The FAST and E-FAST in 2013: Trauma Ultrasonography

Overview, Practical Techniques, Controversies, and New Frontiers

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KEYWORDS

• Trauma • FAST • E-FAST • Ultrasound • Point-of-care • Hemoperitoneum
• Hemothorax • Pneumothorax

KEY POINTS

- The FAST (Focused Assessment with Sonography in Trauma) and E-FAST (Extended Focused Assessment with Sonography in Trauma) examinations provide critical information during the real-time evaluation of complex trauma patients, directly at the bedside.
- The FAST examination can identify free fluid suggestive of abdominal solid-organ injury, hemothorax, or pericardial fluid collections.
- The sensitivity of E-FAST for pneumothorax and hemothorax is superior to that of chest radiography.
- To use the FAST and E-FAST optimally, physicians must be familiar with both their strengths and their weaknesses.

INTRODUCTION: TRAUMA "EPIDEMIC"

Trauma continues to be a major cause of morbidity and mortality worldwide. The percentage of global deaths attributable to injuries in 2010 (5.1 million deaths) was higher than 2 decades earlier. This trend was driven primarily by a worldwide 46% increase in deaths caused by motor vehicle collisions and from falls.[1]

In the United States, vigorous safety regulations as well as an interdisciplinary trauma care systems have provided relative protection from fatalities, which were at a 60-year low in 2011. However, early statistics from 2012 suggest that numbers are again on the rise (an increase of 7.1%).[2] Among the young (aged 0–19 years),

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unintentional injuries continue to be the leading cause of death, with approximately 12,000 annual fatalities. However, more than 9 million young persons present to emergency departments (EDs) yearly with nonfatal injuries.[3] Unfortunately, violent injuries also continue to be a major cause of death and morbidity; an estimated 50,000 persons die yearly in the United States from these injuries.[4]

Overall, unintentional and violence-related injuries together caused 48.5% of the deaths of persons aged 1 to 44 years of age in the United States: more fatalities than by infectious disease and noncommunicable diseases combined.[5]

With American EDs already beyond capacity[6] and trauma rates increasing worldwide, these statistics emphasize the continued importance of optimizing trauma care with resource-efficient and cost-efficient modalities. There is also now significant concern over radiation levels involved in standard imaging modalities such as computed tomography (CT). The FAST (Focused Assessment with Sonography in Trauma) examination addresses many of these issues in the evaluation of chest and abdominal trauma.

FAST: INTRODUCTION AND ENDORSEMENT

Over the last 2 decades the FAST examination, and thereafter the E-FAST (Extended Focused Assessment with Sonography in Trauma) examination, have transformed the management of trauma patients in the United States. In 2013 and beyond, it is critical for clinicians to be adept at its use, while also understanding its limitations. The American College of Emergency Physicians (ACEP) recognized its critical importance in the landmark 2008 ACEP Ultrasound Guidelines.[7] These guidelines were also recognized in 2011 by the American Institute of Ultrasound in Medicine (AIUM).[8] The American College of Surgeons has adopted the FAST into the Advanced Trauma Life Support (ATLS) protocol. The ninth edition of ATLS has DPL (diagnostic peritoneal lavage) as only an optional skill station, owing to the widespread utilization of the FAST examination.[9] This situation is remarkable when one considers that before 1995, abdominal trauma was being evaluated with the invasive diagnostic peritoneal lavage (DPL) test[10] at most trauma centers. Following several seminal studies, this approach to trauma patients radically changed. Trauma ultrasonography is one of the key applications of point-of-care ultrasound.[11]

Cases

Three cases are presented, each highlighting important aspects of the E-FAST examination. These cases are referred to throughout the article.

Case 1

History and physical examination. A 9-year-old boy who was involved in a serious rollover minivan crash presents via paramedic transport to your Emergency Department (ED). There were fatalities on scene. The child has an altered mental status and is unable to actively participate in the examination. The vital signs include: blood pressure (BP) 88/60 mm Hg, heart rate (HR) 122 beats per minute, respiratory rate (RR) 25 breaths per minute, pulse oxygenation (POX) 99% on supplemental oxygen. The primary survey is significant for a patent airway, ashen skin appearance with poor capillary refill and a right leg below-the-knee amputation with ongoing hemorrhage despite a tourniquet. The Glasgow Coma Scale (GCS) is 14, due to the presence of confusion. Chest and abdominal examinations are significant for mild diffuse tenderness to palpation.

ED course/imaging. Crystalloid and blood were administered. It was unclear if the patient's shock state was due to the hemorrhage from the leg amputation or from another potential source. Bedside E-FAST was immediately performed and was positive for free fluid in the abdomen and pelvis. Due to the patient's unstable hemodynamic status, CT scan was deferred and the patient was taken immediately to the operating room for abdominal laparotomy, as well as for definitive control of the hemorrhage from the amputation.

Case 2

History and physical examination. A 23-year-old male bicyclist arrives to your ED via paramedic transport after being thrown while traveling at a high rate of speed down a hill. He was wearing a helmet. On primary survey, he is alert and awake, appropriately interactive with GCS 15, and in no acute respiratory distress. His vital signs include BP 95/50 mm Hg, HR 110 beats per minute, RR 20 breaths per minute, POX 98% on room air. On further examination, he has diffuse abdominal tenderness to palpation without rebound or guarding. The pelvis is tender diffusely. The remainder of the examination is within normal limits.

ED course/imaging. Resuscitation was initiated with intravenous fluids. Chest radiograph (CXR) and pelvis X-ray were ordered. Bedside E-FAST was negative for free fluid within the thorax, abdomen and pelvis. No pneumothorax was noted in either the right or left thoracic cavities. Repeat vital signs were taken: BP 75/52 mm Hg, HR 120 beats per minute. Pelvis radiograph demonstrated an open book pelvic fracture. A pelvic binder was immediately placed and massive transfusion protocol was initiated. A repeat E-FAST was negative. After discussion with both orthopedics and interventional radiology (IR), the patient was taken to the IR suite, where hemostasis was achieved after pelvic vessel embolization.

Case 3

History and physical examination. A 55-year-old male was transported by paramedics following a motor vehicle crash. The paramedics reported that the vehicle had a moderate amount of damage. On their examination, the patient had decreased breath sounds on the right side of the chest. He also appeared intoxicated. On ED trauma survey, the vital signs included: BP 150/92 mm Hg, HR 95 beats per minute, RR 14 breaths per minute and POX 92% on room air. The patient was intoxicated, but following commands. He had a patent airway. Breath sounds were decreased at both lung bases. The chest and abdomen were non-tender to palpation.

ED course/imaging. A CXR was ordered. The trauma surgery team initially wanted to place a chest tube on the patient's right side, given the history of decreased breath sounds and relative hypoxia. However, E-FAST was immediately performed and demonstrated positive lung sliding and the presence of comet-tail artifacts on examination of both the right and left thoracic cavities. The chest tube was deferred. Supplemental oxygen was administered, with improvement of the POX to 100%. Subsequent imaging with CXR, followed by CT scan of the chest, demonstrated no pneumothorax. The patient was observed, made a complete recovery, and was discharged from the ED.

Utility of the FAST Examination: Evidence

As these cases demonstrate, the management of trauma patients is highly complex. Patients often arrive with multiple injuries and/or are in shock. Patients may have altered mental status resulting from head injury, intoxication, or cerebral hypoperfusion; they often have distracting injuries, which further confounds the ability to diagnose their injury pattern with physical examination alone. Several studies have shown the physical examination to be highly inaccurate in trauma patients.[12–14]

The FAST examination is a noninvasive test that can be done rapidly at the bedside to address a specific clinical question. The examination evaluates for the presence of intra-peritoneal free fluid in the abdomen and pelvis. In addition, the cardiac views allow for detection of cardiac injury and pericardial effusion. The E-FAST allows for the assessment of a hemothorax or pneumothorax, and has become an accepted standard of care in the resuscitation of the injured patient.[15] The FAST exam has been shown to have good to outstanding sensitivity in many studies (73%–99%).[16–21] A recent study of more than 4000 patients with blunt trauma by Lee and colleagues[22] had a sensitivity of 85%, regardless of blood pressure. In this series the specificity was 96% and overall accuracy 95%. A recent meta-analysis of 62 trials (including more than 18,000 patients) using FAST showed a pooled sensitivity of 78.9% and specificity of 99.2%, demonstrating that while the FAST exam may miss smaller amounts of fluid in some trauma patients, a positive exam is highly accurate for significant intra-peritoneal injury and can be reliably used in clinical practice.[23]

Quinn and Sinert[24] recently performed a systematic review of the literature on penetrating torso injury. These investigators found that a positive study had a high incidence of intra-abdominal injury, and recommended exploratory laparotomy in these patients. However, a negative study cannot be used as a single rule-out tool.

