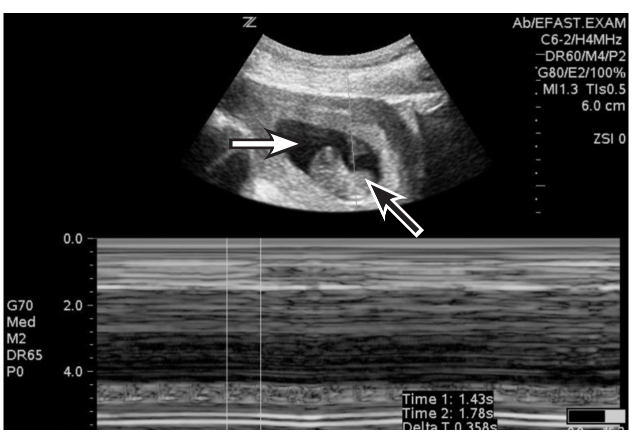
Direct visualization of an ectopic pregnancy can be challenging, and is even more so when TVUS is not performed, since the most frequent finding in ectopic pregnancy is a complex adnexal mass.[42] Although the emergency clinician may directly visualize an ectopic pregnancy, the focus of the scan is on assessing for an IUP (or lack thereof) or for the presence of free fluid in the hepatorenal space (Morison's pouch) or the pelvic space (Pouch of Douglas). Transabdominal views of the right upper quadrant and pelvis are integral to ultrasound imaging of the symptomatic first-trimester pregnant patient. Although the presence of significant intraperitoneal fluid in a pregnant patient without a definite IUP is indirect evidence, it is suggestive of an ectopic pregnancy, and its detection can be life-saving.[46]

Figure 4. Normal Sagittal View Of The Female Pelvis



White arrow points to uterine fundus.
Black arrow points to rectouterine space (Pouch of Douglas).
Gray arrow points to endometrial stripe.

Figure 5. Fetal Heart Rate Measurement With Motion Mode Imaging



White arrow points to the gestational sac.
Black arrow points to the fetal pole.
Motion mode imaging can be performed to determine fetal heart rate.

Length Of Stay In The Emergency Department And Cost-Effectiveness

Bedside TAUS and TVUS performed and interpreted by physicians have been shown to decrease ED lengths of stay. Blaivas et al performed a retrospective chart review identifying 1419 symptomatic first-trimester patients who had ultrasound examinations that confirmed live IUP.[37] Lengths of stay for patients who received their pelvic ultrasound from emergency physicians were compared to those for patients who had studies performed by radiology staff. This study found that the median length of stay was 21% (59 minutes) less than those who received a pelvic ultrasound from radiology; this difference increased to 28% (1 hour and 17 minutes) during evening hours.

In a study by Burgher et al, the findings were similar and demonstrated that pelvic ultrasonography performed by emergency physicians saved an average of 60 minutes when compared with scans done by consultative services.[47] Shih also assessed the effect of pelvic ultrasonography performed by emergency clinicians on length of stay and found that the time savings were significant when an IUP was detected.[48] Durston et al evaluated the quality and cost-effectiveness of detecting an ectopic pregnancy with ultrasound in a single ED over a 6-year period. The study was divided into 3 similar time frames, with 3 different approaches to ultrasound availability: 1) limited availability of radiology staff-performed pelvic ultrasound, 2) readily available radiology staff-performed pelvic ultrasound, and 3) readily available emergency clinician-performed and radiology-staff performed pelvic ultrasound.[49] This study found that the most cost-effective strategy is for emergency physicians to screen all patients with first trimester symptoms with emergency physician-performed pelvic ultrasounds and to obtain formal studies during the initial ED visit if the emergency physician-performed study is indeterminate. More specifically, Durston et al found that emergency physician-performed pelvic ultrasound saved 15.9 formal radiology studies and 9.7 ultrasound technician call-ins per ectopic pregnancy diagnosed.[49]

Conclusions

Pelvic ultrasound has been shown to be useful in the management of symptomatic first-trimester pregnant patients and is a core application of emergency ultrasound. Studies demonstrate that emergency physicians can make a definite diagnosis in the majority of such patients. When an IUP is identified, emergency physician-performed pelvic ultrasound has been shown to decrease length of stay. When indirect or direct evidence of an ectopic pregnancy is noted, emergency physician-performed pelvic ultrasound has been shown to expedite care and to be life-saving.

Ultrasound For Abdominal Aortic Aneurysm

Abdominal aortic aneurysms (AAA) are a leading cause of death in the United States. Abdominal aortic aneurysms occur when the walls of the aorta weaken due to atherosclerosis and hypertension. They are most common in males over the age of 50, especially those with a history of smoking or hypertension. Initially, AAAs are asymptomatic, but with expansion, they classically present as pain in the abdomen, flank, or back, and the risk of rupture is related to the size of the aneurysm. When it occurs, rupture results in the above symptoms or presents as syncope, dizziness, hypotension, pulseless electrical activity, or cardiac arrest. Emergent surgical repair is often the only possible life-saving measure, so rapid identification of AAAs is a critical skill for all emergency clinicians.

Physical examination is the fastest way to determine whether a patient has an AAA. Traditionally, the finding of a pulsatile abdominal mass is associated with an AAA; however, both the sensitivity and the specificity of the physical examination are relatively poor. In 1999, a meta-analysis of 15 studies was carried out to see how accurate clinicians are in detecting AAAs on physical examination.[50] The study found that pooled sensitivities for AAA increased with the size of the aneurysm, from 29% for AAAs of 3.0 to 3.9 cm, to 50% for AAAs of 4.0 to 4.9 cm, and to 76% for AAAs of 5.0 cm or larger.

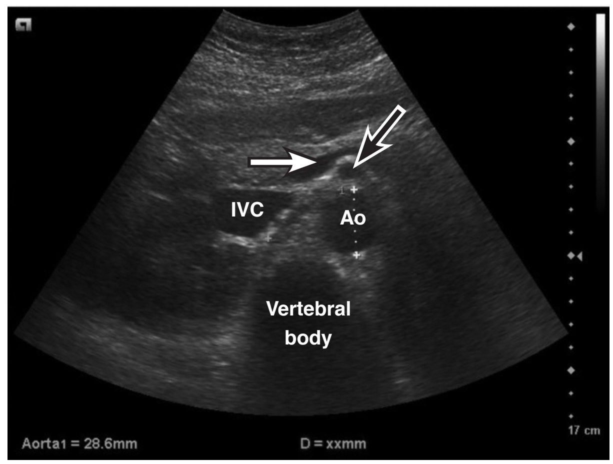
Review Of The Literature

In many ways, ultrasound is the ideal tool for diagnosing AAAs. **(See Figures 6 and 7.)** It offers the same benefits as for other applications, in that it is rapid, accurate, noninvasive, inexpensive, and reproducible; it involves nonionizing radiation; and it can be done at the patient's bedside. This is particularly important in the unstable hypotensive patient who cannot travel to the CT scanner. The use of ultrasound to assess for AAAs was described in the literature as early as 1977. Goldberg described its use in detecting a normal aorta or an AAA and in defining the anatomy and extent of disease.[51] Since then, there has been considerable research on the role of bedside ultrasound in the assessment of AAAs.

As for many applications of ultrasound, some reports have focused on the ability of emergency clinicians to accurately perform bedside ultrasound and to interpret the results. Dent et al described scans done by emergency physicians to assess for AAAs and found a sensitivity of 96% and a specificity of 100%.[52] Costantino et al compared ultrasound performed by emergency physicians to a gold standard of CT, magnetic resonance imaging (MRI), or operative findings. In 238 patients, they found a sensitivity of 94% and a specificity of 100%.[53] Similarly, in a study involving 104 patients, Knaut et al found good agreement between measurements of the aorta made with ultrasound by emergency physicians and those made with CT by radiology staff.[54] The time needed to perform ultrasound was less than 5 minutes in the majority of cases. Tayal et al prospectively studied the accuracy of emergency physician–performed ultrasound compared with radiology staff–performed ultrasound, CT, MRI, or laparotomy over a 2-year period.[55] They found that in 125 patients, the sensitivity and specificity were 98% and 100%, respectively, for emergency physician-performed studies.

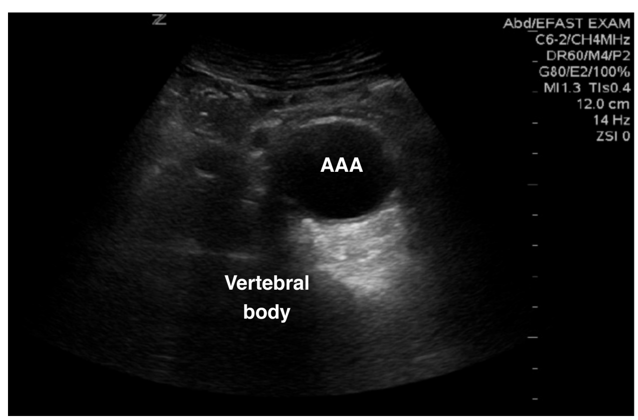
As a screening tool, ultrasound is an effective way to identify AAAs that may require treatment. The Multi-

Figure 6. Normal Transverse View Of The Abdominal Aorta



White arrow points to splenic vein.
Black arrow points to superior mesenteric artery.
Normal transverse view of the proximal abdominal aorta demonstrating the splenic vein, superior mesenteric artery, inferior vena cava (IVC), aorta (Ao), and vertebral body.

Figure 7. Abdominal Aortic Aneurysm On Transverse View



Abbreviation: AAA, abdominal aortic aneurysm.

Transverse view of the abdominal aorta demonstrating an AAA anterior and to the left of the vertebral body. The abdominal aorta is measured on the transverse view and an AAA is present when the abdominal aorta measures > 3 cm.

centre Aneurysm Screening Study (MASS) prospectively evaluated mortality and the cost-effectiveness of ultrasound screening in asymptomatic men in a large outpatient program. The study enrolled 67,800 males ages 65 to 74 who were randomized to receive or not receive a screening ultrasound. Subjects with positive results were followed up or referred for surgery. There was a 53% relative reduction in aneurysm-related death in the group that was screened when compared with the unscreened control group.[56] In addition, short-term (30-day) mortality was 6% after elective aneurysm repair vs 37% after emergency surgery. A secondary analysis demonstrated that this screening was cost-effective.[57] A 2007 Cochrane review of 4 studies confirmed a mortality reduction in men but stated that the evidence is not sufficient to prove the same in women.[58]

Few studies have examined the screening of asymptomatic patients in the ED. Moore et al studied 179 patients who presented to the ED with unrelated complaints.[59] They found an incidence of AAA of 6.7%, and of the 12 patients with AAA, repair was recommended in 3. As in other studies, emergency physician-performed ultrasound was fast and accurate. Since mass screening has been shown to reduce mortality, some third-party payers have, over the past few years, approved reimbursement for screening at-risk patients. This practice has not yet been adopted in EDs, but theoretically could be if the appropriate equipment, documentation, and follow-up systems were in place.

Although ultrasound is an excellent tool for detecting AAA, its ability to differentiate between a ruptured and a nonruptured aneurysm is limited. Free fluid seen on a FAST examination certainly could represent blood from a ruptured aneurysm, but the majority of AAAs rupture into the retroperitoneum and thus are more challenging to detect on a FAST examination. Sensitivity may be improved with contrast-enhanced sonography. Ultrasound contrast solutions contain microbubbles that, when injected, flow within vessels and capillaries and better delineate their anatomy by "lighting up" the image. Recent reports have described the use of contrast-enhanced ultrasound in detecting aortic aneurysmal rupture.[60,61] Evidence is limited to a case series, however, so the ability to definitively detect or rule out aortic aneurysm rupture is unclear.

Finally, ultrasound is also able to detect another aortic emergency: aortic dissection. When blood dissects into the tunica media and the tunica adventitia, an intimal flap can be seen moving within the aorta. Two case series of patients in the ED describe the use of ultrasound in detecting aortic dissection.[62,63] While the exact sensitivity and specificity of emergency clinician-performed echo for aortic dissection have not been studied, ultrasound is likely specific when a flap is seen, but not sensitive, as complete evaluation of the aorta requires multiple views and can be difficult.

Conclusions

Bedside ultrasound scanning for AAA is a high-yield application with high sensitivity and specificity that can be easily learned by emergency clinicians. Rapid diagnosis of an AAA in the unstable patient can be life-saving. Though this conclusion has not been confirmed in the literature, it would be difficult to perform a randomized controlled clinical trial to demonstrate it. Bedside ultrasound is not a sensitive test to differentiate between ruptured and unruptured aortic aneurysms, and in stable patients a CT scan is the test of choice.

Ultrasound For Deep Venous Thrombosis

Evaluation of a painful, swollen leg is a common work-up in the ED. The differential diagnosis usually includes deep venous thrombosis (DVT), cellulitis, venous stasis, or some combination of these. Ultrasound is the test of choice to identify or exonerate DVT, and with the increasing availability of ultrasound machines, more emergency clinicians are becoming facile in performing and interpreting this examination at the bedside. **(See Figures 8 and 9.)**

Review Of The Literature

Many studies have examined the ability of emergency physicians to accurately diagnose DVT on BUS. A 1997 study looked at whether emergency physicians could accurately diagnose DVT using color-flow Doppler after a modest training program and found a sensitivity of 100% and specificity of 75%.[64] A recent review by Burnside et al summarized these findings.[65] They performed a systematic review of emergency physician-performed ultrasound for the diagnosis and exclusion of DVT. They included original prospective studies of emergency physician-performed ultrasound in symptomatic patients and compared the results with a second venous ultrasound performed by radiology or a vascular lab. Of 1162 publications reviewed, 6 studies met inclusion criteria and relevance screening.[66-71] When these 6 studies were combined, 132 cases of DVT were detected in 936 patients. Pooled sensitivities and specificities were 95% (95% CI, 0.87-0.99) and 96% (95% CI, 0.87-0.99), respectively.[65] Despite some limitations, the overall pooled sensitivity and specificity are very high, suggesting that properly trained emergency clinicians can diagnose DVT at the bedside using ultrasound with an accuracy approaching that of formal studies.[65]

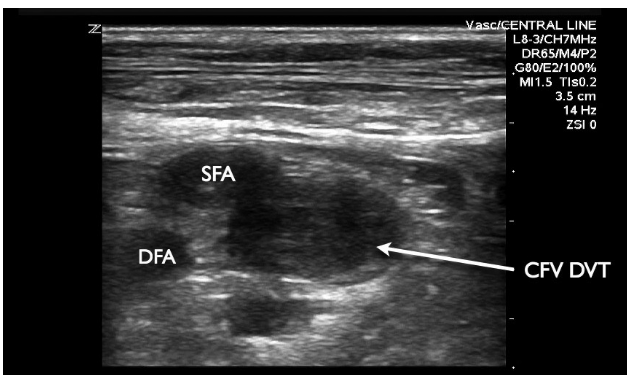
Shortly after the Burnside review, Kline et al published a study evaluating the sensitivity and specificity in detecting DVT on ultrasound by a heterogeneous group of providers.[72] This was a prospective, single-center study conducted at an urban academic ED in which faculty, residents, and midlevel providers underwent a training course for 3-point compression BUS. The overall sensitivity and specificity were 70% and 89%, respectively.

Time And Cost Savings

In general, it is reasonable to postulate that ultrasonography performed by an emergency clinician at the bedside would almost invariably take less time than obtaining a comprehensive study in radiology or the vascular lab. Studies examining the time and potential costs saved by emergency clinician-performed ultrasound to detect DVT are limited.