The FAST examination is particularly powerful in patients with precordial penetrating wounds and in hypotensive patients with blunt torso trauma, with sensitivity of 100%.[25] In this subset of patients, immediate surgical intervention is indicated in patients with a positive FAST.[25–29]

It is extremely important to remember that the abdominal components of the FAST are specifically designed to evaluate for free fluid suggestive of hemoperitoneum, a condition most commonly resulting from injuries to the spleen or liver, among other pathology. The FAST exam is not designed to reliably detect injuries to the solid organs, intestine, mesentery, diaphragm, nor the retroperitoneal hemorrhage that may occur with pelvic fractures (as in Case 2). Further details are given in the Pitfalls section. Some studies suggest the utility of contrast agents that can improve visualization of solid-organ injury, and this is discussed in the section New Frontiers.

Feasibility

Several studies support both the feasibility and the rapid nature of performing the FAST examination. The entire scan can be performed in around 3 to 4 minutes.[30–33] Additional benefits include the lack of ionizing radiation and the ability to easily repeat the examination, especially in cases of high clinical suspicion or a change in clinical status. This aspect is particularly important, considering that approximately one-third of stable patients with significant intra-abdominal injury may not have significant free fluid evident on initial evaluation.[34] Potentially unstable patients can also be assessed in the ED or other critical care areas, decreasing the risk of transport.

The number of proctored examinations required for competence has been a matter of debate, as numbers established previously by imaging organizations did not take into account several aspects of the FAST: (1) the rapid point-of-care nature of the study, (2) the single "yes/no" binary quality of the study outcome, and (3) the fact that clinical correlation was being immediately applied. Shackford and colleagues[35] found an initial error rate of 17% in nonradiologist clinical sonographers, which decreased to 5% after 10 examinations. Jang and colleagues[36] found that the incidence of technical errors of emergency physicians learning to perform FAST improved with hands-on experience. Noninterpretable or misinterpreted views occurred in 24% of examinations for those performing their first 10 examinations, 3.6% for those performing their 41st to 50th examinations, and 0% for those performing their 71st to 75th examinations. Interpretive skills improved more rapidly than image acquisition skills. The ACEP Guidelines recommend at least 25 to 50 studies in this core US application.[7]

PITFALLS OF FAST

Quantity of Fluid

The FAST examination is designed to evaluate for intraperitoneal free fluid. Volumes of less than 400 mL in the right upper quadrant (RUQ) have been hard to distinguish. In a study on infused volumes of DPL fluid, Branney and colleagues[37] found that only 10% of participants performing FAST could detect fluid volumes of less than 400 mL. The mean volume detected was 619 mL. This volume fits in well with the classes of hemorrhage described in ATLS, corresponding to a Class 3 hemorrhage (loss of 30%–40% of blood volume) and potential hypotension.[9] After all, this is where the FAST has shown the greatest benefit in trauma care. The pelvic views of the FAST have shown better sensitivity, although they are limited if the bladder is empty or if a Foley catheter has already been placed. Von Kuenssberg, Jehle and colleagues[38] found that the mean minimal volume of fluid needed for pelvic ultrasonography detection by the examiner was 157 mL.

Therefore, the FAST examination cannot be used as a diagnostic test to rule out small amounts of intra-peritoneal hemorrhage in all trauma patients. However, as discussed above, its utility chiefly lies in the ability to rapidly detect the significant amount of blood that can result in hemodynamic instability in the trauma patient. Given the relative benefits of the FAST exam, DPL has been relegated to a very rare procedure, especially since this test is over-sensitive and has resulted in unnecessary surgeries in the past. CT remains the gold standard for the detection of intra-abdominal injury and free fluid, although the discriminatory zone for this test is estimated to be 100–250 cc of fluid and CT may also potentially miss some smaller quantities of bleeding.[39] Furthermore, CT may miss clinically significant injuries that may result in little free abdominal bleeding, such as mesenteric, intestinal and pancreatic injuries.[40]

Solid-Organ Injury

Ultrasonography cannot reliably grade solid-organ injuries that do not result in significant hemoperitoneum.[41–44] CT imaging and/or careful serial abdominal examinations remain indicated to further delineate these injuries in high-risk patients. See also section on Pitfalls and Negative FAST: Clinical Judgment and Serial Examinations Remain Paramount, below.

Delayed Presentation

Free fluid only remains echolucent, or anechoic (black), on ultrasound until it begins to clot. It can then become more echogenic (bright) and more difficult to differentiate from the surrounding tissue. Therefore, extra care must be taken in assessing patients with a delayed presentation after trauma, as the FAST may be falsely reassuring.

Pelvic Fracture/Pelvic Trauma

In cases where pelvic fracture is suspected, ultrasonography cannot reliably evaluate for hemorrhage from a pelvic-fracture source, as in Case 2 (see also **Table 1** for further details). A rapid pelvic radiograph is critical in this patient population. Also, if free fluid is present the FAST cannot delineate between free fluid from a bladder rupture and hemoperitoneum. Further imaging is warranted in this patient subset.[45,46]

As many trauma patients have hemorrhage from multiple sources, many trauma teams use the FAST to evaluate for evidence of intra-abdominal free fluid even with pelvic fracture, as the optimal approach in these patients will be both interventional radiology (to embolize the pelvic vessels) and concurrent laparotomy.

Table 1
Summary of studies using FAST and their key findings

Authors,Ref. Year	Study Design and Findings	Key Points
Branney et al,[54] 1997	Prospective analysis of blunt abdominal trauma patients. 486 patients were enrolled in KCP including FAST. This group was compared with historical cohort. DPL was reduced from 17% to 4%; CT was reduced from 56% to 26%. US examinations were used exclusively in 65% of the patients	A US-based KCP resulted in significant reductions in the use of invasive DPL and costly CT scanning without risk to the patient
Blackbourne et al,[34] 2004	Prospective observational study of 547 trauma patients with both initial and secondary US within 24 h of admission. The accuracy of initial US was 92.1% and 96.7% on the secondary US. No clinically significant hemoperitoneum developed in any patients with negative secondary US after 4 h	A second FAST examination significantly improves accuracy. Consider repeat US after an observation period of 4 h
Sarkisian et al,[55] 1991	US was performed as the primary screening procedure in 400 of 750 mass casualty patients with trauma in the first 72 h after the 1988 Armenian earthquake. Average time per patient was 4 min. More than 130 follow-up US were also performed. 12.8% of patients had trauma-associated pathology, with a 1% false-negative rate	The first article showing the utility of trauma US in mass casualty settings where resource utilization is paramount
Plummer et al,[26] 1992	A 10-year retrospective review of outcomes of patients with penetrating cardiac injuries. 49 patients were reviewed. 28 of these received immediate bedside echo; 21 did not. The probability of survival in each group was 34.2% and 31.8%, respectively. The actual survival was 100% in the echo group and 57.1% in the nonecho group. Neurologic outcome was also better in the echo group	An early important study showing significantly enhanced survival in patients with penetrating cardiac injury who received early echo
Ma et al,[32] 1995	Data from a prior prospective US study of 245 trauma patients with blunt or penetrating trauma injuries was retrospectively analyzed to determine if a multiple-view FAST examination had higher sensitivity than a single view. The multiple-view technique had a sensitivity of 87%. The Morison view alone had a sensitivity of only 51%. Gold standards were exploratory laparotomy, CT, or DPL	This early study on FAST showed the need for a multiple views to achieve acceptable sensitivity