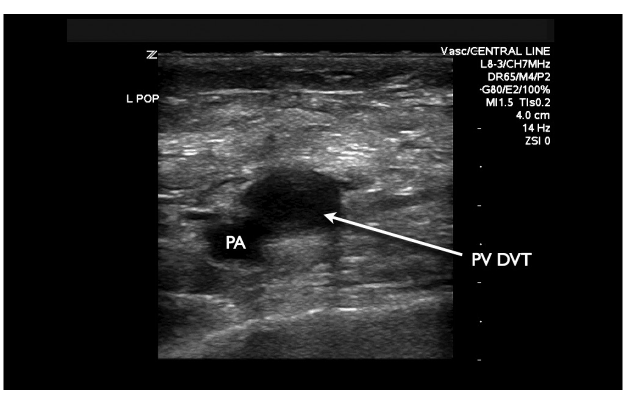
In 2004, a prospective, single-blind, observational study by Theodoro et al studied the time savings associated with emergency physician -performed ultrasound studies versus studies performed by radiologists.[68] A convenience sample of 156 patients was enrolled. A statistically significant difference ($P < 0.0001$) existed between the mean time from triage to ED disposition (95 min) and the mean time from triage to radiology disposition (220 min), with excellent agreement between the 2 studies. A similar trend was described, but not explicitly studied, by Blaivas et al.[71] In this study, the median scan time for emergency physician-performed ultrasound was 3 minutes, 28 seconds. The longest time required to complete an emergency physician-performed ultrasound study was 18 minutes, 20 seconds, whereas the vascular lab performed a complete duplex ultrasound examination within 8 hours. Although scant, the literature supports what is already intuitive—that BUS is considerably faster than studies performed by radiology or in the vascular lab.

Figure 8. Deep Vein Thrombosis In Common Femoral Vein On Transverse View Of Right Inguinal Area



White arrow points to the common femoral vein deep vein thrombosis (CFV DVT). The superficial femoral artery (SFA) and the deep femoral artery (DFA) are also seen.

Figure 9. Deep Vein Thrombosis In Popliteal Vein On Transverse View



White arrow points to a deep vein thrombosis within the popliteal vein (PV DVT). The popliteal artery (PA) is also seen.

Many radiology departments and vascular labs perform full-length lower-extremity ultrasound and use sonographic techniques including color-flow Doppler, augmentation, and respiratory variation of veins to assess for DVT. Compression alone has also been shown to be a powerful detector of DVT. Patent veins should compress completely when downward pressure is applied with an ultrasound probe. Clots may appear hyperechoic, but since some are anechoic, failure to visualize a clot does not rule out its presence. Regardless of its echogenicity, when a clot is present, the vein does not fully compress.

A study by Biondetti et al compared vein compressibility alone to a gold standard of venography.[73] They found that vein compressibility had a sensitivity of 87% and specificity of 100% for detecting DVT. Six of the 7 false-negative results were from isolated distal DVT. The sensitivity of ultrasound for detecting proximal DVT was 98%.

Another variable in scanning technique is performing 2-point compression (femoral vein at the groin only and popliteal vein) versus full-length lower-extremity ultrasound. The obvious advantage of the 2-point compression technique is the shorter time required to perform the examination. But how does it compare in terms of diagnostic accuracy?

A recent study by Bernardi et al prospectively randomized 2098 patients with suspected DVT to serial 2-point ultrasound in combination with a D-dimer test versus whole-leg color-flow Doppler ultrasound.[74] One group of patients was randomized to full-length lower-extremity ultrasound, including evaluation of the calf veins. The other group was examined with 2-point ultrasound (common femoral vein and popliteal vein compression only) and a D-dimer test. Those with a negative ultrasound and positive D-dimer underwent repeat ultrasound at 1 week's time. Those with a negative 2-point ultrasound and negative D-dimer and those with a negative repeat ultrasound at 1 week were not treated with an anticoagulant and were not further investigated. The incidence of proximal DVT on 1-week testing in the group with a positive D-dimer test was 5.5%. The incidence of confirmed symptomatic DVT on 3-month follow-up was 1.2% versus 0.9% in the whole-leg group versus 2-point ultrasound group, respectively. This study supports the idea that 2-point compression in combination with a D-dimer test is equivalent to whole-leg color-flow Doppler ultrasound in the management of symptomatic patients with suspected DVT. The authors also note that the initial prevalence of proximal DVT was similar in both groups (22.1% vs 20.2%), suggesting that proximal DVT always involves the common femoral vein, the popliteal vein, or both. They suggest that superficial and deep femoral veins are usually not worth investigating.

Evaluation Of Calf Veins

The evaluation of distal (calf) veins for DVT is also a controversial topic. The natural history of distal DVT is that in the majority of cases, the thrombi are resorbed and do not propagate, while a small number (0% to 29%)[75] do propagate and extend to involve the popliteal vein, thus becoming proximal DVT. Proximal DVTs carry a high risk of embolization, and as such, the use of anticoagulation in patients with isolated distal DVTs is controversial. The goal, then, is to identify patients who have distal DVTs that then develop into proximal DVTs. **(See Figures 8 and 9, page 9.)** One common practice pattern is to refer ED patients for a repeat ultrasound in 1 week's time.

A study by Kearon et al studied outpatients with suspected DVT and negative results on proximal vein ultrasound.[76] Patients received a repeat ultrasound in 1 week and then were followed for 6 months. Three of 402 patients (0.7%) were diagnosed with DVT on the 1-week ultrasound. Of the other 399, 5 patients (1.3%) were found to have DVT within the 6-month follow-up period. This study supports the concept that with a negative 1-week ultrasound, the rate of symptomatic DVT during the next 6 months is very low. Care must be taken by the emergency clinician to communicate with the patient's primary care provider, as many providers seem unaware of the need for a repeat ultrasound.[77]

Finally, when using ultrasound to evaluate a patient for DVT, is it useful to scan the contralateral leg? Pennell et al sought to answer this question in a 2008 study of 239 patients with unilateral symptoms and a DVT on ultrasound; 47 patients (19.7%) were found to have thrombosis in the (asymptomatic) contralateral leg. Patients with active malignancy carried a 38% incidence of an asymptomatic contralateral clot, so the authors recommend routine scanning of both legs in this population.[78]

Conclusions

Bedside ultrasound to detect DVT offers excellent sensitivity and specificity when performed by skilled emergency clinicians. Its use in the ED is likely to decrease patients' length of stay. The 2-point compression technique is sufficient for diagnosing proximal DVT. Evaluation of calf veins for distal DVT is not usually necessary as long as a follow-up ultrasound can be obtained within a week.

Ultrasound For Soft Tissue And Musculoskeletal Applications

Point-of-care ultrasound can be used for a wide variety of soft tissue and musculoskeletal applications in the ED, including the diagnosis of soft tissue infections and masses, tendon injuries, joint effusions, and fractures, as well as the localization of foreign bodies. Ultrasound offers the emergency clinician rapid bedside evaluation of and procedural guidance for a wide array of these commonly encountered conditions.

Cellulitis And Abscesses

An increasing body of literature has demonstrated the utility of BUS in the management of soft tissue infections in the ED by aiding in the differentiation between cellulitis and abscess, as well as localizing and guiding drainage of fluid collections.[79-81] **(See Figures 10 and 11.)** Ultrasound has been shown to be superior to the physical examination and to alter the management of patients with soft-tissue infections.

How often have you wondered if a skin infection actually has a drainable fluid collection? A prospective study by Squire et al evaluated 107 patients with suspected cellulitis or abscess and compared the accuracy of physical examination with that of ultrasound in detecting subcutaneous abscesses.[79] Prior to obtaining the ultrasound, the treating clinician reported a "yes" or "no" assessment on the presence of an abscess. Ultrasonography was performed by physicians and residents who had attended a 30-minute training session on this application. The gold standard was purulent drainage on incision or resolution of symptoms on antibiotics alone at follow-up on day 7. The authors found ultrasound to be more accurate when compared with the clinical examination in terms of sensitivity (98% vs 86%), specificity (88% vs 70%), positive predictive value (93% vs 81%), and negative predictive value (97% vs 77%).

The findings on bedside soft tissue ultrasound can dramatically alter how the patient is managed. Tayal et al enrolled 126 patients with soft tissue infections and asked the clinicians about their treatment plan.[80] Ultrasonography was then performed by 1 of the study physicians who had significant experience in the use of emergency ultrasound. Overall, the ultrasound findings resulted in a change in management in 71 of the 126 patients (56%). The changes included new plans for drainage (all of which returned purulent material), sparing a planned drainage, and further testing or consultation. Interestingly, although not the purpose of the study, 4 other diagnoses were made using BUS, including enlarged lymph nodes, DVT, and superficial phlebitis.

In addition to its value in assessing cutaneous infections, ultrasound has been found useful in the diagnosis and management of suspected peritonsillar abscesses (PTA).[82-84] In this situation, a high-frequency intracavitary probe is used to visualize the posterior pharyngeal space. In a descriptive study, Lyon and Blaivas retrospectively reviewed 43 cases of patients with clinically suspected PTA who underwent BUS in their ED.[84] Thirty-five (81%) were diagnosed with PTA and 8 (19%) with tonsillar cellulitis. All patients diagnosed with PTA underwent ultrasound-guided drainage in the ED with no complications or need for return visits, although no formal follow-up was carried out.

Foreign Bodies, Joint Effusions, And Fractures

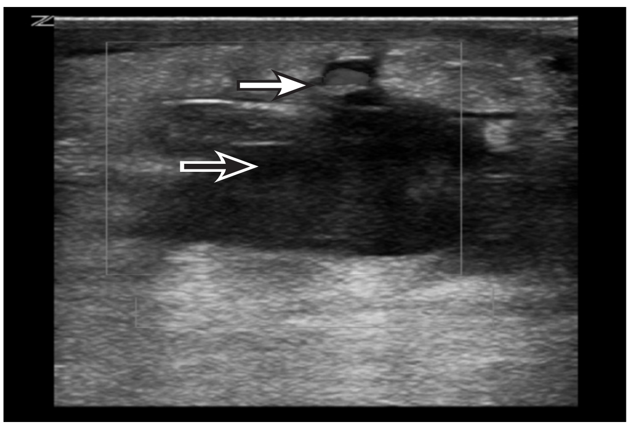
Bedside ultrasound is also useful for other common soft tissue and musculoskeletal diagnosis in the ED. Ultrasound can be used to screen for superficial foreign bodies, although it has significant limitations. A variety of studies have sought to determine the accuracy of ultrasound for foreign body localization, often in cadaveric or simulated models, with varied results.[85-91] One study demonstrated a sensitivity of 93% for detecting radiolucent wooden objects and of 73% for detecting radiolucent plastic objects in human cadaver legs.[88] In another study, minimally trained emergency physicians used ultrasound to detect small foreign bodies (less than 5 mm).[89] Ultrasound was found to have an overall sensitivity of 53% and a specificity of 47%, with a positive predictive value of 80%. It is likely that the sensitivity and specificity achieved in localizing a foreign body depends on numerous factors, including the experience of the sonographer, the frequency and quality of the transducer, the type of tissue model used, as well as the composition, size, and depth of the foreign body.

Ultrasound can be used to both diagnose joint effusions and to assist in arthrocentesis. In a randomized trial comparing ultrasound-guided versus landmark-based knee arthrocentesis, the findings on ultrasound did not change the success rate of the procedure but did lead to more fluid aspirated and to greater provider confidence.[92] Case series have been reported that describe the diagnosis and drainage of ankle effusions and of both adult and pediatric hip effusions by emergency physicians using ultrasound in the ED.[93-95]

Although the current standard of care for the evaluation of bony fractures is radiography (as well as CT and MRI), ultrasound may potentially be useful in a number of scenarios. In certain environments where plain x-rays are not available (such as military battlefields, in space, or remote or international locations), ultrasound may potentially be utilized for diagnosing fractures with acceptable accuracy. In a study of 58 patients with suspected long-bone fractures, ultrasound had a sensitivity of 92% and specificity of 83% compared with x-ray and was more sensitive than physical examination for the diagnosis of fractures.[96] In another study designed to evaluate extremity injury in austere settings, nonphysician personnel, using ultrasound, correctly diagnosed extremity injuries in 94% of patients.[97]

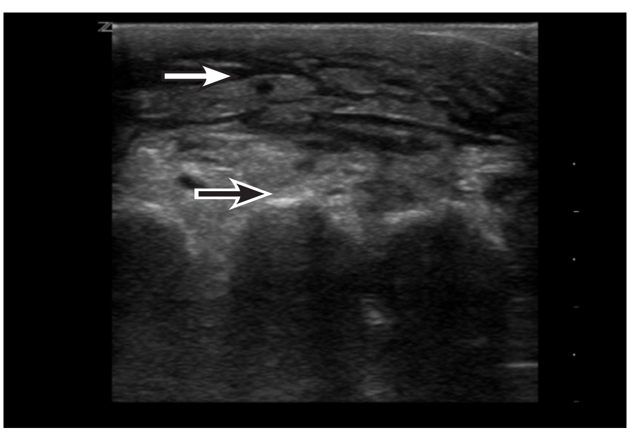
Ultrasound may be superior to plain x-ray for select fractures that are traditionally difficult to evaluate by radiography. In a study of 88 patients with chest trauma, ultrasound was found to be superior to clinical acumen and radiography for detecting rib and sternal fractures.[98] In certain clinical situations, ultrasound may be useful in expediting and assisting management, such as during bedside reduction requiring sedation. In 1 study of 68 pediatric patients with suspected forearm fractures, ultrasound had a sensitivity of 97% and a specificity of 100% for detecting fractures when compared with plain films.[99] Ultrasound-guided reduction of those fractures had an initial success rate of 92%, with only 2 of 26 patients requiring re-reduction based on x-ray findings.

Figure 10. Color-Flow Doppler Of Blood Vessel Overlying Abscess



White arrow demonstrates flow in a superficial vessel overlying the abscess.
Black arrow points to the irregularly bordered hypoechoic abscess.
Ultrasound can help locate an abscess; color Doppler can help avoid vessels when planning incision and drainage procedures.

Figure 11. Cobble-Stoning Consistent With Cellulitis



White arrow points to the "cobblestone" appearance of inflamed cellulitic tissue without identifiable fluid collection.
Black arrow points to bone with underlying shadow.

Conclusions

Bedside ultrasound has been shown to be of value in a wide range of soft tissue and musculoskeletal applications. Ongoing research and increasing utilization at the bedside will provide greater understanding of the benefits and limitations of each of the various applications.

Ocular Ultrasound

Bedside ocular ultrasound has been used by emergency clinicians to detect various disorders within the eye as well as a tool to screen for increased intracranial pressure.

Ocular Disorders

Approximately 2 million people present each year to the ED with ocular injuries.[100] In a busy setting, delays in obtaining CT or MRI imaging or ophthalmologic consultation can become significant. In addition, in many cases of acute ocular injuries, physical examination can be challenging and quite limited. The ability to rapidly assess the eye with a noninvasive bedside examination performed in the ED can help diagnose and expedite the work-up for potentially vision-threatening conditions.

Since the anterior and posterior chambers of the eye contain vitreous fluid, the eye is an ideal acoustic window for ultrasound imaging. Moreover, the contralateral eye can serve as a normal control for the symptomatic eye. Structures such as the anterior chamber, lens, posterior chamber, retina, and optic nerve can all be visualized. As such, conditions such as retinal detachment, vitreous hemorrhage, ocular foreign bodies, lens dislocation, retrobulbar hematoma, and globe rupture can be detected on BUS. **(See Figure 12.)** Because of the dynamic nature of ultrasound imaging, extraocular eye movements and pupillary response can also be visualized on ultrasound, even when swollen lids prevent direct visualization.[101]

Although ophthalmologists have been using ocular ultrasound for decades, emergency clinicians have only recently begun to incorporate this tool into their practice.[102,103] The current technique involves the high-frequency linear-array transducer (7.5-10 MHz), which is the same probe used for ultrasound-guided vascular access or soft tissue ultrasound. In the largest study of bedside ocular ultrasound performed by emergency physicians, Blavais et al evaluated 61 patients who presented to the ED with a history of eye trauma or an acute change in vision.[104] The study physicians included residents and attending emergency physicians who received a 1-hour lecture and 1 hour of hands-on instruction by an ultrasound-fellowship-trained emergency physician. Of the 61 total patients, 26 (43%) were found to have intraocular disorders on BUS. The findings included 9 retinal detachments, 5 vitreous hemorrhages, 3 globe ruptures, 2 lens dislocations, and 1 central retinal artery occlusion. Other findings included papilledema and intraocular foreign body. Ultrasound examinations were followed by either orbital CT or formal ophthalmologic evaluation and were in agreement with the confirmatory studies in 60 out of 61 cases, with a resulting sensitivity of 100% and specificity of 97%. This descriptive feasibility study demonstrated that emergency physicians could accurately detect intraocular disorders using BUS.

Other small studies have described the use of ocular ultrasound in penetrating ocular injuries, to detect intraocular foreign bodies in a porcine eye model, and even aboard the International Space Station.[105-107] There have been no further large studies, however, to confirm these initial results.