Friese et al,[46] 2007	Retrospective review of 146 patients with pelvic fracture with at least 1 of the following risk factors for hemorrhage: age ≥55, evidence of hemorrhagic shock (SBP <100), or unstable fracture pattern. 126 of these patients had a FAST examination performed; 104 had confirmatory CT or exploratory laparotomy. Sensitivity and specificity of US were 26% and 96%, respectively	A negative FAST examination does not preclude the need for laparotomy or pelvic angiography in patients with pelvic fracture at risk for hemorrhage
Rozycki et al,[25] 1998	FAST examinations were performed on 1540 patients with precordial or transthoracic wounds or blunt abdominal trauma. Patients with positive US for hemopericardium underwent immediate surgery; patients with positive US for hemoperitoneum received either a CT (if stable) or immediate celiotomy if unstable. There were 1440 true-negative results, 80 true-positive results, 16 false negatives, and 4 false positives. Overall sensitivity was 83.3% and specificity was 99.7%. US had 100% sensitivity for patients with precordial or transthoracic wounds and hypotensive patients with blunt abdominal trauma	Recommended that US should be the initial diagnostic test for evaluating patients with precordial wounds and blunt truncal injuries. Also recommended immediate surgical intervention in patients with positive US with precordial wounds or blunt torso trauma patients with hypotension
Nishijima et al,[56] 2012	Extensive meta-analysis of literature since 1950 on intra-abdominal injuries; included 12 studies on clinical findings and 22 studies on bedside US. The presence of intraperitoneal fluid or organ injury on bedside US was more accurate than any history or physical examination findings (LR 30). These findings included US, seat-belt sign, hypotension, abdominal distension, and guarding. Importantly, the absence of abdominal tenderness did not rule out an intra-abdominal injury	Important meta-analysis confirming high accuracy of US in trauma. However, a negative result does not rule out injury; the ideal combination of variables needs further study

Abbreviations: CT, computed tomography; DPL, diagnostic peritoneal lavage; KCP, key clinical pathway; LR, likelihood ratio; SBP, systolic blood pressure; US, ultrasonography.

Retroperitoneal Hemorrhage

Retroperitoneal hemorrhage is poorly visualized on ultrasonography.[43,47] Retroperitoneal bleeding can result from a multitude of sources: pelvic fracture, injury to the great vessels (inferior vena cava [IVC] and aorta), and renal injuries. If the hemorrhage remains encapsulated in the retroperitoneal space and does not flow into the abdominal/pelvic compartments, the FAST can remain negative.

Positive FAST That May Not Be Due To Hemoperitoneum

In unstable patients with positive FAST examinations in whom there is a diagnostic dilemma regarding the type of free fluid present (ie, patients with a history of ascites or a concern about bladder rupture), an emergency bedside paracentesis may be performed under ultrasound guidance.[33] In these cases, the color of the aspirate will be immediately useful (red for blood, yellow for urine or ascites).

Negative FAST in an Unstable Patient

In patients with hemodynamic instability for whom the FAST examination is negative and the patient is too unstable to go to CT, a diagnostic peritoneal aspirate (DPA) may be useful if the cause of shock remains unknown. This technique is a modified version of the DPL, which has now been largely replaced by the FAST examination. In this procedure, the abdomen is aspirated for the presence of gross blood. No lavage is done. If positive, the patient should go immediately to the operating room.[48]

False-Positive FAST

Occasionally, false-positive FAST examinations occur, which can result from misinterpreting fluid-filled bowel as free fluid.[49] If in doubt, watch for peristalsis, and/or repeat the examination to ensure the fluid pocket(s) are in the appropriate tissue planes. If the gallbladder or renal cysts are prominent in the Morison's pouch, these can also be interpreted as a positive FAST. The key is the contained and circular appearance of cysts and body structures as opposed to the free-flowing appearance of blood. The fat surrounding the kidney in some obese patients may also occasionally be misinterpreted as free fluid.[50] Evaluating for the double line sign around the kidneys may be helpful in differentiating some cases of prominent perinephric fat, where this finding is noted, from free abdominal fluid.[50]

False-Negative FAST

False negative FAST examinations may occur when the scan is performed soon after the injury and the volume of free fluid is small. Repeating the exam at regular intervals, or especially if the clinical status changes, is an excellent approach to increasing the sensitivity of the exam and avoiding a false negative result.[34] Many times an initial negative exam may convert to a positive one as further fluid accumulates during resuscitation with intravenous fluids and/or blood. Delayed presentation of injury can also allow time for blood to clot, changing the echogenicity of blood and decreasing its tendency to layer out; additional care needs to be taken in this patient subset.

Laselle and colleagues[51] provide an excellent overview of false-negative FAST scans. These investigators studied 332 patients with a median injury severity score of 27. Of these, 49% had a false-negative FAST. Patients with severe head injuries and minor abdominal injuries were more likely to have a false-negative than a true-positive FAST. However, they also found that patients with liver, spleen, or abdominal vascular injuries are less likely to have false-negative FAST scans. Of importance, adverse outcomes were not associated with false-negative FASTs. In fact, patients with false-negative FAST scans were less likely to have a therapeutic laparotomy.

Negative FAST: Clinical Judgment and Serial Examinations Remain Paramount

In patients with a significant mechanism or concern, clinical judgment must prevail; reaching “premature closure” with a negative FAST examination can result in significant morbidity and mortality. In one study, 60% of deaths resulted largely from delayed treatment of splenic or other abdominal injuries.[52] By comparison, a large study of almost 4000 patients showed that a combination of careful negative serial examinations and negative screening ultrasonograms, over an observation period of at least 12 to 24 hours, virtually excluded abdominal injury.[53]

Summary Table: FAST Studies

A summary of some of the key original FAST studies, including study design, patient population, and key findings, are presented in **Table 1**. An important recent meta-analysis is also included.

TUTORIAL: FAST

When performing a FAST examination, it is important to remember that free fluid will first collect in the most dependent regions of the abdomen and pelvis. In the supine patient, the most dependent portion of the abdominal cavity is the right upper quadrant area region around Morison’s pouch.[57] In the pelvis, the retro-vesicular space in the male and the pelvic cul-de-sac in the female are the most dependent regions. Unfortunately, one single view is not sufficient to rule out free fluid.[52]

If the trauma patient has been in an upright position, the free fluid may be more evident within the pelvis. It is critical to perform the exam of the pelvis prior to placing a Foley catheter, as a full bladder serves as the acoustic window for the imaging of free fluid in this area. Another potential pitfall is that rolling the patient to inspect the back prior to the FAST exam may disturb the normal flow of blood and limit the sensitivity of the exam. Positioning the patient in Trendelenburg may improve the sensitivity of the right upper quadrant FAST views by up to one third, through the shifting of blood from the pelvis into the right upper quadrant.[58]

Performing the FAST Examination: Technique

Evaluate all 4 regions (RUQ, left upper quadrant [LUQ], cardiac, and suprapubic views) with a low-frequency (3–5 MHz) probe; this can be a small footprint phased-array (which aids in evaluating between the ribs) or a curved probe (**Fig. 1**). The convention is to orient the probe marker to the patient’s right (for transverse views) or head (for longitudinal or coronal views). The ultrasound machine should be set to abdominal presets.

Intraperitoneal fluid is anechoic (black); it appears as a black stripe on standard machine settings. Intraparenchymal or clotted blood can become more echogenic and heterogeneous. This caveat is important, and should be considered if presentation is delayed and no gross free fluid is evident.

If suspicion for hemorrhage is high, the patient should be placed in Trendelenburg.[58] Increased fluid collection with ongoing hemorrhage will increase the likelihood of visualization (especially after resuscitation with crystalloid and blood products). In high-risk patients, a CT scan should be strongly considered if the patient is stable.