Screening For Increased Intracranial Pressure

There is a growing body of literature describing the use of ocular ultrasound as a noninvasive method to detect elevated intracranial pressures (ICP). Increased ICP is transmitted through the subarachnoid space surrounding the optic nerve, causing expansion of the optic nerve sheath. The optic nerve sheath diameter (ONSD) can be measured on ultrasound using either the visual axis (probe placed directly over the closed eyelid in transverse orientation) or the coronal axis (probe placed temporally and directed nasally).[108] **(See Figure 13.)** The approach most widely used is the visual axis, which measures the diameter of the optic nerve sheath at a point 3 mm posterior to the globe.[109] Unlike most BUS examinations, which are adept at "ruling in" pathology, the current literature suggests that an ONSD of less than 5 mm may have excellent specificity for "ruling out" elevated ICP.

In an observational study involving 59 adult patients with head injury in the ED, Tayal et al measured ONSD using ultrasound and compared the results with CT findings suggestive of increased ICP.[109] The finding of an ONSD greater than 5 mm on BUS had a sensitivity of 100% and a specificity of 63%, with a negative predictive value of 100% for the increased ICP noted on CT.

Using direct measurements of increased ICP by means of ventriculostomy (serving as the gold standard), 3 recent studies with slightly different protocols further characterized the direct correlation between ONSD and ICP with slightly varied results. The conclusion from these studies is that ONSD has a strong statistical correlation with ICP but that exact ICP prediction based on ONSD remains difficult and further studies evaluating different techniques are required. Ultrasound will not replace the need for invasive intracranial monitoring, but it can be used as a helpful bedside screening tool. A useful approach to assessing ICP is ONSD < 5 mm, no elevated ICP; ONSD > 6 mm, elevated ICP likely; ONSD = 5 to 6 mm, elevated ICP indeterminate/possible.

Conclusions

Bedside ocular ultrasound is a relatively new modality and shows promise both in diagnosing a wide range of ocular disorders and as a screening tool for elevated ICP.

Ultrasound Of The Hepatobiliary System

Focused BUS of the hepatobiliary system is well-suited for ED investigations of suspected biliary disease. Gallbladder disease is endemic in our population; approximately 10% of adults have gallstones, although the prevalence varies with age, sex, and ethnicity. After age 60, 10% to 15% of men and 20% to 40% of women have gallstones.[110] Acute cholecystitis accounts for 3% to 9% of hospital admissions for acute abdominal pain, and the current practice standard is early cholecystectomy, making it an important diagnosis.

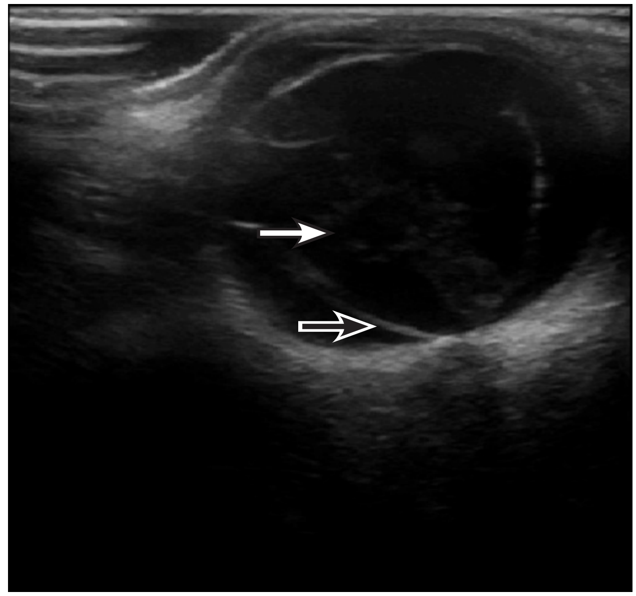
Nonetheless, the diagnosis of cholecystitis cannot be based on clinical examination and laboratory findings alone. One meta-analysis reported that no clinical or laboratory finding (including leukocytosis, fever, or Murphy's sign) had a sufficiently high-positive or low-negative likelihood ratio to rule in or rule out acute cholecystitis.[111]

The most commonly used imaging modality in suspected cholecystitis is right upper quadrant (RUQ) ultrasound. **(See Figures 14 and 15, page 14.)** Radiology-performed ultrasound has good sensitivity (88% to 94%) and specificity (78% to 80%) and is more convenient than radionuclide scanning, without the radiation exposure of CT.[110] In comparison with comprehensive radiology-performed ultrasound, emergency clinician–performed focused RUQ ultrasound describes a focused ultrasound performed at the patient's bedside and designed to answer targeted questions. It has excellent comparative sensitivity and specificity, can be performed and interpreted at the bedside, and has been shown to decrease ED length of stay.

Focused Ultrasound Of The Right Upper Quadrant

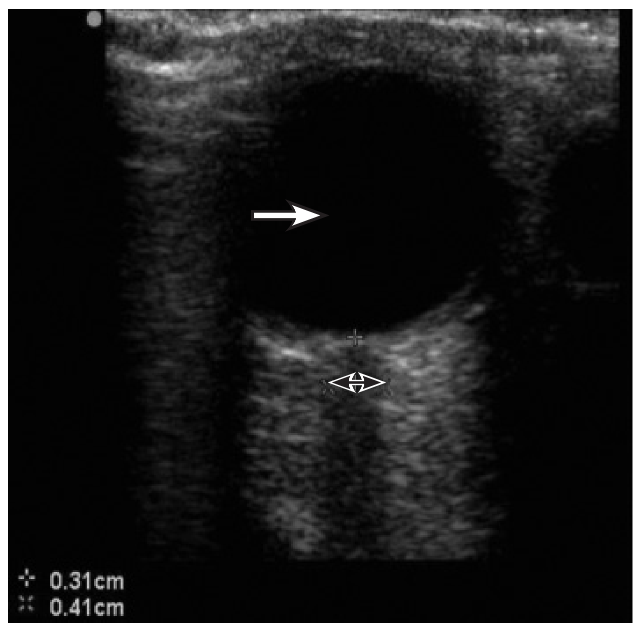
Although there are many sonographic criteria for acute cholecystitis (including gallstones, sonographic Murphy's sign, gallbladder wall thickening greater than 4 mm, pericholecystic fluid, and common bile duct dilation), gallstones are present in over 90% of cases of acute cholecystitis.[112] A radiology-performed study of 497 patients found the combination of gallstones with a positive sonographic Murphy's sign had a positive predictive value of 92%, and the combination of gallstones with a thickened gallbladder wall had a positive predictive value of 95% in diagnosing acute cholecystitis.[113] Hence, many studies of ED ultrasound of the gallbladder have focused on the presence of gallstones. This finding, along with a sonographic Murphy's sign or thickened gallbladder wall, can then be considered in conjunction with the clinical presentation and laboratory findings.

Figure 12. Retinal Detachment On Visual Axis



White arrow points to associated vitreous hemorrhage, the heterogeneous gray material within the anechoic vitreous fluid.
Black arrow points to detached retina.

Figure 13. Normal Optic Nerve Sheath Diameter On Visual Axis



White arrow points to normal ocular globe with black (anechoic) vitreous fluid. By convention, the optic nerve sheath diameter is measured 3 mm posterior to the retina.
Black arrowheads demonstrate a normal optic nerve sheath diameter (ONSD) measurement of 4.1 mm.

Emergency clinicians are adept at finding gallstones on BUS. In a study of 109 patients with suspected biliary disease in the ED, emergency physicians (minimally trained attending physicians and residents) demonstrated a sensitivity of 96% and specificity of 88% in diagnosing cholelithiasis on ultrasound compared with the radiology-performed ultrasound.[114] These emergency physicians were more accurate than radiologists in assessing for sonographic Murphy's sign (as compared with pathologic specimens of acute cholecystitis), and the average length of the emergency physician–performed study was less than 10 minutes. In a similar study of 116 ED patients suspected of biliary disease, ultrasound performed by 15 emergency medicine attending physicians with various amounts of prior training had a sensitivity of 92% and specificity of 78% for cholelithiasis compared with radiology-performed ultrasound.[115] They also noted a sensitivity of 91% and specificity of 66% for diagnosing acute cholecystitis (using stones and positive Murphy's sign) compared with clinical follow-up. Although ED clinicians demonstrate excellent ability to find gallstones, the presence of gallstones and sonographic Murphy's sign on emergency clinician–performed BUS should be considered within the larger clinical context of each individual patient (including physical examination and laboratory findings).

Learning Curve For Bedside Ultrasound

As in all cases of BUS, the performance and interpretation of the findings are operator-dependent. Currently, ACEP recommends 25 to 50 documented and reviewed cases to become clinically competent.[1] There is some literature to support these recommendations. Gaspari et al reviewed 352 RUQ ultrasound studies by emergency medicine residents and attendings in an academic ED for both technical and interpretive errors.[116] They found that the number of poor-quality ultrasound scans decreased after the operator had performed 7 examinations and that sonographers who had performed over 25 ultrasound examinations had an excellent level of agreement with the expert over-reads for detecting cholelithiasis (kappa = 0.92). Jang et al evaluated the learning curve for resident-performed RUQ ultrasound based on a gold standard of radiology-performed RUQ ultrasound/CT or pathology results and found the sensitivity and specificity for cholelithiasis or cholecystitis increased from 83% to 96% and from 88% to 100%, respectively, after residents performed 20 scans.[117]

Length Of Stay In The Emergency Department

One of the benefits of emergency clinician–performed BUS is the potential for expedited patient flow. A retrospective review of 1252 cases of suspected cholecystitis demonstrated that a bedside RUQ ultrasound performed by emergency physicians versus radiology-performed ultrasound decreased length of stay by 7% (22 min) overall and 15% (52 min) during evening or nighttime hours.[118]

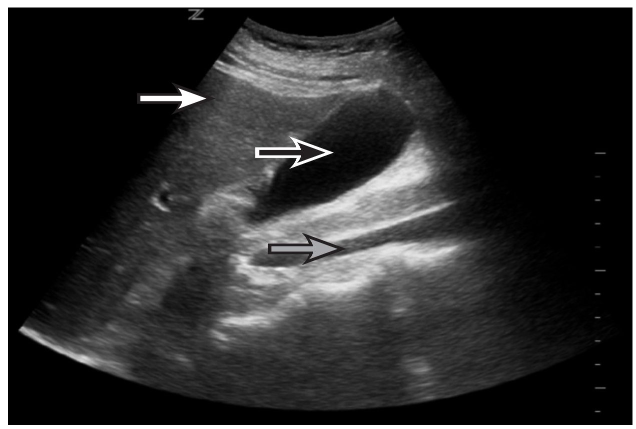
Conclusions

Focused ED biliary ultrasound can answer key clinical questions, such as whether gallstones or the sonographic Murphy's sign are present, and that information can then be incorporated into the clinical context of the patient's presentation. Studies demonstrate that emergency clinicians can achieve ultrasound results with reasonable sensitivity and specificity after a brief learning curve. Bedside biliary ultrasound has the potential to improve patient flow and decrease ED length of stay.

Ultrasound For Procedural Guidance

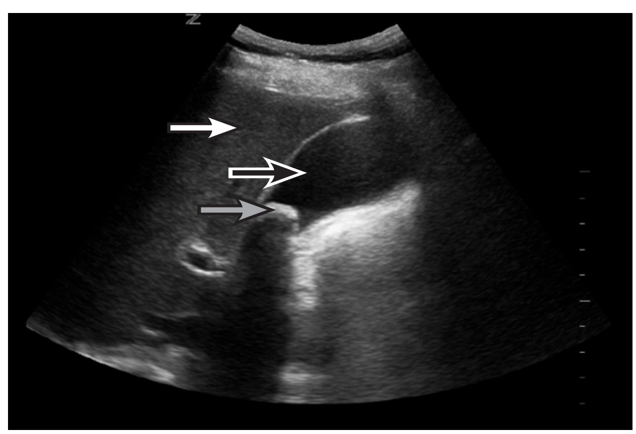
The use of ultrasound for procedural guidance has been well-established in the radiology literature. In more

Figure 14. Normal Long-Axis View Of The Gallbladder



White arrow points to liver.
Black arrow points to normal fluid-filled anechoic gallbladder.
Gray arrow points to the inferior vena cava.

Figure 15. Gallstone In Gallbladder Neck On Long-Axis View



White arrow points to liver.
Black arrow points to gallbladder.
Gray arrow points to large gallstone, with characteristic shadowing, located in the gallbladder neck.

recent years, sonography has moved from the radiology suite to the bedside and is used by a variety of practitioners to improve the safety and success of potentially dangerous procedures.

Central Venous Catheterization

Central venous catheterization is a procedure that is often required for critically ill ED patients. Although this is generally a safe procedure, the complication rate has been reported to vary from 3% to as high as 20% in some studies.[119-121] Complications range from minimal to life-threatening and include arterial cannulation, pneumothorax, cardiac tamponade, air embolus, hematoma formation, and injury to adjacent neurovascular structures. The goal of real-time ultrasound is to enable the operator to visualize the target vessel and surrounding structures before and during needle insertion. **(See Figure 16.)** While the traditional landmark technique is successful in many cases, factors such as patient body habitus, prior cannulation, the presence of scar tissue or thrombus, and variant anatomy can all make the landmark approach to vascular access more difficult.

There is ample literature supporting the use of ultrasound for the placement of central venous catheters. Leung et al in a randomized prospective trial demonstrated the superiority of sonographic guidance compared with landmark methods in the rate of successful internal jugular venous catheterization and the rate of complications, even when performed by inexperienced operators (as defined by those with less than 25 previous central venous catheterizations).[119] Various other authors have demonstrated decreased time for cannulation and the need for fewer attempts, even with minimal training in the use of ultrasound.[120-124] Miller and colleagues showed a significantly reduced time for central venous catheter placement in their study, with operators having minimal ultrasound training (1 hr) prior to participation.[125] Of note, the greatest reduction in time to successful line placement in this study was seen in patients considered to have difficult access, as defined by coagulopathy, obesity, abnormal anatomy, or a history of intravenous drug use.

It should be mentioned that there are concerns with the routine use of ultrasound for central line placement. Potential disadvantages include a time-consuming learning process, an initial delay due to set-up, the need to prepare the machine and the transducer (applying a sterile probe cover) for use, and the initial cost of an actual ultrasound machine for use in the clinical setting. In addition, more clinical trials may be needed to prove the utility of sonographic guidance for sites other than the internal jugular vein, since there are limited data on subclavian, axillary, and femoral approaches.[126-129] A recent case series reported 6 accidental arterial cannulations despite ultrasound guidence.[130] The authors report that the short-axis approach can lead to a false sense of security and that the long-axis approach should also be used to verify the position of the needle or guidewire in the vein.

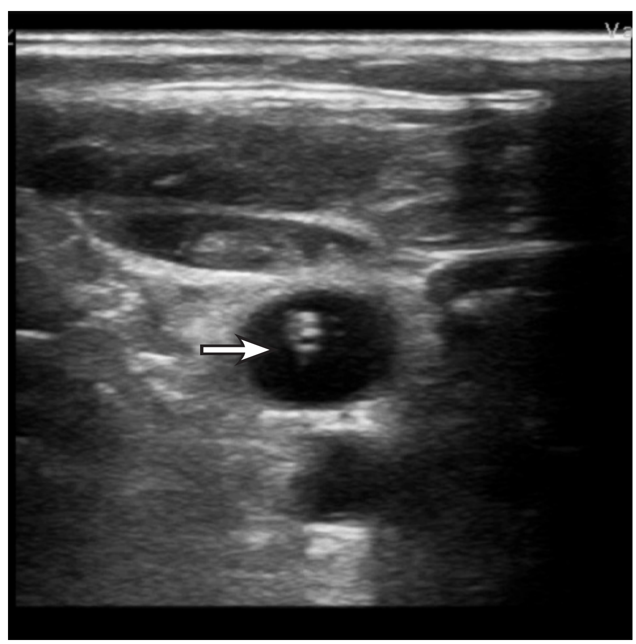
The potential limitations of ultrasound are outweighed, however, by the evidence supporting its routine use for central line placement. The role of real-time ultrasonographic guidance has become so well-established in the medical literature that it is now recommended by multiple societies, including the Agency for Healthcare Research and Quality,[131] the American College of Emergency Physicians,[1] the American College of Chest Physicians,[132] and the British National Institute for Clinical Excellence.[133] Given this overwhelming support and the potential for error reduction as compared with traditional landmark techniques for line placement, ultrasound guidance for central venous catheterization should be used whenever possible and is considered by many to be the standard of care.

Paracentesis

Paracentesis, thoracentesis, and pericardiocentesis are all commonly performed procedures with potentially severe complications. The use of BUS has been advocated as a means to decrease the incidence of complications as well as to improve procedure success.

As early as 1970, clinicians realized that ascites and abdominal fluid could be detected by ultrasonogra-

Figure 16. Catheter In Internal Jugular Vein On Transverse View



Arrow points to catheter within the jugular vein.

In addition to using ultrasound to guide line placement, sonography can be used to confirm appropriate line placement.

phy.[134] Many authors consider this the "gold-standard" test for the diagnosis of ascites, since it can detect as little as 100 mL of fluid in the abdomen.[135,136]

Although paracentesis is generally safe when performed by the conventional method of blind-needle entry, it can be aided by the use of BUS, especially in patients with small or moderate amounts of abdominal fluid or with abnormal anatomy. The first clinicians to study the use of ultrasound for procedural guidance in paracentesis noted that loops of bowel were often present between the abdominal wall and the expected location of ascitic fluid based on physical examination.[137] They concluded that the distribution of ascites was too variable in most patients to identify a single ideal site for blind-needle puncture and that patients with minimal fluid in the abdomen were more difficult to drain without sonography.

Recent authors have examined the benefits of real-time procedural guidance during paracentesis. In a prospective randomized study comparing ultrasound guidance versus the traditional technique of needle entry, Nazeer and colleagues noted that ultrasound guidance improved the success rate of paracentesis and, moreover, identified a number of patients in whom the procedure could not be performed owing to the presence of too little fluid or the presence of another disease process that had been mislabeled as ascites based on physical examination.[138] Another interesting finding of this study was the ability of novice operators (emergency medicine residents given a 1-hour didactic course) to perform ultrasound guidance after minimal training.

Thoracentesis

The ability of ultrasound to detect disease processes in the thorax has been well established.[139] In the critically ill patient, the presence of pleural effusions can be easily detected on BUS and with greater accuracy than with portable chest radiography.[140,141] In patients with respiratory insufficiency due to pleural effusions, therapeutic thoracentesis may be indicated, with drainage of significant amounts of fluid. Patients with undifferentiated pleural effusions require diagnostic thoracentesis as a part of their medical work-up. Because both physical examination findings and the presence of a density on a chest radiograph can be misleading, ultrasound-guided thoracentesis offers a safer alternative to thoracentesis with blind-needle entry. Ultrasound allows for direct visualization of surrounding anatomic structures such as the liver, spleen, diaphragm, and lung parenchyma. In a prospective study of 26 patients referred for ultrasound-guided thoracentesis after failed attempts with blind-needle passage, Weingardt et al found that when the puncture sites from these previous attempts were examined, errors in needle placement were noted, including insertion below the hemidiaphragm, above the fluid collection, into consolidated lung, or into multiple solid organs.[142]

Thoracentesis is recognized as one of the most common causes of iatrogenic pneumothorax, and this is the most common major complication of this procedure.[143,144] It is noted to occur in 4% to 30% of cases performed without sonographic guidance, and of these, up to 50% of patients require tube thoracostomy.[145,146] A number of authors have noted that ultrasound-guided thoracentesis significantly decreases the rate of iatrogenic pneumothorax and the subsequent need for tube thoracostomy.[145,147-150] Ultrasound-guided thoracentesis has also been shown to decrease the incidence of other common minor complications, including cough and bleeding at the puncture site.[147] To decrease pain and improve patient comfort, BUS can be used in real time to visualize and anesthetize the pleural lining prior to puncture. An additional benefit of bedside sonography in this setting is post-procedure evaluation of the thorax for both pneumothorax and re-expansion pulmonary edema.

Pericardiocentesis

A number of diseases can lead to the development of a pericardial effusion. Typically, traumatic injury leads to the rapid accumulation of pericardial blood and cardiac tamponade, whereas chronic processes such as malignancy, infection, connective tissue disorders, and renal failure result in a more gradual accumulation of pericardial fluid. The ability to detect pericardial effusions and tamponade is important to the emergency clinician, since rapid decompensation or frank arrest can result from the hemodynamic effects of cardiac tamponade physiology.

Emergency echocardiography is rapid and noninvasive and can be performed at the bedside to detect pericardial effusions. **(See the section on Emergent Echocardiography, page 18.)** Once a pericardial effusion has been noted, management will vary according to patient status. The patient with cardiac tamponade and hemodynamic compromise may need emergent pericardiocentesis.[151]

For years, clinicians have been instructed to carry out emergent pericardiocentesis using a blind subxiphoid approach, with a complication rate reported to be near 50%.[152] Complications include ventricular puncture, coronary vascular laceration, pneumothorax, visceral abdominal puncture, and diaphragmatic injury. Bedside cardiac ultrasound guidance during this procedure has been shown by multiple authors to decrease the risk of these complications.[153-157] **(See Figure 17.)** The largest of these studies examined a series of 1127 patients over a period of 21 years and noted a complication rate below 5%, well below the rate reported for standard pericardiocentesis using the landmark-based approach. The same group published a study of pericardiocentesis in pediatric patients in which the use of ultrasound guidance not only resulted in a lower complication rate but also reduced the need for repeat drainage and surgical intervention, probably owing to more accurate catheter placement and increased drainage made possible by direct ultrasound visualization.[158] Interestingly, most authors note that the subxiphoid approach may not be the optimal approach, and that with ultrasound guidance, the parasternal or apical approach may provide more direct access to pericardial fluid.

One potential criticism of these studies is that they were carried out by cardiologists in a cardiology laboratory using large, cumbersome diagnostic echocardiography machines, which are not readily available in the ED. Despite this, the same basic principle of increased safety with direct visualization should apply in emergency situations. In addition, one group has looked at the utility of hand-carried ultrasound for procedural guidance during pericardiocentesis and thoracentesis. Although a small study, their results indicate that this is not only feasible but also increases patient safety.[159]

Conclusions

Sonographic guidance has resulted in improved success, more rapid completion, and decreased incidence of iatrogenic injury for a variety of procedures. Whether using the static or dynamic technique, needle-guidance should be performed with ultrasound, whenever possible. In particular, the use of ultrasound guidance for central venous catheterization is nearly uniformly recommended by professional societies and healthcare quality agencies around the globe.

Ultrasound Of The Urinary Tract

Ultrasound of the renal and urinary system is easily performed and is a core application of emergency ultrasound.[1] It is fundamental to the evaluation of patients who present to the ED with undifferentiated flank or abdominal pain and is an integral component of the FAST examination. **(See Figure 18, page 18.)** Although not typically a life-saving examination, renal and urinary tract ultrasound can expedite patient care and avoid exposing patients to unnecessary ionizing radiation. The scan focuses on identifying hydronephrosis, assessing for ureteral jets, and determining bladder volume. Possible additional findings on urinary tract ultrasound include renal cysts or masses and bladder masses as well as abdominal aortic aneurysms, which often present similarly.

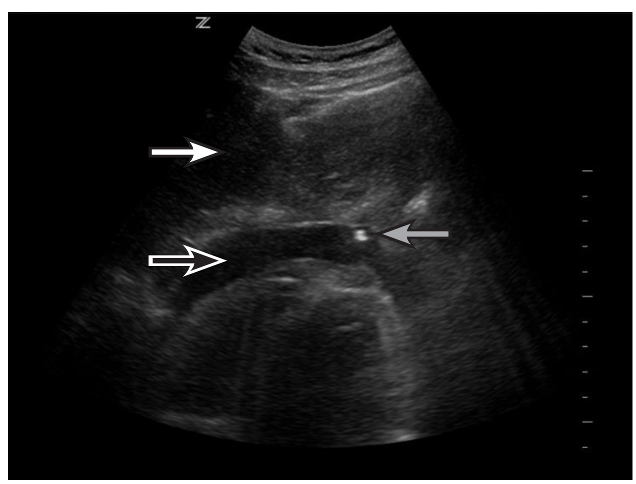
Assessing For Hydronephrosis

Hydronephrosis is noted on ultrasound when dilatation of the calyces and pelvis result in anechoic areas within the central collecting system. **(See Figure 19, page 18.)** Use of color-flow Doppler can help differentiate between renal vasculature and hydronephrosis. When hydronephrosis is noted, it is important to determine whether the obstruction is unilateral or bilateral and, if possible, intrinsic or extrinsic. Hydronephrosis is usually graded as follows: mild (defined by prominent calyces and mild splaying of the renal pelvis), moderate (characterized by a bear-claw appearance), or severe (defined by the presence of cortical thinning). Of note, hydronephrosis may be challenging to appreciate in volume-depleted patients; such patients may need to be hydrated first.

When combined with urine studies and clinical examination, BUS helps the emergency clinician better differentiate the diagnosis in patients who present with acute flank pain. Studies show that the sensitivity of emergency physician–performed urinary tract ultrasound for the detection of hydronephrosis approaches that reported in the radiology literature. Rosen et al examined the use of ultrasound by emergency physicians to detect hydronephrosis in patients with ureteral colic and reported the following test characteristics: sensitivity of 72%, specificity of 73%, positive predictive value of 85%, and negative predictive value of 54%.[160] Gaspari and Horst assessed the value of BUS in determining the cause of renal colic and found its overall sensitivity and specificity for detecting hydronephrosis to be 87% and 82%, respectively.[161] Stratification of the renal ultrasound data according to the results on urinalysis revealed a similar sensitivity (88%) and improved specificity (85%).

It has been suggested that the presence or absence and frequency of ureteral jets (assessed with color-flow or power Doppler) correlate with the presence or absence and degree of ureteral obstruction. The value of Doppler visualization of ureteral jets in hydronephrosis has been studied in both children and adults, and re-

Figure 17. Pericardiocentesis Using Subxiphoid Approach



White arrow points to liver.
Black arrow points to pericardial effusion.
Gray arrow points to the needle tip visualized in the pericardial space.

Subxiphoid view of the heart demonstrating a pericardial effusion. This patient arrested and had emergent pericardiocentesis performed from the subcostal approach.

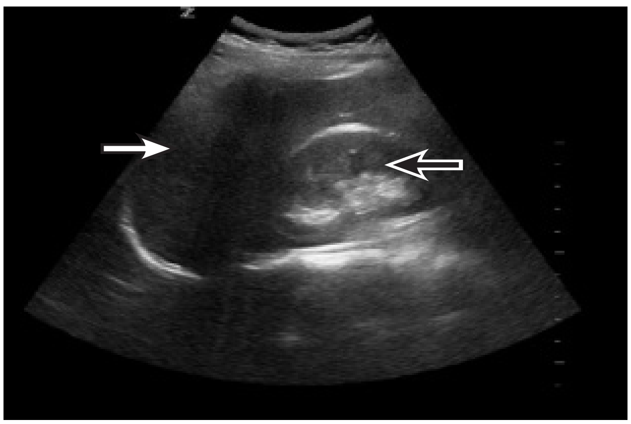
sults are encouraging in terms of differentiating severe from nonsignificant obstruction.[162,163]

Bladder Ultrasound Prior To Urethral Catheterization In Young Children

Bladder catheterization is the method of choice for obtaining appropriate urine samples in young children. The minimum volume of urine necessary for accurate urinalysis and culture is 2 mL,[164] yet it is often unclear whether or not the patient has a sufficient amount of urine in the bladder for the test to be of value. Urethral catheterization is uncomfortable and should not be repeated, to avoid urethral trauma and additional pain.

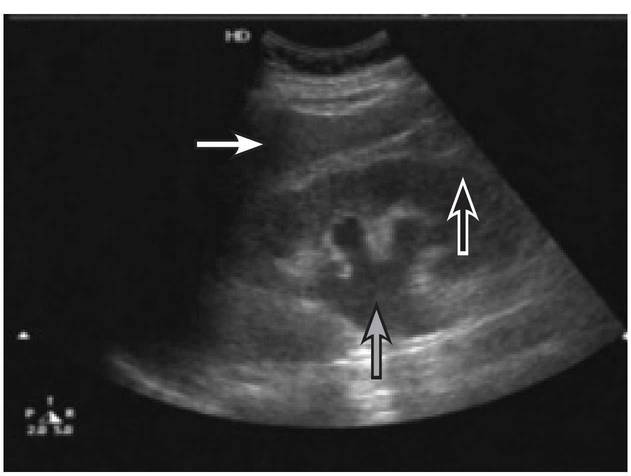
Bedside ultrasound is a simple, noninvasive modality that can assess bladder volume and has been shown to reduce the number of unsuccessful urethral catheterization attempts because of an empty bladder.[164-171] Chen et al performed a prospective, 2-phase study comparing success rates between an observational period and an intervention phase in which rapid BUS was performed prior to urethral catheterization. They noted that 24% of the patients were initially identified as having insufficient urine and that the overall initial urethral catheterization success rate was higher with the use of ultrasound (96%) than without (72%).[169] Milling et al likewise performed a prospective study on the use of ultrasound in infants undergoing urinary catheterization.[170] Although they observed a similar urinary catheterization failure rate (16%), they developed a urinary bladder index (ie, the product of anteroposterior and transverse diameters expressed in centimeters squared) and determined its sensitivity and specificity. Milling et al found that the sensitivity of this index in predicting the failure to obtain 2 mL of urine was 100% and that its specificity was 97%.[170] Several other studies have demonstrated the value of performing BUS prior to suprapubic bladder aspiration.[172-175] Both Gochman et al[172] and Munir et al[173] showed that ultrasound significantly improved suprapubic aspiration success rates and decreased the number of failed attempts.

Figure 18. Normal Kidney On Coronal View



White arrow points to liver.
Black arrow points to right kidney.

Figure 19. Mild To Moderate Hydronephrosis On Coronal View



White arrow points to liver.
Black arrow points to right kidney.
Gray arrow points to moderate hydronephrosis.

Conclusions

Renal ultrasound has been shown to be useful in the management of patients who present to the ED with undifferentiated flank or abdominal pain. Renal and urinary tract ultrasound may obviate CT in a subset of ED patients and, in doing so, decrease ED length of stay and avoid unnecessary exposure to ionizing radiation. Bladder ultrasound is simple and noninvasive and should be performed in order to decrease the number of unsuccessful urethral catheterization attempts in young children.

Emergent Echocardiography

Emergency echocardiography is a core application of emergency ultrasound and is a key element of the FAST examination.[1,176,177] Although comprehending image orientation[178] and acquiring images can be somewhat challenging, emergency echocardiography has had a major impact on emergency clinicians' ability to detect cardiac abnormalities and on patient care and can be life-saving.[179] **(See Figure 20.)** It provides emergency clinicians with time-sensitive anatomic and physiologic information in a variety of cardiac-related scenarios, including cardiac arrest, unexplained hypotension, syncope, shortness of breath, and chest pain.[180-183] Emergency echocardiography can help risk-stratify patients in the ED and further guide resuscitative efforts.[184,185] At times, the information and disorders noted on focused cardiac ultrasound are vast and may surpass what the emergency clinician is able to appreciate and integrate. As per the American Society of Echocardiography (ASE)/ACEP Consensus

Statement, the ability to assess global left ventricular function and detect pericardial effusions and right heart dilatation (chamber sizes) are within the scope of emergency clinicians and can help answer critical patient management questions.[186,187]

Left Ventricular Function

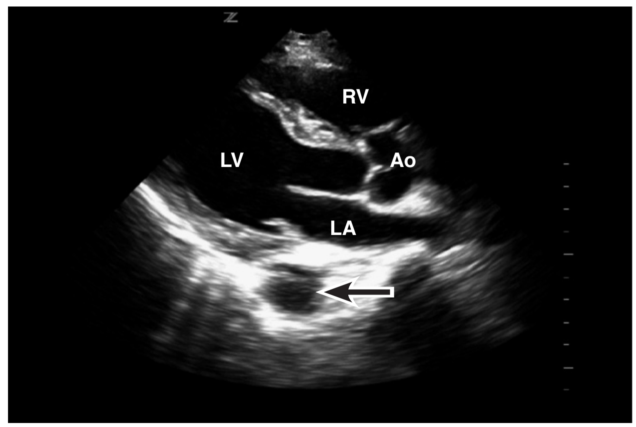
Assessment of left ventricular function is a fundamental application of emergency echocardiography and helps predict clinical outcomes for a variety of disease states. The ability to assess a patient's overall left ventricular function — from cardiac standstill to a hyperdynamic ejection fraction — allows emergency clinicians to better manage patients who present with chest pain, dyspnea, or unexplained hypotension or who are in cardiac arrest.[188] Although regional wall motion abnormalities and quantitative measurements are beyond the scope of most emergency clinicians, the visual (qualitative) assessment of global left ventricular systolic function is not.[187] With appropriate education and training, emergency clinicians can differentiate between normal and severely depressed left ventricular systolic function similar to cardiologists. Moore et al demonstrated that, with focused training, emergency physicians can accurately determine left ventricular function in hypotensive patients.[188] Although this study showed good agreement between emergency physicians and cardiologists for patients with normal and severely depressed left ventricular function, emergency physicians had more trouble categorizing patients with moderately depressed left ventricular function. This underscores the need for emergency clinicians to recognize their limitations and to obtain consultative imaging studies when indicated.