Cardiac view

For the cardiac view (Please refer to Cardiac Echocardiography article by Perera and colleagues elsewhere in this issue), indications include assessment for free fluid within

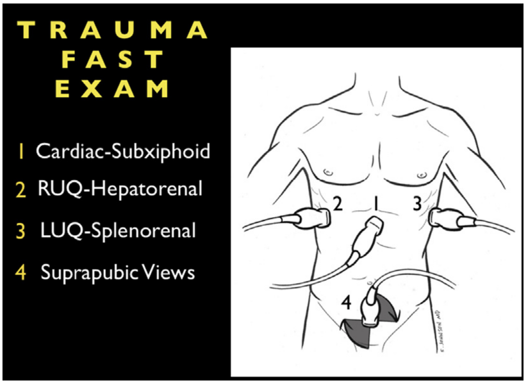

Fig. 1. Probe placement for FAST examination. In penetrating trauma, position 1 (cardiac) should be performed first, to rule out pericardial tamponade. In blunt trauma, position 2 (right upper quadrant [RUQ]) should be performed first, as this is usually the most sensitive view for hemoperitoneum. LUQ, left upper quadrant.

the pericardium to evaluate for tamponade. It can also be used to evaluate for cardiac activity in cases of traumatic cardiac arrest.

- Technique
  a. Place the probe just inferior to the xiphoid process with the indicator toward the right and angle it up toward the left shoulder.
  b. Ensure visualization of the entire heart, including the posterior pericardium, as pericardial effusions start here; this can be done by increasing the depth on the ultrasound system or having the patient breathe in deeply (Fig. 2).
  c. If you are unable to use this view because of habitus or pain, use the parasternal long-axis view. Place the probe between the second and fourth intercostal spaces on the anterior chest wall just to the left of the sternum, with the indicator toward the patient's left hip (see also the articles on echo and resuscitation elsewhere in this issue) (Figs. 3–5).

Fig. 2. Probe placement: subxiphoid (subcostal) view.

Fig. 3. Probe placement: parasternal long-axis view.

Fig. 4. Negative subxiphoid cardiac view.

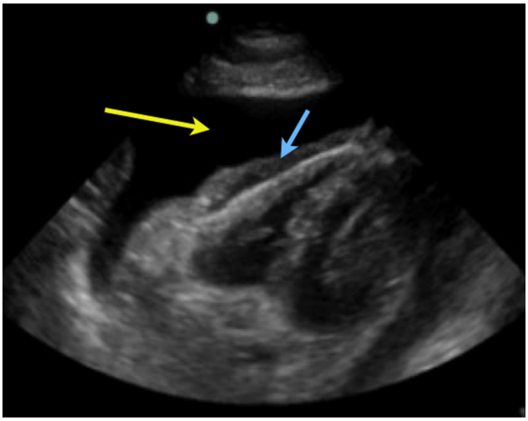

Fig. 5. Positive subxiphoid view for pericardial fluid (*yellow arrow*). Of note, a clot sealing a penetrating wound in the right ventricle is also present (*blue arrow*).

Right upper quadrant (including Morison's pouch)

This view assesses the potential space between the liver and kidney in the RUQ, using the liver as the sonographic window. It also assesses the regions just above and below the diaphragm and the upper portion of the paracolic gutter on the right.

- Indications: assessment for hemoperitoneum and hemothorax.
- This view is the most sensitive of the abdominal FAST views for free intraperitoneal fluid.
- However, it is imperative to complete the FAST if this view is negative.
- Technique
  a. Place the probe in the right anterior to midaxillary line between the seventh and eighth interspaces (Figs. 6 and 7).
  b. It is important to visualize the diaphragm to assess for free fluid in the thorax (position 1 in Fig. 6).
  c. Fan through the entire interface of the liver and right kidney through at least 2 respiratory cycles (position 2 in Fig. 6).
  d. Assess the caudal tip of the liver, as small fluid collections start here; this is depicted by position 3 in Fig. 6. Effectively this is the beginning of the right paracolic gutter, and fluid will often pool here before entering the Morison's pouch. Historically, the right and left paracolic views were part of some FAST protocols. However, this caudal view of the tip of the liver is the most sensitive of these views and maximizes the entire RUQ view (Figs. 8–10).

Left upper quadrant

This view assesses the potential space between the spleen and the kidney in the LUQ, using the spleen as the sonographic window. It also assesses the regions just above and below the diaphragm and the upper portion of the paracolic gutter on the left.

- Indications: assessment for hemoperitoneum and hemothorax.
- Technique
  a. Place the probe in the left posterior-axillary line between the seventh and eighth interspaces (Figs. 11 and 12).
  b. Fan through the entire interface of the spleen and the left kidney.
  c. The spleen is a smaller sonographic window than the liver. Usually the probe needs to be placed both more cephalad and more posterior to obtain a good view. This view is often considered the most difficult of the FAST views, owing to the smaller size of the spleen (in reference to the liver). In addition, air and

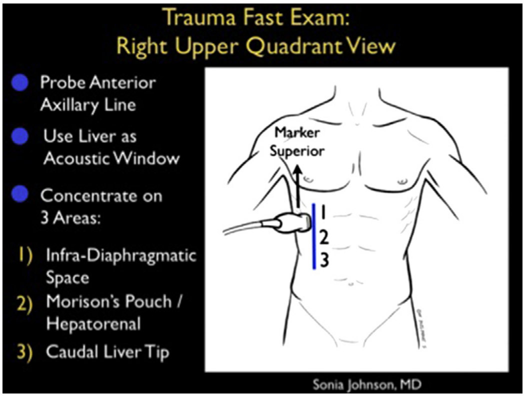

Fig. 6. Placement of probe for RUQ evaluation.

Fig. 7. Probe placement: RUQ view.

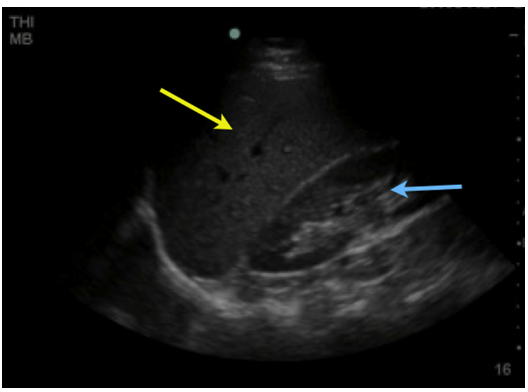

Fig. 8. Normal RUQ view. Liver (*yellow arrow*); right kidney (*blue arrow*).

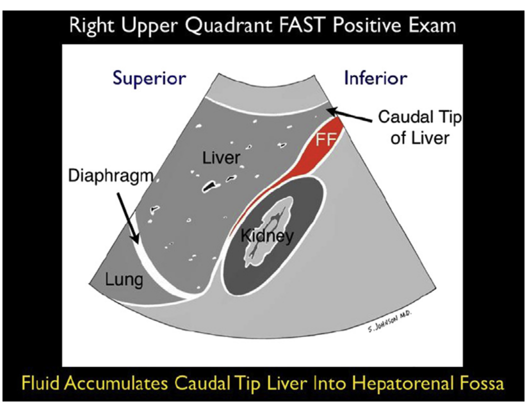

Fig. 9. Positive RUQ FAST examination. FF, free fluid.

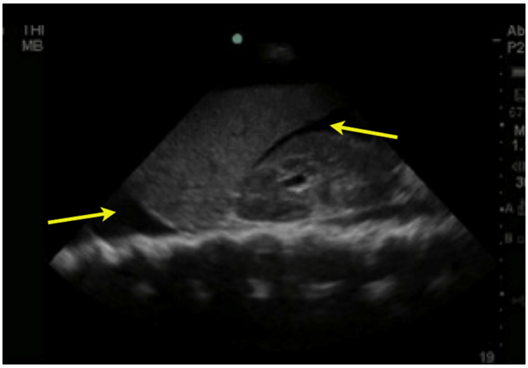

Fig. 10. Abnormal RUQ view: free fluid (*arrows*) in Morison's pouch (between liver and kidney) and in the chest cephalad to the diaphragm (hemothorax).