Pericardial Effusions

Pericardial fluid typically appears as an anechoic space between the epicardium and the pericardium. **(See Figure 21.)** Ultrasound is an ideal modality to detect the presence of pericardial fluid and its impact on right heart filling.[177,189,190] Although cardiac tamponade is largely a clinical diagnosis, emergency echocardiography may demonstrate findings consistent with impending tamponade prior to the development of physical examination findings and hemodynamic compromise.[191-193] The amount of fluid required to impair filling and cause circulatory failure depends on the rate of accumulation. Pericardial effusions may be graded as small (less than 10 mm), moderate (10-15 mm), or large (greater than 15 mm).[193-196]

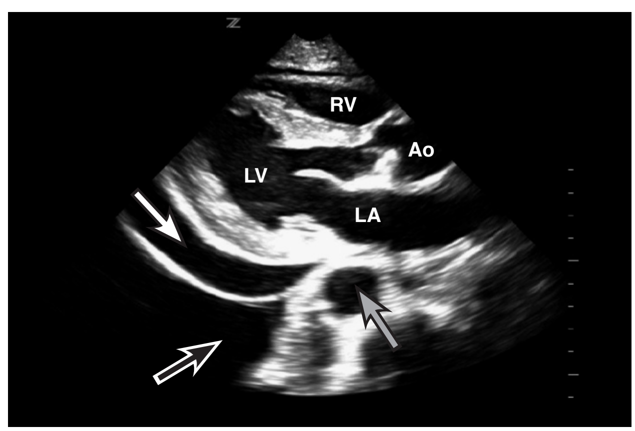
Numerous studies have demonstrated that emergency physician–performed emergency echocardiography has sensitivities approaching 100% for the detection of pericardial effusions.[184,197,198] When compared with the expert over-read of images, emergency physician–performed emergency echocardiography for effusion has a sensitivity of 96% to 100%, a specificity of 98% to 100%, a positive predictive value of 93% to 100%, and a negative predictive value of 99% to 100%.[1] The echocardiographic findings consistent with cardiac tamponade include the following: right ventricular (RV) free wall inversion during ventricular diastole (the hallmark finding), right atrial inversion during ventricular systole (more common and one of the earliest findings), increased respiratory variation of mitral or aortic inflow velocities (inspiratory decrease greater than 25%), and a dilated inferior vena cava with decreased inspiratory collapse.[196]

Figure 20. Normal Parasternal Long-Axis View



Normal parasternal long axis view demonstrating the left atrium (LA), left ventricle (LV), aortic root (Ao), right ventricle (RV), and descending thoracic aorta (black arrow).

Figure 21. Pericardial And Left Pleural Effusions On Parasternal Long-Axis View



White arrow points to pericardial effusion.
Black arrow points to left pleural effusion.
Gray arrow points to descending thoracic aorta.
Abbreviations: Ao, aortic root; LA, left atrium; LV, left ventricle; RV, right ventricle.

Parasternal long axis view demonstrating both a pericardial effusion and a left pleural effusion. Pericardial effusions track anterior to the descending thoracic aorta; left pleural effusions track posteriorly.

Risk-Management Pitfalls For Emergency Ultrasound

1. **"I didn't know there was so much literature to support the use of ultrasound."**
   Know the emergency ultrasound literature. For the previously established applications, research has moved beyond the assessment of technical and diagnostic accuracy and toward diagnostic decision-making and patient outcomes research.

2. **"The views weren't great, but the images I did see looked negative, so I sent the patient home."**
   Know your limitations. When used appropriately, clinician-performed bedside ultrasound is a powerful tool that can improve patient safety, improve quality of care, and decrease ED lengths of stay. Clinicians put their patients and themselves at risk, however, when they do not recognize the limitations of ultrasound and the limitations of their own ultrasound skills.

3. **"Ultrasound is great because its sensitivity is so high."**
   Be focused and specific. The goal of emergency ultrasound is to assess for specific abnormalities with appropriate sensitivity rather than performing comprehensive studies. It is more important for emergency clinicians to be able to recognize, integrate, and act on abnormal ultrasound findings, especially life-threatening ones, than to try and perform consultative ultrasound examinations.

4. **"There wasn't much space in the room, so I decided to scan the patient from the opposite side and use my non-dominant hand since it was closer."**
   Develop, perform, and practice your scanning approach the same way every time. Good scanning habits will avoid errors, improve consistency, and increase efficiency.

5. **"The ultrasound looked abnormal, so that must be the problem."**
   Avoid over-relying on or being overly influenced by information obtained on bedside ultrasound. Clinicians must always remember to integrate findings on ultrasound into the patient's overall clinical presentation (ie, findings on history and physical examination, laboratory studies, and results of other imaging modalities).

6. **"It looked abnormal on the initial view, so I stopped the exam and then called the consultant."**
   Remember to confirm or refute findings seen on 1 view with a second or multiple views. Findings seen on a single view may be secondary to artifact or may under- or over-represent an abnormal finding. Be sure to interrogate any abnormal finding from multiple different views in order to confirm and better characterize the finding. Avoid arriving at a final impression until multiple views have been attempted and used.

7. **"The initial ultrasound scan was negative, so I didn't bother to repeat it."**
   One of the many benefits of clinician-performed bedside ultrasound is its ability to be repeated. Repeat scans may reveal abnormal findings—which may have taken some time to accumulate—and should be performed when a patient's clinical course deteriorates.

8. **"It was so busy that I didn't have time to do the ultrasound."**
   With appropriate training and practice, emergency ultrasound can be performed rapidly and efficiently integrated into almost any patient work-up. For several of the 11 emergency ultrasound applications, decreased lengths of ED stay and significant time savings have been shown.

9. **"The FAST examination was negative, so I assumed the patient wasn't bleeding in the abdomen."**
   While the FAST examination has good sensitivity and excellent specificity for intraperitoneal bleeding, ultrasound is a poor diagnostic test for the detection of hollow viscous injury and retroperitoneal blood.

10. **"The patient had large-volume ascites, so I didn't need to use ultrasound to guide my paracentesis."**
    Loops of bowel can be present between the abdominal wall, and the expected location of ascitic fluid based on physical examination and the distribution of ascites may often be variable as well, even in patients with large fluid volumes.[137]

Right Heart Dilatation

Patients with right heart failure can be difficult to diagnose and manage. The thin-walled right ventricle (RV) is extremely sensitive to load, so small changes in pressure lead to large changes in volume. Right ventricular dilatation is the normal response to RV pressure or volume overload.[195] Although assessing for RV systolic dysfunction and for paradoxical septal motion are beyond the scope of most emergency clinicians, assessing for RV dilatation (chamber size) may not be.[187] Typically, the RV is smaller than the left ventricle (LV), with an RV-to-LV ratio of 0.6:1.0. When the RV is noted to be equal in size to the LV, the RV is moderately dilated. When the RV is larger than the LV, severe dilatation is present.[201] The apical 4-chamber view is used to compare RV and LV size, and the relative sizes are compared at the tips of the atrioventricular valves. When RV dilatation is present, the RV apex is closer to – or even encompasses – the LV apex.[196] In the appropriate clinical setting, RV dilatation can suggest RV outflow tract obstruction possibly due to pulmonary embolism; however, emergency echocardiography is not sensitive for pulmonary embolism. Patients with pulmonary embolism and evidence of right-heart dysfunction have increased morbidity and mortality, and emergency echocardiography can be used to risk-stratify and to better manage these patients.[201,202]

Conclusions

Emergency echocardiography provides emergency clinicians with immediate structural and physiologic data that can be life-saving. The ability to assess patients for pericardial effusions, global left ventricular function, and right heart dilatation can provide answers to critical questions, risk-stratify patients in the ED, and further guide resuscitative efforts. Although there is literature to support the ability of emergency clinicians to detect pericardial effusions and to assess global left ventricular function, future studies should further investigate their ability to detect echocardiographic signs of tamponade and right heart dilatation.

Summary

Many clinicians practice emergency medicine with minimal integration of clinician-performed bedside ultrasound. To save time, consultative studies are often ordered, and when that is not available, succumb to altering practice patterns or attempt to answer the clinical question through alternative means. Historically, emergency clinicians have provided high-quality patient care without it and can perhaps continue doing so — or perhaps it's time to change.

Emergency ultrasound has become increasingly available. The literature reviewed here supports its use and suggests that patient care can be improved when clinicians develop the knowledge and skills to perform bedside ultrasound. Like emergent airways and electrocardiograms, emergency ultrasound is now a core component of emergency medicine residency training and is becoming fundamental to the clinical practice of emergency medicine. It is now a part of the Advanced Trauma Life Support (ATLS) algorithm and may perhaps, in the not-so-distant future, be likewise integrated into Advanced Cardiac Life Support (ACLS) algorithms.

There are now 11 core emergency ultrasound applications available to emergency clinicians to help diagnose and guide treatment for a wide range of acute and life-threatening medical conditions. As this article has made evident, the existing literature on emergency ultrasound is sound for some applications and more preliminary for others. This literature continues to develop, and the quality of the work continues to improve. With larger data networks being formed, multicenter collaborative efforts are on the horizon and are likely to yield more evidence to support and to further define the evolving role of emergency ultrasound.

Case Conclusions

Having recruited your young colleague, an E-FAST examination is performed, and it is noted that the patient has free fluid in Morison's pouch. There is no fluid in the left upper quadrant, but fluid is present in the pelvis. Your interrogation of the right hemidiaphragm reveals a small-to-moderate amount of fluid above the diaphragm, consistent with a hemothorax. Your colleague helps you scan multiple rib interspaces over the anterior chest, revealing lung sliding on both the left and the right, consistent with no large pneumothorax. The subxiphoid view of the heart is somewhat limited, but no pericardial effusion is evident. Given the limited subxiphoid view, your colleague then helps you obtain a parasternal long-axis view of the heart, which confirms no pericardial effusion but is notable for severely depressed LV function and what appears to be a dilated LV. You then scan the patient's aorta and see no aneurysm. Your colleague then helps you interrogate the inferior vena cava, and you find it to be flat and with near complete collapse on inspiration. Integrating these ultrasound findings into the overall clinical picture, you surmise that the patient may have had a syncopal event from cardiomyopathy or dysrhythmia. In terms of the patient's hypotension, you rule out cardiac tamponade, tension pneumothorax, and a ruptured aortic aneurysm and conclude that it is most likely due to solid organ injury, intraperitoneal bleeding, and depressed LV function. Despite numerous attempts, the nursing staff is unable to place a second peripheral IV line, and you use the ultrasound machine to place a femoral introducer sheath on your first attempt. You ask for uncrossmatched blood to be made available and prepare the patient for transport to the operating room. Later in the week at your group meeting, you reflect on this case and consider how BUS helped you narrow your differen-

tial, provide time-sensitive physiologic information, guide your resuscitation, and perform an invasive procedure. You are excited to hear about the implementation of an ultrasound program, glad to know that there is literature supporting the use of ultrasound, and eager to learn more emergency ultrasound.

References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study, will be included in bold type following the reference, where available. In addition, the most informative references cited in this paper, as determined by the authors, will be noted by an asterisk (*) next to the number of the reference.

1. American College of Emergency Physicians. Emergency ultrasound guidelines – 2008. *Ann Emerg Med.* 2009;53:550-570. (Policy statement)
2. Kristensen JK, Buemann B, Kuhl E. Ultrasonic scanning in the diagnosis of splenic haematomas. *Acta Chir Scand.* 1971;137(7):653-657.
3. Kimura A, Otsuka T. Emergency center ultrasonography in the evaluation of hemoperitoneum: a prospective study. *J Trauma.* 1991;31(1):20-23. **(Prospective study; 72 patients)**
4. Tso P, Rodriguez A, Cooper C, et al. Sonography in blunt abdominal trauma: a preliminary progress report. *J Trauma.* 1992;33(1):39-43. **(Prospective study; 163 patients)**
5. Jehle D, Guarino J, Karamanoukian H. Emergency department ultrasound in the evaluation of blunt abdominal trauma. *Am J Emerg Med.* 1993;11(4):342-346. **(Study of 44 patients)**
6. Bode PJ, Niezen RA, van Vugt AB, et al. Abdominal ultrasound as a reliable indicator for conclusive laparotomy in blunt abdominal trauma. *J Trauma.* 1993;34(1):27-31. **(Retrospective review; 353 patients)**
7. American College of Surgeons. Advanced trauma life support for physicians. Chicago: ACS; 1997.
8. Hoff WS, Holevar M, Nagy KK, et al. Practice management guidelines for the evaluation of blunt abdominal trauma: the EAST practice management guidelines work group. *J Trauma.* 2002;53(3):602-615.
9. ACR Practice Guideline For The Performance Of An Ultrasound Examination Of The Abdomen And/Or Retroperitoneum. http://www.acr.org/SecondaryMainMenuCategories/quality_safety/guidelines/us/us_abdomen_retro.aspx
10. Stengel D, Bauwens K, Sehouli J, et al. Emergency ultrasound-based algorithms for diagnosing blunt abdominal trauma (Review). *The Cochrane Collaboration.* February 18, 2008. Hoboken, NJ: Wiley; 2008.
11.* Melniker LA, Leibner E, McKenney MG, et al. Randomized controlled clinical trial of point-of-care, limited ultrasonography for trauma in the emergency department: the first sonography outcomes assessment program trial. *Ann Emerg Med.* 2006;48(3):227-235. **(Multicenter, randomized, controlled trial; 262 patients)**
12.* Branney SW, Moore EE, Cantrill SV, et al. Ultrasound based key clinical pathway reduces the use of hospital resources for the evaluation of blunt abdominal trauma. *J Trauma.* 1997;42(6):1086-1090. **(Prospective study; 486 trauma patients vs. 516 historical controls)**
13. Helling TS, Wilson J, Augustosky K. The utility of focused abdominal ultrasound in blunt abdominal trauma: a reappraisal. *Am J Surg.* 2007;194(6):728-732; discussion 732-723. **(Retrospective study; 299 patients)**
14.* Plummer D, Brunette D, Asinger R, et al. Emergency department echocardiography improves outcome in penetrating cardiac injury. *Ann Emerg Med.* 1992;21:709-712. **(10-year retrospective study; 49 patients)**
15 Moylan M, Newgart C, Ma J, et al. Association between a positive ED FAST examination and therapeutic laparotomy in normotensive blunt trauma patients. *J Emerg Med.* 2007;33(3):265-271. **(Retrospective cohort analysis; 1636 patients)**
16.* Blaivas M, Lyon M, Duggal S. A prospective comparison of supine chest radiography and bedside ultrasound for the diagnosis of traumatic pneumothorax. *Acad Emerg Med.* 2005;12(9):844-849. **(Prospective, single-blinded study with convenience sampling; 176 patients enrolled)**
17. Rowan KR, Kirkpatrick AW, Liu D, et al. Traumatic pneumothorax detection with thoracic US: correlation with chest radiography and CT — initial experience. *Radiology.* 2002;225(1):210-214. **(Prospective analysis; 27 patients)**
18.* Soldati G, Testa A, Sher S, et al. Occult traumatic pneumothorax: diagnostic accuracy of lung ultrasonography in the emergency department. *Chest.* 2008;133(1):204-211. **(Prospective study; 109 trauma patients)**
19. Soldati G, Testa A, Pignataro G, et al. The ultrasonographic deep sulcus sign in traumatic pneumothorax. *Ultrasound Med Biol.* 2006;32(8):1157-1163. **(186 trauma patients)**
20. Zhang M, Liu ZH, Yang JX, et al. Rapid detection of pneumothorax by ultrasonography in patients with multiple trauma. *Crit Care.* 2006;10(4):R112. **(Prospective study; 135 patients)**
21.* Kirkpatrick AW, Sirois M, Laupland KB, et al. Hand-held thoracic sonography for detecting post-traumatic pneumothoraces: the Extended Focused Assessment with Sonography for Trauma (EFAST). *J Trauma.* 2004;57(2):288-295. **(Prospective study; 208 patients)**
22. Lichtenstein DA, Menu Y. A bedside ultrasound sign ruling out pneumothorax in the critically ill. Lung sliding. *Chest.* 1995;108(5):1345-1348. **(43 cases)**
23. Lichtenstein DA, Meziere G, Lascols N, et al. Ultrasound diagnosis of occult pneumothorax. *Crit Care Med.* 2005;33(6):1231-1238. **(Retrospective analysis; ICU patients)**
24. Ma OJ, Mateer JR, Ogata M, et al. Prospective analysis of a rapid trauma ultrasound examination performed by emergency physicians. *J Trauma.* 1995;38(6):879-885. **(Prospective study; 245 patients)**
25. Ma OJ, Mateer JR. Trauma ultrasound examination versus chest radiography in the detection of hemothorax. *Ann Emerg Med.* 1997;29(3):312-316. **(Retrospective study; 245 patients)**
26.* Sisley AC, Rozycki GS, Ballard RB, et al. Rapid detection of traumatic effusion using surgeon-performed ultrasonography. *J Trauma.* 1998;44(2):291-297. **(Prospective study; 360 patients)**
27. Wustner A, Gehmacher O, Hammerle S, et al. Ultrasound diagnosis in blunt thoracic trauma. *Ultraschall Med.* 2005;26(4):285-290. **(Prospective study; 100 trauma patients)**
28. Brooks A, Davies B, Smethhurst M, et al. Emergency ultrasound in the acute assessment of haemothorax. *Emerg Med J.* 2004;21(1):44-46. **(Prospective study; 61 patients)**
29. Rothlin MA, Naf R, Amgwerd M, et al. Ultrasound in blunt abdominal and thoracic trauma. *J Trauma.* 1993;34(4):488-495. **(Prospective study; 312 trauma patients)**
30. Juhl JH. Diseases of the pleura, mediastinum, and diaphragm. In: Juhl JH, Crummy AB, eds. *Essentials of Radiologic Imaging.* 6th ed. Philadelphia, Pa: Lippincott; 1993:1026.

31. Brenner DJ, Hall EJ. Computed tomography — an increasing source of radiation exposure. *N Engl J Med.* 2007;357(22):2277-2284.
32. Einstein AJ, Henzlova MJ, Rajagopalan S. Estimating risk of cancer associated with radiation exposure from 64-slice computed tomography coronary angiography. *JAMA.* 2007;298(3):317-323.
33. Sodickson A, Baeyens PF, Andriole KP, et al. Recurrent CT, cumulative radiation exposure, and associated radiation-induced cancer risks from CT of adults. *Radiology.* 2009;251(1):175-184.
34. Moore C, Promes SB. Ultrasound in pregnancy. In: Rosen CL, Wolfe RE, eds. *Emergency Medicine Clinics of North America – Ultrasound in Emergency Medicine.* Philadelphia, Pa: Saunders; 2004:697-722. **(Review)**
35. Filly RA. Ectopic pregnancy: the role of sonography. *Radiology.*1987;162(3):661-668. **(Review)**
36. Abbott J, Emmans LS, Lowenstein SR. Ectopic pregnancy: ten common pitfalls in diagnosis. *Am J Emerg Med.* 1990;8:515-522. **(Retrospective review; 65 patients)**
37. Blaivas M, Sierzenski P, Plecque D, et al. Do emergency physicians save time when locating a live intrauterine pregnancy? *Acad Emerg Med.* 2000;7(9):988-993. **(Retrospective chart review; 1419 patients)**
38. Durham B. Emergency medicine physicians saving time with ultrasound. *Am J Emerg Med.* 1996;14:309-313.**(Case Series)**
39. Mateer JR, Valley VT, Aiman EJ, et al. Outcome analysis of a protocol including bedside endovaginal sonography in patients at risk for ectopic pregnancy. *Ann Emerg Med.* 1996;27:283-289. **(Prospective; convenience sample of 314 patients; 56 historical controls)**
40. Kaplan BC, Dart RG, Moskos M, et al. Ectopic pregnancy: prospective study with improved diagnostic accuracy. *Ann Emerg Med.* 1996;28:10-17. **(Prospective; 481 patients)**
41. Durham B, Lane B, Burbridge L, et al. Pelvic ultrasound performed by emergency physicians for the detection of ectopic pregnancy in complicated first-trimester pregnancies. *Ann Emerg Med.* 1997;29:338-347. **(Prospective; 136 patients)**
42. Tayal VS, Cohen H, Norton HJ. Outcome of patients with an indeterminate emergency department first-trimester pelvic ultrasound to rule out ectopic pregnancy. *Acad Emerg Med.* 2004;11:912-917. **(Prospective, observational; 1490 patients)**
43. Stein JC, Wang R, Adler N, et al. Emergency physician ultrasonography for evaluating patients at risk for ectopic pregnancy: a meta-analysis. *Ann Emerg Med.* 2010;56(6):674-683. **(Meta-analysis; 2,057 patients, 152 with ectopic pregnancy)**
44. Pennell RG, Needleman L. Prospective comparison of vaginal and abdominal sonography in normal early pregnancy. *J Ultrasound Med.* 1991;10:63-67.
45. Dart R. Role of pelvic ultrasonography in evaluation of symptomatic first-trimester pregnancy. *Ann Emerg Med.* 1999;33:310-320. **(Review)**
46. Atri M, Valenti DA, Bret PM, et al. Effect of transvaginal sonography on the use of invasive procedures for evaluating patients with a clinical diagnosis of ectopic pregnancy. *J Clin Ultrasound.* 2003;22(4):409-410. **(Retrospective review; 290 patients)**
47. Burgher SW, Tandy TK, Dawdy MR. Transvaginal ultrasonography by emergency physicians decreases patient time in the emergency department. *Acad Emerg Med.* 1998;5:802-807. **(Retrospective analysis; 84 patients)**
48. Shih CH. Effect of emergency physician-performed pelvic sonography on length of stay in the emergency department. *Ann Emerg Med.* 1999;6:1020-1023. **(Prospective observational study; 115 patients)**
49. Durston WE, Carl ML, Guerra W, et al. Ultrasound availability in the evaluation of ectopic pregnancy in the ED: comparison of quality and cost-effectiveness with different approaches. *Am J Emerg Med.* 2000;18(4):408-417. **(Retrospective; 120 patients)**
50. Lederle FA, Simel DL. The rational clinical examination. Does this patient have abdominal aortic aneurysm? *JAMA.* 1999;281:77-82. **(Meta-analysis)**
51. Goldberg BB. Aortosonography. *Int Surg.* 1977;62:294-297.
52. Dent B, Kendall RJ, Boyle AA, et al. Emergency ultrasound of the abdominal aorta by UK emergency physicians: A prospective cohort study. *Emerg Med J.* 2007;24:547-549. **(Prospective cohort study)**
53. Costantino TG, Bruno EC, Handly N, et al. Accuracy of emergency medicine ultrasound in the evaluation of abdominal aortic aneurysm. *J Emerg Med.* 2005;29:455-460. **(238 patients)**
54. Knaut AL, Kendall JL, Patten R, et al. Ultrasonographic measurement of aortic diameter by emergency physicians approximates results obtained by computed tomography. *J Emerg Med.* 2005;28:119-126. **(104 patients)**
55. Tayal VS, Graf CD, Gibbs MA. Prospective study of accuracy and outcome of emergency ultrasound for abdominal aortic aneurysm over two years. *Acad Emerg Med.* 2003;10:867-871. **(Prospective study; 125 patients)**
56. Ashton HA, Buxton MJ, Day NE, et al. The Multicentre Aneurysm Screening Study (MASS) into the effect of abdominal aortic aneurysm screening on mortality in men: A randomised controlled trial. *Lancet.* 2002;360:1531-1539. **(Randomized, controlled trial of screening)**
57. Multicentre Aneurysm Screening Study Group. MulticentreAneurysm Screening Study (MASS): Cost effectiveness analysis of screening for abdominal aortic aneurysms based on four year results from randomised controlled trial. *BMJ.* 2002;325:1135-1141. **(Randomized, controlled trial of screening; 67,800 males; follow-up analysis)**
58. Cosford PA, Leng GC. Screening for abdominal aortic aneurysm. *Cochrane Database Syst Rev.* 2007;(2):CD002945. **(Review)**
59. Moore CL, Holliday RS, Hwang JQ, et al. Screening for abdominal aortic aneurysm in asymptomatic at-risk patients using emergency ultrasound. *Am J Emerg Med.* 2008;26:883-887. **(Screening study; 179 patients)**
60. Catalano O, Lobianco R, Cusati B, et al. Contrast-enhanced sonography for diagnosis of ruptured abdominal aortic aneurysm. *AJR Am J Roentgenol.* 2005;184:423-427. **(Case series)**
61. Catalano O, Sandomenico F, Raso MM, et al. Real-time, contrast-enhanced sonography: a new tool for detecting active bleeding. *J Trauma.* 2005;59:933-939. **(Case series)**
62. Fojtik JP, Costantino TG, Dean AJ. The diagnosis of aortic dissection by emergency medicine ultrasound. *J Emerg Med.* 2007;32:191-196. **(Case series)**
63. Blaivas M, Sierzenski PR. Dissection of the proximal thoracic aorta: A new ultrasonographic sign in the subxiphoid view. *Am J Emerg Med.* 2002;20:344-348. **(Case series)**
64. Jolly BT, Massarin E, Pigman EC. Color Doppler ultrasonography by emergency physicians for the diagnosis of acute deep venous thrombosis. *Acad Emerg Med.* 1997;4:129-132. **(Retrospective, observational review; 25 patients)**
65. Burnside PR, Brown MD, Kline JA. Systematic review of emergency physician–performed ultrasonography for lower-extremity deep vein thrombosis. *Acad Emerg Med.* 2008;15:493-498. **(Systematic review and meta-analysis; 6 articles, 936 patients)**
66. Jacoby J, Cesta M, Axelband J, et al. Can emergency medicine residents detect acute deep venous thrombosis with a limited, two-site ultrasound examination? *J Emerg Med.* 2007;32:197-200. **(Prospective; 121 extremities scanned)**
67. Magazzini S, Vanni S, Toccafondi S, et al. Duplex ultrasound in the emergency department for the diagnostic management of clinically suspected deep vein thrombosis. *Acad Emerg Med.* 2007;14:216-220. **(Prospective; 399 patients)**
68. Theodoro D, Blaivas M, Duggal S, et al. Real-time B-mode ultrasound in the ED saves time in the diagnosis of deep vein thrombosis (DVT). *Am J Emerg Med.* 2004;22:197-200. **(Prospective, single-blind observational study; 156 patients)**

69. Jang T, Docherty M, Aubin C, et al. Resident-performed compression ultrasonography for the detection of proximal deep vein thrombosis: fast and accurate. *Acad Emerg Med.* 2004;11:319-322. **(Prospective, observational; 72 patients)**
70. Frazee BW, Snoey ER, Levitt A. Emergency department compression ultrasound to diagnose proximal deep vein thrombosis. *J Emerg Med.* 2001;20:107-112. **(Prospective, observational; 76 patients)**
71. Blaivas M, Lambert MJ, Harwood RA, et al. Lower-extremity Doppler for deep venous thrombosis — can emergency physicians be accurate and fast? *Acad Emerg Med.* 2000;7:120-126. **(Prospective; 112 patients)**
72. Kline JA, O'Malley PM, Tayal VS, et al. Emergency clinician-performed compression ultrasonography for deep venous thrombosis of the lower extremity. *Ann Emerg Med.* 2008 Oct;52(4):437-445. **(Prospective; 183 patients)**
73. Biondetti PR, Vigo M, Tomasella G, et al. Diagnosis of deep venous thrombosis of the legs: accuracy of ultrasonography using vein compression. *Radiol Med.*1990;80(4):463-468. **(Prospective; 171 patients)**
74. Bernardi E, Camporese G, Büller HR, et al. Erasmus Study Group. Serial 2-point ultrasonography plus D-dimer vs whole-leg color-coded Doppler ultrasonography for diagnosing suspected symptomatic deep vein thrombosis: a randomized controlled trial. *JAMA.* 2008;300(14):1653-1659. **(Prospective, randomized, multicenter; 2098 patients)**
75. Philbrick JT, Becker DM. Calf deep venous thrombosis: a wolf in sheep's clothing? *Arch Intern Med.* 1988;148:2131–2138. **(Analytic review)**
76. Kearon C, Ginsberg JS, Douketis J, et al. A randomized trial of diagnostic strategies after normal proximal vein ultrasonography for suspected deep venous thrombosis: D-dimer testing compared with repeated ultrasonography. *Ann Intern Med.* 2005;142:490-496. **(Randomized, multicenter; 801 patients)**
77. McIlrath ST, Blaivas M, Lyon M. Patient follow-up after negative lower extremity bedside ultrasound for deep venous thrombosis in the ED. *Am J Emerg Med.* 2006;24:325-328. **(Prospective; 85 patients)**
78. Pennell RC, Mantese VA, Westfall SG. Duplex scan for deep vein thrombosis — defining who needs an examination of the contralateral asymptomatic leg. *J Vasc Surg.* 2008;48:413-416. **(Prospective; 239 patients)**
79. Squire BT, Fox JC, Anderson, C. ABSCESS: applied bedside sonography for convenient evaluation of superficial soft tissue infections. *Acad Emerg Med.* 2005;12:601-606. **(Prospective; 107 patients)**
80. Tayal VS, Hasan N, Norton HJ, et al. The effect of soft-tissue ultrasound on the management of cellulitis in the emergency department. *Acad Emerg Med.* 2006;13:384-388. **(Prospective; 126 patients)**
81. Ramirez-Schrempp D, Dorfman DH, Baker WE, et al. Ultrasound soft-tissue applications in the pediatric emergency department: to drain or not to drain? *Pediatr Emerg Care.* 2009;25:44-48. **(Review)**
82. Araujo Filho BC, Sakae FA, Sennes LU, et al. Intraoral and transcutaneous cervical ultrasound in the differential diagnosis of peritonsillar cellulitis and abscesses. *Braz J Otorhinolaryngol.* 2006;72:377-381. **(Prospective; 39 patients)**
83. Blaivas M, Theodoro D, Duggal S. Ultrasound-guided drainage of peritonsillar abscess by the emergency physician. *Am J Emerg Med.* 2003;21:155-158. **(Case series)**
84. Lyon M, Blaivas M. Intraoral ultrasound in the diagnosis and treatment of suspected peritonsillar abscess in the emergency department. *Acad Emerg Med.* 2005;12:85-88. **(Retrospective review; 43 patients)**
85. Blankstein A, Cohen I, Heiman Z, et al. Ultrasonography as a diagnostic modality and therapeutic adjuvant in the management of soft tissue foreign bodies in the lower extremities. *Isr Med Assoc J.* 2001;3:411-413. **(Case series; 21 patients)**
86. Blankstein A, Cohen I, Heiman Z, et al. Localization, detection and guided removal of soft tissue in the hands using sonography. *Arch Orthop Trauma Surg.* 2000;120:514-517. **(Case series, 12 patients)**
87. Bray PW, Mahoney JL, Campbell JP. Sensitivity and specificity of ultrasound in the diagnosis of foreign bodies in the hand. *J Hand Surg [Am].* 1995;20:661-666. **(Prospective; 315 sites)**
88. Hill R, Conron R, Greissinger P, et al. Ultrasound for the detection of foreign bodies in human tissue. *Ann Emerg Med.* 1997;29:353-356. **(Prospective; 80 sites)**
89. Crystal CS, Masneri DA, Hellums JS, et al. Bedside ultrasound for the detection of soft tissue foreign bodies: a cadaveric study. *J Emerg Med.* 2009;36:377-380. **(Prospective; 900 examinations)**
90. Orlinsky M, Knittel P, Feit T, et al. The comparative accuracy of radiolucent foreign body detection using ultrasonography. *Am J Emerg Med.* 2000;18:401-403. **(Prospective; 114 sites, 57 foreign bodies)**
91. Sargsyan AE, Dulchavsky AG, Adams J, et al. Ultrasound detection of simulated intra-ocular foreign bodies by minimally trained personnel. *Aviat Space Environ Med.* 2008;79:58-61. **(Prospective; 14 patients)**
92. Wiler JL, Costantino TG, Filippone L, et al. Comparison of ultrasound-guided and standard landmark techniques for knee arthrocentesis. *J Emerg Med.* 2010;39(1):78-82. **(Prospective, randomized, controlled trial; 66 patients)**
93. Tsung JW, Blaivas M. Emergency department diagnosis of pediatric hip effusion and guided arthrocentesis using point-of-care ultrasound. *J Emerg Med.* 2008;35:393-399. **(Case series)**
94. Freeman K, Dewitz A, Baker WE. Ultrasound-guided hip arthrocentesis in the ED. *Am J Emerg Med.* 2007;25:80-86. **(Case series)**
95. Roy S, Dewitz A, Paul I. Ultrasound-assisted ankle arthrocentesis. *Am J Emerg Med.* 1999;17:300-301. **(Case report)**
96. Marshburn TH, Legome E, Sargsyan A, et al. Goal-directed ultrasound in the detection of long-bone fractures. *J Trauma.* 2004;57:329-332. **(Prospective; 58 patients)**
97. Dulchavsky SA, Schwarz KL, Kirkpatrick AW, et al. Advanced ultrasonic diagnosis of extremity trauma: the FASTER examination. *J Trauma.* 2002;53:28-32. **(Prospective; 158 examinations)**
98. Rainer TH, Griffith JF, Lam E, et al. Comparison of thoracic ultrasound, clinical acumen, and radiography in patients with minor chest injury. *J Trauma.* 2004;56:1211-1213. **(Prospective; 88 patients)**
99. Chen L, Kim Y, Moore CL. Diagnosis and guided reduction of forearm fractures in children using bedside ultrasound. *Pediatr Emerg Care.* 2007;23:528-531. **(Prospective; 68 patients)**
100. McGwin G Jr, Xie A, Owsley C. Rate of eye injury in the United States. *Arch Ophthalmol.* 2005;123:970-976. **(Comprehensive estimate and review)**
101. Ma OJ, Mateer JR, Blaivas M. *Emergency Ultrasound.* New York: McGraw-Hill; 2007.
102. Lizzi FL, Coleman DJ. History of ophthalmic ultrasound. *J Ultrasound Med.* 2004;23:1255-1266. **(Review)**
103. Blaivas M. Bedside emergency department ultrasonography in the evaluation of ocular pathology. *Acad Emerg Med.* 2000;7:947-950. **(Brief report of case series)**
104. Blaivas M, Theodoro D, Sierzenski PR. A study of bedside ocular ultrasonography in the emergency department. *Acad Emerg Med.* 2002;9:791-799. **(Prospective observational study; 61 patients)**
105. Chiao L, Sharipov S, Sargsyan AE, et al. Ocular examination for trauma; clinical ultrasound aboard the International Space Station. *J Trauma.* 2005;58:885-889. **(Case report)**
106. Sawyer MN. Ultrasound imaging of penetrating ocular trauma. *J Emerg Med.* 2009;36:181-182. **(Case report)**
107. Shiver SA, Lyon M, Blaivas M. Detection of metallic ocular foreign bodies with handheld sonography in a porcine