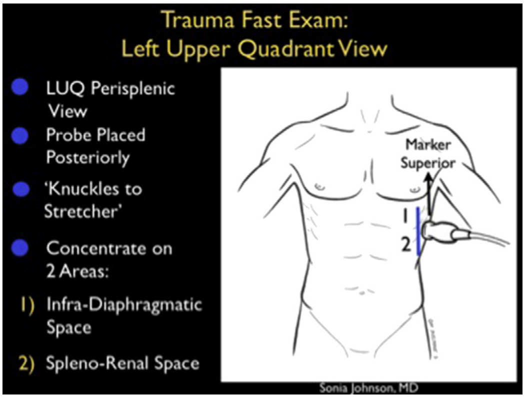

Fig. 11. Placement of probe for left upper quadrant (LUQ) evaluation.

Fig. 12. Probe placement: LUQ view.

gas in the stomach and colon can obstruct this view. Positioning the probe in a more superior and posterior position (relative to the right), with the examiner's knuckles touching the gurney, can often facilitate improved views by moving the probe around the intestinal gas and fluid. In addition, turning the probe into a more oblique orientation parallel to the ribs (with the indicator dot oriented superiorly and posteriorly) can allow for better imaging by avoiding interference from the rib shadows. Aiming the probe posteriorly also minimizes interference from the stomach.

d. Fluid flows differently in the LUQ than in the RUQ. The phrenicolic ligament limits the flow of free fluid down the left paracolic gutter. It is extremely important to visualize the interface between the diaphragm and the spleen to avoid false negatives. It is helpful to use respirations to visualize the subdiaphragmatic space.
e. Visualize the space above the diaphragm to check for free fluid in the thorax.
f. Complete the left upper quadrant exam by moving the probe more inferiorly to assess the inferior pole of the kidney and the area between the spleen and the kidney (Figs. 13–15).

Suprapubic (pelvic) view

This view assesses the pelvis for free fluid, using the bladder as the sonographic window.

- Indications: assessment for free fluid in pelvis. Note that this view cannot be used to rule out hemorrhage from a pelvic fracture source (see Pitfalls).
- A small amount of free fluid in women can be physiologic; clinical correlation is important.
- Technique
  a. Place the probe just above the pubic symphysis and aim down toward the feet, fanning through the bladder in both longitudinal and transverse orientations (Figs. 16–18).
  b. In the female, free pelvic fluid will first be seen in the cul-de-sac, posterior to the uterus. Larger amounts of fluid will collect behind the bladder, both anteriorly and posteriorly to the uterus. In the male, free pelvic fluid will be seen in the retrovesical space (Figs. 19 and 20).

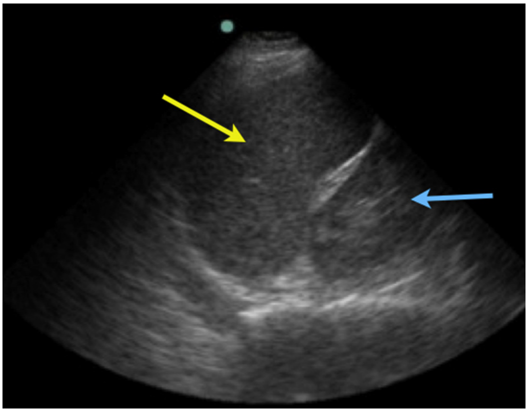

Fig. 13. Normal LUQ view. Spleen (*yellow arrow*); left kidney (*blue arrow*).

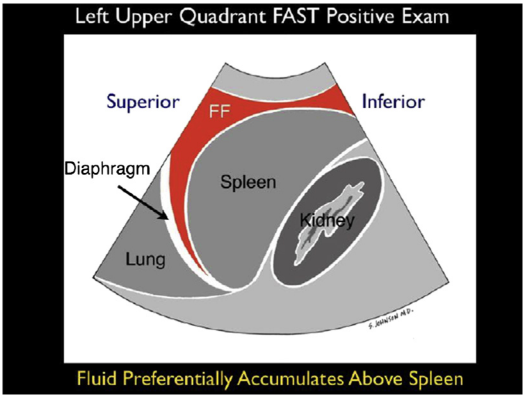

Fig. 14. Positive LUQ FAST examination. FF, free fluid.

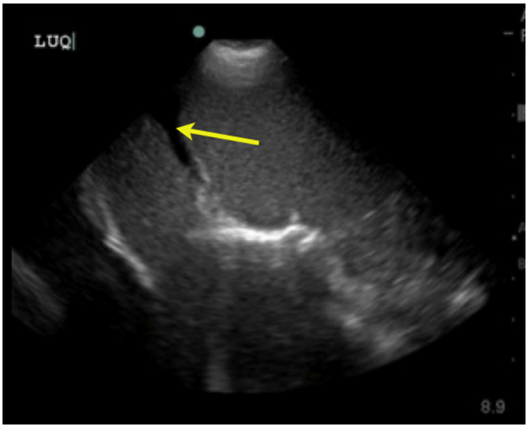

Fig. 15. Abnormal LUQ view: free fluid (*arrow*) in spleen in a pediatric trauma patient (e.g., Case 1).

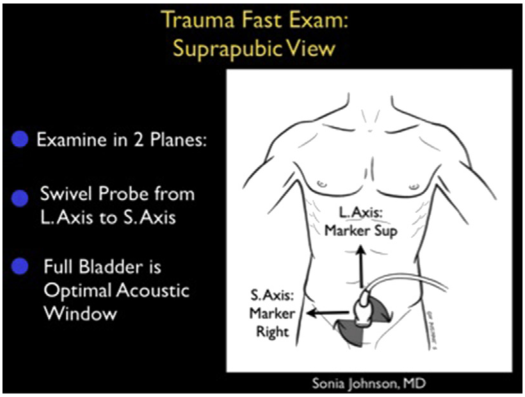

Fig. 16. Placement of probe for pelvis evaluation.

Fig. 17. Probe placement: suprapubic.

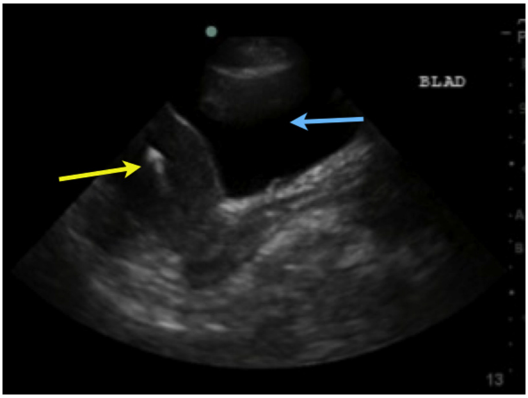

Fig. 18. Negative suprapubic FAST view (female): no significant free fluid. Note that an intrauterine device is present (*yellow arrow*). Bladder (*blue arrow*).

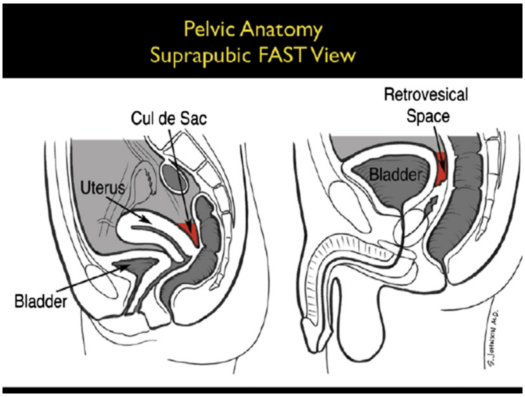

Fig. 19. Pelvic anatomy for suprapubic FAST examination.