model. *J Ultrasound Med.* 2005;24:1341-1346. **(Prospective randomized pig model study; 28 eyes used)**
108. Blehar DJ, Gaspari RJ, Montoya A, et al. Correlation of visual axis and coronal axis measurements of the optic nerve sheath diameter. *J Ultrasound Med.* 2008;27:407-411. **(Prospective; 27 subjects)**
109. Tayal VS, Neulander M, Norton HJ, et al. Emergency department sonographic measurement of optic nerve sheath diameter to detect findings of increased intracranial pressure in adult head injury patients. *Ann Emerg Med.* 2007;49:508-514. **(Prospective, blinded, observational study; 59 patients)**
110. Johnston DE, Kaplan MM. Pathogenesis and treatment of gallstones. *N Engl J Med.* 1993;328:1855. **(Review)**
111. Trowbridge RL, Rutkowski NK, Shojania KG. Does this patient have acute cholecystitis? *JAMA.* 2003;289:80-86. **(Meta-analysis; 17 studies)**
112. Strasberg SM. Clinical practice. Acute calculous cholecystitis. *N Engl J Med.* 2008;358:2804-2811. **(Review)**
113. Ralls PW, Colletti PM, Lapin SA, et al. Real-time sonography in suspected acute cholecystitis. Prospective evaluation of primary and secondary signs. *Radiology.* 1985;155:767-771. **(Prospective; 497 patients)**
114. Kendall JL, Shimp RJ. Performance and interpretation of focused right upper quadrant ultrasound by emergency physicians. *J Emerg Med.* 2001;21:7-13. **(Prospective; 109 patients)**
115. Rosen CL, Brown DF, Chang Y, et al. Ultrasonography by emergency physicians in patients with suspected cholecystitis. *Am J Emerg Med.* 2001;19:32-36. **(Prospective; 116 patients)**
116. Gaspari RJ, Dickman E, Blehar D. Learning curve of bedside ultrasound of the gallbladder. *J Emerg Med.* 2009;37(1):51-56. **(Prospective, descriptive; 352 patients)**
117. Jang T, Aubin C, Naunheim R. Minimum training for right upper quadrant ultrasonography. *Am J Emerg Med.* 2004;22:439-443. **(Retropsective review; 224 patients)**
118. Blaivas M, Harwood RA, Lambert MJ. Decreasing length of stay with emergency ultrasound examination of the gallbladder. *Acad Emerg Med.* 1999;6:1020-1023. **(Retrospective chart review; 753 patients)**
119.* Leung J, Duffy M, Finckh A. Real-time ultrasonographically guided internal jugular vein catheterization in the emergency department increases success rates and reduces complications: a randomized, prospective study. *Ann Emerg Med.* 2006;48(5):540-547. **(Prospective, randomized study, 130 patients)**
120.* Karakitsos D, Labropoulos N, De Groot E, et al. Real-time ultrasound-guided catheterisation of the internal jugular vein: a prospective comparison with the landmark technique in critical care patients. *Crit Care.* 2006;10(6):R162. **(Prospective, randomized study; 900 patients)**
121. Slama M, Novara A, Safavian A, et al. Improvement of internal jugular vein cannulation using an ultrasound-guided technique. *Intensive Care Med.* 1997;23(8):916-919. **(Prospective, randomized study in ICU setting, 79 patients)**
122. Hind D, Calvert N, McWilliams R, et al. Ultrasonic locating devices for central venous cannulation: meta-analysis. *BMJ.* 2003;327(7411):361. **(Systematic review and meta-analysis of RCTs; 18 trials, 1648 participants)**
123. Randolph AG, Cook DJ, Gonzales CA, et al. Ultrasound guidance for placement of central venous catheters: a meta-analysis of the literature. *Crit Care Med.* 1996;24(12):2053-2058. **(Meta-analysis; 8 RCTs identified)**
124.* Milling TJ Jr, Rose J, Briggs WM, et al. Randomized, controlled clinical trial of point-of-care limited ultrasonography assistance of central venous cannulation: the Third Sonography Outcomes Assessment Program (SOAP-3) Trial. *Crit Care Med.* 2005;33(8):1764-1769. **(Prospective, randomized, controlled trial; 201 patients)**
125.* Miller AH, Roth BA, Mills TJ, et al. Ultrasound guidance versus the landmark technique for the placement of central venous catheters in the emergency department. *Acad Emerg Med.* 2002;9(8):800-805. **(Prospective, randomized study; 122 patients)**
126. Sharma A, Bodenham AR, Mallick A. Ultrasound-guided infraclavicular axillary vein cannulation for central venous access. *Br J Anaesth.* 2004;93(2):188-192. **(Observational study; 200 consecutive patients)**
127. Skolnick ML. The role of sonography in the placement and management of jugular and subclavian central venous catheters. *AJR Am J Roentgenol.* 1994;163(2):291-295. **(Review article)**
128. Hughes P, Scott C, Bodenham A. Ultrasonography of the femoral vessels in the groin: implications for vascular access. *Anaesthesia.* 2000;55(12):1198-1202. **(Review article)**
129. Kwon TH, Kim YL, Cho DK. Ultrasound-guided cannulation of the femoral vein for acute haemodialysis access. *Nephrol Dial Transplant.* 1997;12(5):1009-1012. **(Prospective evaluation; 28 patients compared with 38 historic controls)**
130. Blaivas M. Video analysis of accidental arterial cannulation with dynamic ultrasound guidance for central venous access. *J Ultrasound Med.* 2009;28:1239-1244. **(Case series)**
131. Agency for Healthcare Research and Quality. Evidence report/technology assessment, No. 43: Making health care safer: a critical analysis of patient safety practices. Chapter 21: Ultrasound guidance of central vein catheterization. AHRQ Publication No. 01-E058. http://www.ahrq.gov/clinic/ptsafety
132. Mayo PH, Beaulieu Y, Doelken P, et al. American College of Chest Physicians/La Société de Réanimation de Langue Française statement on competence in critical care ultrasonography. *Chest.* 2009;135(4):1050-1060. **(Practice statement)**
133. National Institute for Clinical Excellence. Guidance on the use of ultrasound locating devices for placing central venous catheters. Technology Appraisal Guidance No. 49 (2002) September. http://www.nice.org.uk.
134. Goldberg BB, Goodman GA, Clearfield HR. Evaluation of ascites by ultrasound. *Radiology.* 1970;96(1):15-22.
135. Williams JW Jr, Simel DL. The rational clinical examination. Does this patient have ascites? How to divine fluid in the abdomen. *JAMA.* 1992;267(19):2645-2648. **(Case series)**
136. Goldberg BB, Clearfield HR, Goodman GA, et al. Ultrasonic determination of ascites. *Arch Intern Med.* 1973;131(2):217-220.
137. Bard C, Lafortune M, Breton G. Ascites: ultrasound guidance or blind paracentesis? *CMAJ.* 1986;135(3):209-210. **(Observational study; 27 patients)**
138.* Nazeer SR, Dewbre H, Miller AH. Ultrasound-assisted paracentesis performed by emergency physicians vs the traditional technique: a prospective, randomized study. *Am J Emerg Med.* 2005;23(3):363-367. **(Prospective, randomized study; 100 patients)**
139. Lichtenstein DA. Ultrasound in the management of thoracic disease. *Crit Care Med.* 2007;35(5 Suppl):S250-261. **(Review)**
140. Lichtenstein DA, Meziere GA. Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol. *Chest.* 2008;134(1):117-125.
141. Lichtenstein D, Goldstein I, Mourgeon E, et al. Comparative diagnostic performances of auscultation, chest radiography, and lung ultrasonography in acute respiratory distress syndrome. *Anesthesiology.* 2004;100(1):9-15. **(32 ICU patients and 10 healthy volunteers)**
142. Weingardt JP, Guico RR, Nemcek AA Jr, et al. Ultrasound findings following failed, clinically directed thoracenteses. *J Clin Ultrasound.* 1994;22(7):419-426. **(Prospective; 26 patients)**
143. Sassoon CS, Light RW, O'Hara VS, et al. Iatrogenic pneumothorax: etiology and morbidity. Results of a Department of Veterans Affairs Cooperative Study. *Respiration.* 1992;59(4):215-220. **(Retrospective review; 538 patients)**
144. Despars JA, Sassoon CS, Light RW. Significance of iatrogenic pneumothoraces. *Chest.* 1994;105(4):1147-1150. **(Retrospective review; 5-year, single-center study)**
145.* Grogan DR, Irwin RS, Channick R, et al. Complications associated with thoracentesis. A prospective, randomized study com-

paring three different methods. *Arch Intern Med.* 1990;150(4):873-877. **(Randomized, prospective study; 52 patients)**
146. Bartter T, Mayo PD, Pratter MR, et al. Lower risk and higher yield for thoracentesis when performed by experienced operators. *Chest.* 1993;103(6):1873-1876. **(Observational study; 50 patients)**
147.* Jones PW, Moyers JP, Rogers JT, et al. Ultrasound-guided thoracentesis: is it a safer method? *Chest.* 2003;123(2):418-423. **(Prospective descriptive study; 941 thoracenteses)**
148. Barnes TW, Morgenthaler TI, Olson EJ, et al. Sonographically guided thoracentesis and rate of pneumothorax. *J Clin Ultrasound.* 2005;33(9):442-446. **(Retrospective review; 450 thoracenteses performed, 305 with sonographic guidance)**
149. Lichtenstein D, Hulot JS, Rabiller A, et al. Feasibility and safety of ultrasound-aided thoracentesis in mechanically ventilated patients. *Intensive Care Med.* 1999;25(9):955-958. **(Feasibility and safety study; 40 ICU patients; no comparison group)**
150. O'Moore PV, Mueller PR, Simeone JF, et al. Sonographic guidance in diagnostic and therapeutic interventions in the pleural space. *AJR Am J Roentgenol.* 1987;149(1):1-5. **(Descriptive case series; 187 diagnostic and therapeutic thoracic interventions)**
151. Spodick DH. Acute cardiac tamponade. *N Engl J Med.* 14 2003;349(7):684-690. **(Review)**
152. Wong B, Murphy J, Chang CJ, et al. The risk of pericardiocentesis. *Am J Cardiol.* 1979;44(6):1110-1114. **(Case review; 52 patients)**
153. Callahan JA, Seward JB, Nishimura RA, et al. Two-dimensional echocardiographically guided pericardiocentesis: experience in 117 consecutive patients. *Am J Cardiol.* 1985;55(4):476-479. **(Observational study; 117 patients)**
154. Callahan JA, Seward JB. Pericardiocentesis guided by two-dimensional echocardiography. *Echocardiography.* 1997;14(5):497-504. **(Descriptive, observational, single-center study; 610 cases over 14 years)**
155. Maggiolini S, Bozzano A, Russo P, et al. Echocardiography-guided pericardiocentesis with probe-mounted needle: report of 53 cases. *J Am Soc Echocardiogr.* 2001;14(8):821-824. **(Descriptive, observational study; 53 procedures in 48 patients)**
156. Vayre F, Lardoux H, Pezzano M, et al. Subxiphoid pericardiocentesis guided by contrast two-dimensional echocardiography in cardiac tamponade: experience of 110 consecutive patients. *Eur J Echocardiogr.* 2000;1(1):66-71. **(110 patients with tamponade)**
157. Tsang TS, Enriquez-Sarano M, Freeman WK, et al. Consecutive 1127 therapeutic echocardiographically guided pericardiocenteses: clinical profile, practice patterns, and outcomes spanning 21 years. *Mayo Clin Proc.* 2002;77(5):429-436. **(Registry data)**
158. Tsang TS, El-Najdawi EK, Seward JB, et al. Percutaneous echocardiographically guided pericardiocentesis in pediatric patients: evaluation of safety and efficacy. *J Am Soc Echocardiogr.* 1998;11(11):1072-1077. **(Retrospective review of registry; 73 patients)**
159.* Osranek M, Bursi F, O'Leary PW, et al. Hand-carried ultrasound-guided pericardiocentesis and thoracentesis. *J Am Soc Echocardiogr.* 2003;16(5):480-484. **(Prospective, observational study; 9 patients)**
160. Rosen CL, Brown DFM, Sagarin M, et al. Ultrasonography by emergency physicians in detecting hydronephrosis in patients with suspected ureteral colic. *Acad Emerg Med.* 1996;3:541. **(Abstract)**
161. Gaspari RJ, Horst K. Emergency ultrasound and urinalysis in the evaluation of flank pain. *Acad Emerg Med.* 2005;12:1180-1184. **Prospective, observational; 104 patients)**
162. Pepe P, Motta L, Pennisi M, et al. Functional evaluation of the urinary tract by color-Doppler ultrasonography (CDU) in 100 patients with renal colic. *Eur J Radiol.* 2005;53(1):131-135. **(Prospective; 100 patients)**
163. Cvitkovic KuzmicA, Brkljacic B, Rados M, et al. Doppler visualization of ureteric jets in unilateral hydronephrosis in children and adolescents. *Eur J Radiol.* 2001;39(3):209-214. **(Prospective; 27 patients)**
164. Nelson W, Behrman R, Kliegman R, et al. *Nelson's Textbook of Pediatrics.* 15th ed. Philadelphia, Pa: WB Saunders; 1995:1530.
165. Kiely EA, Hartnell GG, Gibson RN, et al. Measurement of bladder volume by real-time ultrasound. *Br J Urol.* 1987;60:33-35. **(Prospective; 18 patients)**
166. Roehrborn CG, Peters PC. Can transabdominal ultrasound estimation of postvoiding residual replace catheterization? *Urology.* 1988;31(5):445-449. **(Prospective; 81 patients)**
167. Ireton RC, Krieger JN, Cardenas DD, et al. Bladder volume determination using a dedicated, portable ultrasound scanner. *J Urol.* 1990;143:9(5):909-911. **(Prospective; 164 measurements)**
168. Chan H. Noninvasive bladder volume measurement. *J Neurosci Nurs.* 1993;25:309. **(Prospective; 90 examinations)**
169. Chen L, Hsiao AL, Moore CL, et al. Utility of bedside bladder ultrasound before urethral catheterization in young children. *Pediatrics.* 2005;115(1):108-111. **(Prospective; 90 examinations)**
170. Milling TJ Jr, Van Amerongen R, Melville L, et al. Use of ultrasonography to identify infants for whom urinary catheterization will be unsuccessful because of insufficient urine volume: validation of the urinary bladder index. *Ann Emerg Med.* 2005;45(5):510-513. **(Prospective; 44 patients)**
171. Witt M, Baumann BM, McCans K. Bladder ultrasound increases catheterization success in pediatric patients. *Acad Emerg Med.* 1991;20(6):631-635. **(Randomized controlled trial; 64 patients)**
172. Gochman RF, Karasic RB, Heller MB. Use of portable ultrasound to assist urine collection by suprapubic aspiration. *Ann Emerg Med.* 1991;20(6):631-635. **(Randomized controlled trial; 66 patients)**
173. Munir V, Barnett P, South M. Does the use of volumetric bladder ultrasound improve the success rate of suprapubic aspiration of urine? *Pediatr Emerg Care.* 2002;18:346-349. **(Prospective 2-phase study; 31 patients in phase 1, 75 patients in phase 2)**
174. Chu RW, Wong YC, Luk SH, et al. Comparing suprapubic urine aspiration under real-time ultrasound guidance with conventional blind aspiration. *Acta Paediatr.* 2002;91(5):512-516. **(Prospective, randomized controlled trial; 60 patients)**
175. Kiernan SC, Pinckert TL, Keszler M. Ultrasound guidance of suprapubic bladder aspiration in neonates. *J Pediatr.* 1993;123(5):789-791. **(Prospective, randomized trial; 53 patients)**
176. Hauser AM. The emerging role of echocardiography in the emergency department. *Ann Emerg Med.* 1989;18:1298-1303. **(Review)**
177. Mayron R, Gaudio FE, Plummer D, et al. Echocardiography performed by emergency physicians: impact on diagnosis and therapy. *Ann Emerg Med.* 1988;17:150-154. **(Review and case series)**
178. Moore CL. Special Contribution: Current Issues with Emergency Cardiac Ultrasound Probe and Image Conventions. *Acad Emerg Med.* 2008;15(3):278-284.
179. Kimura BJ, Bocchicchio M, Willis CL, et al. Screening cardiac ultrasonographic examination in patients with suspected cardiac disease in the emergency department. *Am Heart J.* 2001;142(2):324-330. **(Prospective; 124 patients)**
180. Stahmer SA. The ASE position statement in echocardiography in the emergency department. *Acad Emerg Med.* 2000;7:306-308.
181. Rose JS, Bair AE, Mandavia D, et al. The UHP ultrasound protocol: a novel ultrasound approach to the empiric evaluation of the undifferentiated hypotensive patient. *Am J Emerg Med.* 2001;19:299-302. **(Description of protocol)**
182. Jones AE, Tayal VS, Sullivan DM, et al. Randomized, controlled trial of immediate versus delayed goal-directed ultrasound to