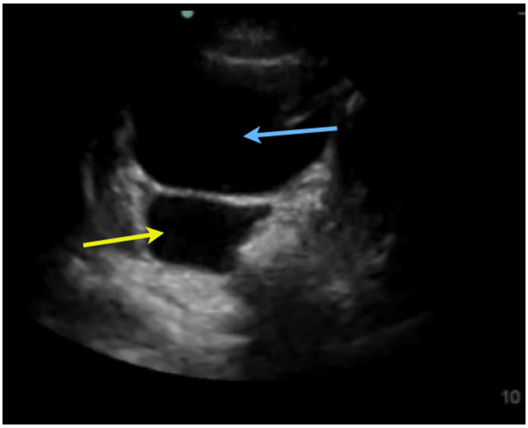

Fig. 20. Positive suprapubic view: free fluid (*yellow arrow*) behind the bladder (*blue arrow*).

c. The term "double-wall sign" is often used to describe a positive pelvic FAST in a male. Free fluid outside the bladder will illuminate the outer bladder wall, and urine will illuminate the inner bladder wall (see Fig. 20).
d. Pitfalls for a false-positive pelvic scan include ovarian cysts in women, seminal vesicles in men, an enlarged rectum, or prominent prostate.
e. Filling the bladder (either with hydration or retrograde fluid infiltration through a Foley catheter) can improve visualization, although this technique has generally fallen out of practice.

E-FAST

Background

For the purposes of this article, this section discusses the evaluation of the chest for hemothorax and pneumothorax on extended FAST (E-FAST). The key is to consider using ultrasonography of the chest for the evaluation of pneumothorax and clinically significant hemothorax as part of the FAST examination. For further discussion of thoracic ultrasound, please refer to the article by Lobo and colleagues elsewhere in this issue.

Hemothorax

The evaluation for hemothorax is performed by using the same windows and probe as for the RUQ and LUQ trauma examination, with attention focused on above the diaphragm and around the adjacent lung. Lung ultrasonography appears to be as sensitive as or more sensitive than chest radiography (CXR) for the evaluation of hemothorax.[20,21] In a recent prospective study by Zanobetti and colleagues[59] on a group of nontrauma patients with symptomatic dyspnea from a pleural effusion, there was a high concordance between ultrasonography and radiography for pleural effusion. However, when there was disagreement, ultrasonography was more accurate than CXR in distinguishing pleural effusion, and much faster to obtain.

Pneumothorax

The evaluation for pneumothorax is optimally performed with a high-frequency linear probe. The probe is positioned in the second intercostal space in the mid-clavicular line with the indicator marker oriented toward the patient's head. The exam utilizes both gray-scale B-mode imaging and M-mode imaging to best demonstrate lung sliding. Case 3 illustrates an example of a chest tube that was avoided in a trauma patient by using rapid bedside ultrasonography.

E-FAST for pneumothorax shows great benefit, as the incidence of occult pneumothoraces approaches 15% among injured patients undergoing CT. Remarkably, up to 76% of all pneumothoraces (detected by CT) may be occult on supine CXR with real-time interpretation by trauma teams.[60] The E-FAST has a greater sensitivity than supine CXR for pneumothorax,[61,62] and may decrease the need to perform chest CT.[63] It has also been shown to be superior to upright CXR in a series of postbiopsy patients with iatrogenic pneumothorax.[64] Chest ultrasonography as part of the E-FAST detects up to 92% to 100% of all pneumothoraces.[60]

PITFALLS OF E-FAST

Choice of Gold-Standard Effects Sensitivity

Ultrasound has been shown to have a sensitivity that equals or exceeds that of CXR for detection of hemothorax. CT imaging remains the gold standard against which all other imaging modalities for pleural fluid are compared. However, ultrasound has been found to have a discriminatory threshold that differs only by 10–50 ml when compared to CT imaging. One study stated that ultrasound had a poor sensitivity for the evaluation of clinically insignificant small hemothoraces as compared to CT imaging.[65] However, due to the ability of ultrasound to detect as little as 20–50 ml of fluid, one may question the study premise of comparing the 2 imaging modalities in their ability to detect pleural fluid that was not deemed clinically significant.

Loculated Pneumothorax and Subcutaneous Emphysema

Loculated traumatic pneumothoraces that are not near the second intercostal space may be difficult to identify using standard E-FAST views.[64] If there is high suspicion for pneumothorax and the E-FAST is negative, the probe should be used to evaluate additional areas of the chest in a manner similar to evaluation for the lung point.[63] Subcutaneous emphysema can interfere with the visualization of the pleural line; however, in these cases pneumothorax is clinically extremely likely.[66]

False Positives for Pneumothorax

False positives in the evaluation of pneumothorax can be caused by the presence of bullae, adhesions, and contusions.[67] Therefore, particular care should be taken in patients with a history of chronic obstructive pulmonary disease or previous lung abnormality.

Summary Table: E-FAST: Hemothorax and Pneumothorax Studies

A summary of some of the key E-FAST studies, including study design, patient population, and key findings, is presented in **Table 2**. An important recent meta-analysis is also included.

TUTORIAL: E-FAST

- Indications: blunt or penetrating trauma to chest with concern for hemothorax or pneumothorax.

Table 2
Summary of E-FAST hemothorax and pneumothorax studies and their key findings

Authors,[Ref.] Year	Study Design and Findings	Key Points
Blaivas et al,[61] 2005	Prospective study of 176 trauma patients receiving CT imaging including lung windows. Attending emergency physicians performed bedside trauma US to determine the presence of lung sliding. Portable supine AP CXRs were reviewed by attending trauma surgeons, blinded to the results of the US. CT or air release on chest-tube placement were considered gold standards. US was 98.1% sensitive and 99.2% specific for PTX. Conversely, CXR had only 75.5% sensitivity, with specificity of 100%. US also allowed for differentiation between small, medium, and large PTX	CXR may miss small to moderate PTX in trauma patients, especially if the PTX is anterior. This study shows that US as part of the E-FAST is more sensitive than supine CXR for identifying traumatic PTX
Ma & Mateer,[20] 1997	Retrospective analysis of a prior prospective study of trauma US on 245 adult patients with blunt and penetrating torso trauma to determine utility of US in assessing hemothorax. The trauma US included evaluation for pleural fluid; US interpretations were recorded before other test results were available. These were compared with CXR and CT interpreted by radiologists (who were not blinded to patient outcome). 5 patients were excluded because of chest-tube placement before the US was done. 26 of 240 study patients had hemothorax confirmed by tube thoracostomy or CT. Both US and CXR showed equivalent sensitivities and specificities for hemothorax, at 96.2% and 100%, respectively	Suggests that US is at least as sensitive and specific as CXR in identification of hemothorax. It may expedite this diagnosis in major trauma patients
Abboud & Kendall,[65] 2003	Prospective study of blunt-trauma patients who underwent CT of the chest, abdomen, or both. Before CT, US was performed to evaluate for free fluid in the thorax. The ED US was 12.5% sensitive and 98.4% specific when using CT as the gold standard. US was limited in its ability to pick up small-volume hemothorax. Of note, patients who had small effusions on CT did not have clinically relevant consequences	US is at least as good as CXR for hemothorax (as above), but not as sensitive as CT for small-volume hemothorax of unclear clinical significance

Lichtenstein et al,[63] 2005	Retrospective study of 200 consecutive undifferentiated ICU patients who received a chest CT in addition to CXR and US. 47 consecutive cases of occult PTX (on CXR) were evaluated and compared with controls. Three signs were evaluated: lung sliding, the A-line sign, and the lung point. The abolition of lung sliding alone had sensitivity of 100% and specificity of 78%. Absent lung sliding plus the A-line sign had sensitivity of 95% and specificity of 94%. The lung point had sensitivity and specificity of 79% and 100%, respectively	ICU study on occult PTX. It is critical to diagnose PTX in this patient population because of the risk of converting to tension PTX on ventilators with positive pressure
Volpicelli,[68] 2011	Evidence-based and expert consensus recommendations for lung US in critical care and emergency settings. A literature review of 320 references was performed, as well as expert recommendations from a multidisciplinary panel of 28 experts from 8 countries	Outstanding analysis, and key recommendations and levels of evidence regarding all aspects of point-of-care lung US (including trauma)
Alrajhi et al,[69] 2012	570 articles were reviewed and 21 selected for full review. Of these, 8 studies met criteria. All studies but one used lung sliding and comet tailing to rule out PTX. A total of 1048 patients were included. US was 90.9% sensitive and 98.2% specific for the detection of PTX, compared with CXR (50.2% sensitivity and 99.4% specificity)	Meta-analysis confirming excellent sensitivity and specificity of lung US primarily utilizing the lung-sliding and comet-tail signs

Abbreviations: AP, anteroposterior; CT, computed tomography; CXR, chest radiography; ED, emergency department; ICU, intensive care unit; PTX, pneumothorax; US, ultrasonography.

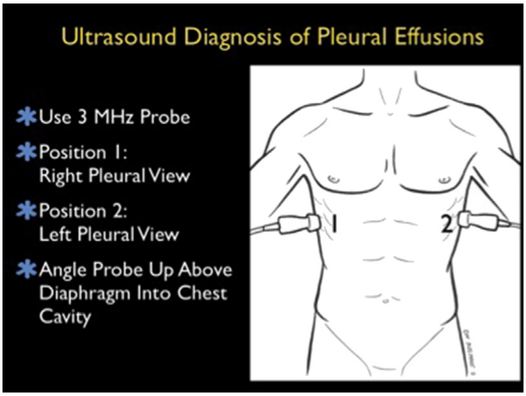

Fig. 21. Probe placement for evaluation of hemothorax/pleural effusion.

- Hemothorax evaluation is performed with the 3- to 5-MHz probe during the diaphragmatic evaluation of the RUQ and LUQ as discussed earlier (**Figs. 21** and **22**).
- Pneumothorax evaluation is best performed with a high-frequency linear probe ($\geq$10 MHz).
- Technique (see also the article on thoracic aspects elsewhere in this issue)
  a. Right chest: Assess for pneumothorax on the right by placing the probe in a longitudinal orientation (indicator marker toward head) in the second intercostal space along the midclavicular line. With high clinical suspicion, scan through other parts of the chest (**Figs. 23–25**).
  b. Evaluate for presence or absence of lung sliding (a real-time appearance of shimmering at the pleural line that has the appearance of ants walking across the screen). Lung sliding is absent in the location of a pneumothorax.
  c. Evaluate for comet-tail artifact (short vertical lines emanating off the pleural line, **Fig. 26**). Comet-tail artifact is absent in the location of a pneumothorax.

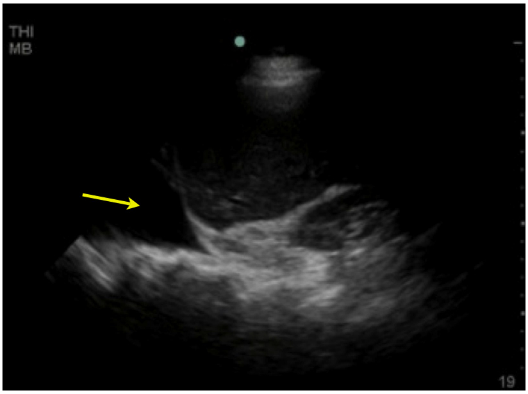

Fig. 22. Hemothorax: collection of free fluid (*arrow*) to left of (cephalad to) the diaphragm.

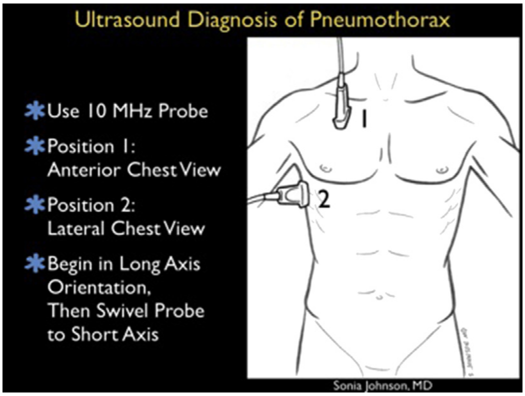

Fig. 23. Probe placement for pneumothorax evaluation.

Fig. 24. Probe placement: scan of right lung pneumothorax.

Fig. 25. Probe placement: scan of left lung pneumothorax.

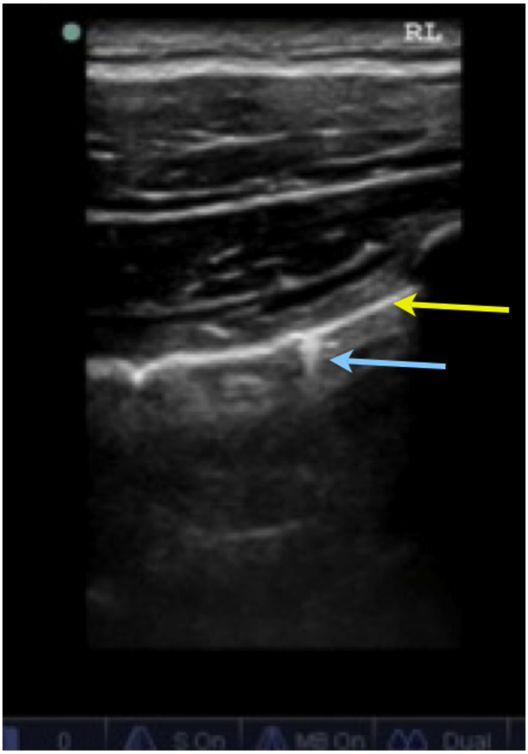

Fig. 26. Short vertical comet tails (*blue arrow*) emanating from pleural line (*yellow arrow*).

d. The "sandy beach" appearance on M-mode scanning can also confirm absence of pneumothorax; conversely, the "stratosphere sign" or "bar-code sign" indicates the presence of pneumothorax (Figs. 27 and 28).
e. Left chest: Repeat as above, on the left side.
f. If identified, the "lung point" shows the edge of the pneumothorax, where lung sliding abruptly ends.

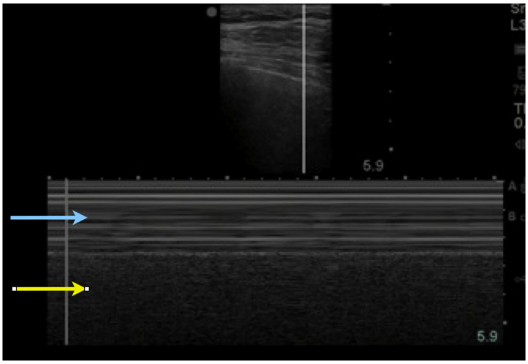

Fig. 27. "Sandy beach" sign of normal lung on M-mode. The "waves" (*blue arrow*) lay above the "sand" (*yellow arrow*).

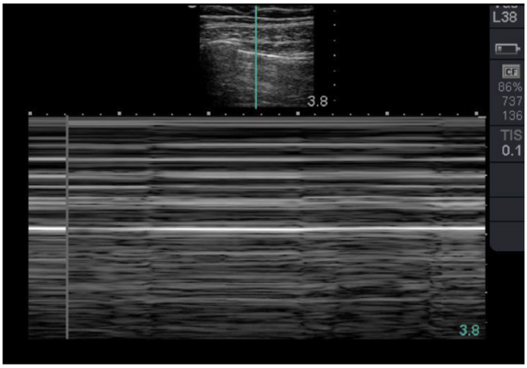

Fig. 28. "Stratosphere sign" of pneumothorax.

STATE OF FAST, 2013: CONTROVERSIES

This article aims to provide an evidence-based review of both the strengths and limitations of the FAST examination in adults. Despite the plethora of evidence supporting the utility of the FAST, there continues to be ongoing debate. Awareness of these continuing issues is imperative if interdisciplinary trauma protocols that optimize patient outcomes in a rational, resource-efficient manner are to be developed.