identify the cause of nontraumatic hypotension in emergency department patients. *Crit Care Med.* 2004;32(8):1798-1800. **(Randomized controlled trial; 184 patients)**
183. Blaivas M. Incidence of pericardial effusion in patients presenting to the emergency department with unexplained dyspnea. *Acad Emerg Med.* 2001;8:1143-1146. **(Prospective, observational; 103 patients)**
184. Mandavia DP, Hoffner RJ, Mahaney K, et al. Bedside echocardiography by emergency physicians. *Ann Emerg Med.* 2001;38(4):377-382. **(Prospective; 515 patients enrolled, 103 with pericardial effusions)**
185. Blaivas M, Fox J. Outcome in cardiac arrest patients found to have cardiac standstill on the bedside emergency department echocardiogram. *Acad Emerg Med.* 2001;8:616-621. **(Prospective; 169 patients)**
186. Jones AE, Tayal VS, Kline JA. Focused training of emergency medicine residents in goal-directed echocardiography: a prospective study. *Acad Emerg Med.* 2003;10:1054-1058. **(Prospective, observational; 51 patients)**
187. Labovitz AJ, Noble VE, Bierig M, et al. Focused cardiac ultrasound in the emergent setting: a consensus statement of the American Society of Echocardiography and American College of Emergency Physicians. *J Am Soc Echocardiogr.* 2010;23(12):1225-1230.
188. Moore CL, Rose GA, Tayal VS, et al. Determination of left ventricular function by emergency physician echocardiography of hypotensive patients. *Acad Emerg Med.* 2002;9:186-193. **(Prospective, observational, educational; 21 residents enrolled)**
189. Martin RP, Rakowski H, French J, et al. Localization of pericardial effusion with wide angle phased array echocardiography. *Am J Cardiol.* 1978;42:904-912. **(Prospective; 56 patients)**
190. Mazurek B, Jehle D, Martin M. Emergency department echocardiography in the diagnosis and therapy of cardiac tamponade. *J Emerg Med.* 1991;9:27-31. **(Case report)**
191. Levine MJ, Lorell BH, Diver DJ, et al. Implications of echocardiographically assisted diagnosis of pericardial tamponade in contemporary medical patients: detection before hemodynamic embarrassment. *J Am Coll Cardiol.* 1991;17:59-65. **(Prospective; 54 patients)**
192. Tsang TSM, Oh JK, Seward JB. Diagnosis and management of cardiac tamponade in the era of echocardiography. *Clin Cardiol.* 1999;22:446-452. **(Review)**
193. Blaivas M, Graham S, Lambert MJ. Impending cardiac tamponade: an unseen danger? *Am J Emerg Med.* 2000;18:339-340. **(Correspondence, case series)**
194. Shabetai R. Pericardial effusion: haemodynamic spectrum. *Heart.* 2004;90:255-256. **(Mini-symposium)**
195. Otto CM. *Textbook of Clinical Echocardiography.* 3rd ed. Philadelphia, Pa: Elsevier– Saunders; 2004. **(Textbook)**
196. ASE Committee Recommendations. Recommendations for chamber quantification: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Chamber Quantification Writing Group, Developed in Conjunction with the European Association of Echocardiography, a Branch of the European Society of Cardiology. *J Am Soc Echocardiography.* 2005;18(12):1440-1463.
197. Tayal VS, Kline JA. Emergency echocardiography to detect pericardial effusion in patients in PEA and near-PEA states. *Resuscitation.* 2003;59(3):315-318. **(Prospective, observational; 20 patients)**
198. Plummer D, Brunette D, Asinger R, et al. Emergency department echocardiography improves outcome in penetrating cardiac injury. *Ann Emerg Med.* 1192;26:709-712. **(Retrospective review; 49 patients)**
199. Gillam LD, Guyer DE, Gibson TC, et al. Hydrodynamic compression of the right atrium: a new echocardiographic sign of cardiac tamponade. *Circulation.* 1983;68:294-301. **(Prospective; 127 patients)**
200. Nazeyrollas P, Metz D, Jolly D, et al. Use of transthoracic echocardiography combined with clinical and electrocardiographic data to predict acute pulmonary embolism. *Eur Heart J.* 1996;17:779-786. **(Prospective; 132 patients)**
201. Kasper W, Konstantinides S, Geibel A, et al. Prognostic significance of right ventricular afterload stress detected by echocardiography in patients with clinically suspected pulmonary embolism. *Heart.* 1997;77:346-349. **(Prospective; 317 patients)**
202. Ribeiro A, Lindmarler P, Juhlin-Dannfelt A, et al. Echocardiography Doppler in pulmonary embolism: right ventricular dysfunction as a predictor of mortality rate. *Am Heart J.* 1997;134:479-487. (**Prospective; 126 patients)**

CME Questions

Take This Test Online!

Current subscribers receive CME credit absolutely free by completing the following test. Monthly online testing is now available for current and archived issues. Visit http://www.ebmedicine.net/CME today to receive your free CME credits. Each issue includes *4 AMA PRA Category 1 Credits™*, 4 ACEP Category 1 credits, 4 AAFP Prescribed credits, and 4 AOA Category 2A or 2B credits.

1. **A diagnostic algorithm utilizing the FAST examination decreases mortality in trauma patients.**
   a. True b. False

2. **Which of the following statements is FALSE regarding the performance of transvaginal ultrasound (TVUS) in first-trimester pregnant patients?**
   a. TVUS provides a global view of the pelvis.
   b. TVUS provides superior imaging of the uterus and adnexa.
   c. TVUS can identify an intrauterine pregnancy 7 to 14 days earlier than transabdominal ultrasound.

3. **An 85-year-old male presents with sudden onset of flank and back pain followed by syncope. His heart rate is 110 and BP 80/40. Your bedside ultrasound shows a 5.5-cm abdominal aortic aneurysm (AAA). The most appropriate next step in management is:**
   a. Palpate his abdomen, since if there is no pulsatile mass he must not have an AAA.
   b. Get a STAT CT to see if the AAA has ruptured.
   c. Google pictures of AAA to make sure you know what you are looking at.
   d. Call for a radiologist to perform a bedside ultrasound.
   e. Call vascular surgery to take the patient to the OR STAT.

4. **Which ultrasound probe is used when scanning soft tissue to evaluate for potential abscess as well as for ocular disorders?**
   a. Linear array transducer
   b. Phased array probe
   c. Curved array probe

5. **Which of the following conditions is not amenable to diagnosis using emergency ultrasound?**
   a. Retinal detachment
   b. Glaucoma
   c. Vitreous hemorrhage
   d. Elevated intracranial pressure

6. **Which 2 ultrasound findings have the highest combined positive predictive value for acute cholecystitis?**
   a. Thickened gallbladder wall + pericholecystic fluid
   b. Thickened gallbladder wall + gallstones
   c. Gallstones + sonographic Murphy's sign
   d. Gallstones + pericholecystic fluid

7. **The landmark-guided approach to pericardiocentesis is said to have a complication rate as high as __%, whereas the sono-guided approach has been shown to have a complication rate as low as __%**
   a. 25, 25
   b. 25, 5
   c. 50, 5
   d. 50, 25

8. **Emergent echocardiography can help answer critical patient management questions and can be life-saving. Which of the following is outside the scope of focused cardiac ultrasound in the emergent setting?**
   a. Global cardiac systolic function
   b. Regional wall motion abnormalities
   c. Pericardial effusion
   d. Right ventricular enlargement

Physician CME Information

Date of Original Release: March 1, 2011. Date of most recent review: February 10, 2011. Termination date: March 1, 2014.

Accreditation: EB Medicine is accredited by the ACCME to provide continuing medical education for physicians.

Credit Designation: EB Medicine designates this educational activity for a maximum of *48 AMA PRA Category 1 Credits™* per year. Physicians should only claim credit commensurate with the extent of their participation in the activity.

ACEP Accreditation: *Emergency Medicine Practice* is approved by the American College of Emergency Physicians for 48 hours of ACEP Category 1 credit per annual subscription.

AAFP Accreditation: *Emergency Medicine Practice* has been reviewed and is acceptable for up to 48 Prescribed credits per year by the American Academy of Family Physicians. AAFP Accreditation begins July 31, 2010. Term of approval is for 1 year from this date. Each issue is approved for 4 Prescribed credits. Credits may be claimed for 1 year from the date of each issue.

AOA Accreditation: *Emergency Medicine Practice* is eligible for up to 48 American Osteopathic Association Category 2A or 2B credit hours per year.

Needs Assessment: The need for this educational activity was determined by a survey of medical staff, including the editorial board of this publication; review of morbidity and mortality data from the CDC, AHA, NCHS, and ACEP; and evaluation of prior activities for emergency physicians.

Target Audience: This enduring material is designed for emergency medicine physicians, physician assistants, nurse practitioners, and residents.

Goals: Upon completion of this article, you should be able to: (1) demonstrate medical decision-making based on the strongest clinical evidence; (2) cost-effectively diagnose and treat the most critical ED presentations; and (3) describe the most common medicolegal pitfalls for each topic covered.

Discussion of Investigational Information: As part of the newsletter, faculty may be presenting investigational information about pharmaceutical products that is outside Food and Drug Administration-approved labeling. Information presented as part of this activity is intended solely as continuing medical education and is not intended to promote off-label use of any pharmaceutical product.

CME Objectives: Upon completion of this article, you should be able to: (1) identify the 11 core emergency ultrasound (EUS) applications; (2) recognize the diversity of literature supporting each of the different EUS applications; and (3) evaluate how and which EUS applications may be life-saving, guide resuscitation, improve patient safety, and expedite patient care.

Faculty Disclosure: It is the policy of EB Medicine to ensure objectivity, balance, independence, transparency, and scientific rigor in all CME-sponsored educational activities. All faculty participating in the planning or implementation of a sponsored activity are expected to disclose to the audience any relevant financial relationships and to assist in resolving any conflict of interest that may arise from the relationship. In compliance with all ACCME Essentials, Standards, and Guidelines, all faculty for this CME activity were asked to complete a full disclosure statement. The information received is as follows: **Dr. Hwang, Dr. Kimberly, Dr. Liteplo, Dr. Sajed, Dr. Andrus, Dr. Nelson, Dr. Nguyen, Dr. Jagoda, and their related parties report no significant financial interest or other relationship with the manufacturer(s) of any commercial product(s) discussed in this educational presentation.**

Method of Participation:

- **Print Semester Program:** Paid subscribers who read all CME articles during each *Emergency Medicine Practice* 6-month testing period, complete the post-test and the CME Evaluation Form distributed with the June and December issues, and return it according to the published instructions are eligible for up to 4 hours of CME credit for each issue.
- **Online Single-Issue Program:** Current, paid subscribers who read this *Emergency Medicine Practice* CME article and complete the online post-test and CME Evaluation Form at www.ebmedicine.net/CME are eligible for up to 4 hours of Category 1 credit toward the AMA Physician's Recognition Award (PRA).

Hardware/Software Requirements: You will need a Macintosh or PC to access the online archived articles and CME testing. Adobe Reader is required to view the PDFs of the archived articles. Adobe Reader is available as a free download at www.adobe.com.

Additional Policies: For additional policies, including our statement of conflict of interest, source of funding, statement of informed consent, and statement of human and animal rights, visit http://www.ebmedicine.net/policies.

CEO: Robert Williford **President & Publisher**: Stephanie Ivy **Managing Editor:** Dorothy Whisenhunt **Director of Member Services**: Liz Alvarez
Managing Editor & CME Director: Jennifer Pai **Marketing & Customer Service Coordinator:** Robin Williford

Direct all questions to:
EB Medicine
1-800-249-5770 or 1-678-366-7933
Fax: 1-770-500-1316
5550 Triangle Parkway, Suite 150
Norcross, GA 30092
E-mail: **ebm@ebmedicine.net**
Website: **www.ebmedicine.net**
To write a letter to the editor, please email: jagodamd@ebmedicine.net

Subscription Information:
48 *AMA PRA Category 1 Credits™*, 48 ACEP Category 1 credits, 48 AAFP Prescribed credits, and 48 AOA Category 2A or 2B CME credits, and full online access to searchable archives and additional CME: $329
Individual issues, including 4 CME credits: $30
(Call 1-800-249-5770 or go to http://www.ebmedicine.net/EMP issues to order)