Melniker and colleagues[70] performed a randomized, controlled clinical trial evaluating the time from ED arrival to transfer to operative care in patients with torso trauma, with the intervention being incorporation of a point-of-care limited sonography (PLUS) protocol versus usual care. Secondary outcomes included CT use, length of stay, complications, and charges. There were no important differences in the characteristics of the groups, and both groups included both stable and unstable patients. Compared with the usual-care group, time to operative care was 64% less for PLUS patients. PLUS patients also underwent fewer CT scans (odds ratio 0.16), spent 27% fewer days in the hospital, and had fewer complications (odds ratio 0.16). Charges were 35% less in comparison with controls. This important study showed that ultrasonography enhanced care and efficiency, all at a lower cost.

A Cochrane database review of the FAST caused concern when it suggested that evidence from randomized controlled trials was insufficient to justify promotion of ultrasonography-based clinical pathways in diagnosing patients with suspected blunt abdominal trauma.[71] However, this study included only 4 articles, 2 of which showed more rapid/efficient care provided with the FAST examination.[72] In addition, when this review was further analyzed, questions arose as to its methodology and suggested that it was flawed.[73]

Natarajan and colleagues[74] posed the question of whether the FAST scan is worth doing in patients with hemodynamically stable blunt trauma. A total of 2105 patients with blunt trauma were evaluated, and 1894 true-negative studies were performed (1201 confirmed with CT and the rest with observation). 88 true-positive studies and 118 false negatives were found. Of the false negatives, 44 eventually required laparotomy. Natarajan and colleagues[74] suggest that the FAST scan should be reserved for hemodynamically unstable patients. However, their own results speak against this. The investigators were able to identify 88 patients with a positive FAST before they became hemodynamically unstable; they avoided CT imaging in 693 patients with negative FAST scans who were evaluated with observation alone after their negative FAST, and only 2% of all of their negative FAST scans needed to go to the operating room (OR).

In 2009, Melniker[75] published a rebuttal to the controversial Cochrane review. In his study, he performed a systematic literature review using verbatim methodologies as described in the Cochrane review with the exception of telephone contacts. Of 487 citations, 163 articles were fully screened, and 11 contained prospectively derived data (instead of the 4 articles cited by Cochrane). Of the 2755 patients in these studies, 16% went to the OR after FAST. Based on this extensive review, Melniker concluded that the FAST examination, when adequately completed, is a nearly perfect test for predicting a "need for OR" in patients with blunt torso trauma.[75]

Becker and colleagues[76] evaluated the reliability of the FAST scan in patients with a high injury severity score (ISS). In their study, 3181 blunt abdominal trauma patients were split into 3 groups based on ISS (groups 1, 2, and 3 with ISS means of 7.9, 19.6, and 41.3, respectively). The accuracy of ultrasonography was 90.6% in the most injured group, versus more than 97% for the other 2 groups. Severely injured patients benefited greatly from early ultrasonographic detection of hemodynamically significant injuries.

In summary, it is clear that despite the controversy, the evidence overwhelmingly supports the recommendation to take unstable adult patients with a positive FAST to the OR. Patients with a negative FAST require further evaluation, with serial examinations, laboratory tests, or imaging, depending on the clinical presentation and management options available.

FUTURE DIRECTIONS

Pulseless Traumatic Arrest

The cardiac views of the E-FAST examination can provide very useful information during the initial resuscitation of a trauma patient. An important study by Cureton and colleagues[77] in 2012 discussed the utility of the cardiac portion of the FAST in pulseless traumatic arrest. To date this is the largest study published on this important topic, being a retrospective analysis of 318 adult trauma patients who were pulseless on hospital arrival. Electrocardiograms and cardiac ultrasonography were performed on 162 of these patients. The sensitivity of cardiac motion on ultrasonography to predict survival to admission was 86%, with a negative predictive value of 99%. This result suggests that the cardiac view of the E-FAST examination may be a rapid method to determine the futility of resuscitation in this patient group, although further studies are warranted. The reader is referred to the articles on echo and resuscitation elsewhere in this issue for a further discussion on future directions of trauma echo.

Contrast-Enhanced Ultrasonography for Solid-Organ Injury

One of the weaknesses of ultrasonography is its inability to effectively evaluate solid-organ injury. Contrast-enhanced ultrasonography, if available, may be beneficial in these cases.[78] Blaivas and colleagues[79] studied the feasibility of using intravenous contrast during the FAST examination in simulated patients. The mean time to initial visualization of contrast was 15 seconds; the latent phase of the intravenous contrast occurred at a mean time of 54 seconds. It was postulated that contrast enhancement would allow better ultrasonographic visualization of hematomas that were not actively bleeding.

Chest-Tube Placement

The utility of ultrasonography in diagnosing hemothoraces and pneumothoraces has been well studied. Bedside ultrasonography has also been shown to be valuable in the management of chest tubes. Ultrasound-guided intercostal nerve blocks can decrease the pain associated with chest-tube placement.[80] In addition, intrathoracic chest-tube placement can be confirmed with ultrasonography.[81]

Diagnosis of Pelvic Fracture

Regarding the limitations of diagnosing hemorrhage from a pelvic-fracture source (as discussed earlier), ultrasonography has shown some utility in the diagnosis of pubic symphysis widening suggestive of unstable pelvic fractures. This modality could potentially lead to faster application of a pelvic binder and tamponade of bleeding,[82] especially if there was a delay in obtaining the pelvic radiograph.

Hemodynamic Evaluation

The FAST examination has been incorporated into the Rapid Ultrasound in Shock Protocol, a targeted assessment for the rapid diagnosis of the etiology of undifferentiated hypotension. It is also a major component of the CORE scan (a Concentrated Overview of Resuscitative Efforts). Changes in the IVC diameter correlate directly with intravascular volume status.[83] A flat IVC (less than 2 cm) has been shown to be an indicator of poor prognosis in trauma patients and acute surgical patients.[84] The IVC is normally assessed in the subxiphoid view, but can also be visualized using a midaxillary view. This view may be more easily obtained in patients with abdominal pain, and is obtained with the probe in the same position as the RUQ FAST view by fanning anteriorly.[85] Serial IVC measurements can be used to help guide intravascular volume resuscitation.

Prehospital, Mass Casualty, and Practice in Austere Environments

Many countries are now incorporating the E-FAST examination into prehospital protocols, as it has the potential to significantly affect scene management. In Europe, physicians routinely ride along in ambulances. A recent study shows promise in utilizing ultrasonography in the periarrest setting. Echo findings altered management in 78% of these cases.[86] Although these systems differ from those in the United States, early studies show promise in the ability to teach basic elements of the E-FAST to paramedics in the United States.[87] However, care must be taken to ensure the appropriate balance of scene time to optimize survival.

With its beginnings in the Armenian earthquake mass casualty incident (MCI), ultrasonography continues to have significant utility in MCIs such as the Haiti earthquake, for both trauma evaluation and venous access.[55,88] In fact, new ultrasonography protocols are being developed that take advantage of the portable nature of this modality during MCIs.

The CAVEAT examination by Stawicki and colleagues[89] incorporates the well-established abdominal and thoracic applications discussed here, as well as assessment for long-bone fractures. Ultrasonography has tremendous potential in multiple extreme environments, even including the International Space Station.[90]

There were 5.1 million deaths from injury worldwide in 2010.[1] Expanding the use of point-of-care ultrasonography in the global care of trauma patients, especially to those in resource-limited areas, has the potential to have a massive impact on mortality.

SUMMARY

The E-FAST evaluation provides critical information during the real-time evaluation of complex trauma patients. It can identify free fluid suggestive of abdominal solid-organ injury, hemothorax, or pericardial fluid collections. Its sensitivity for pneumothorax is superior to that of CXR.

This article reviews important literature on the FAST and E-FAST examinations in the acute care setting. Also reviewed are key pitfalls, limitations, and controversies. A practical "how-to" guide and exploration of new frontiers are presented. The authors hope that this knowledge will enable physicians and their teams to further optimize trauma care, both in the United States and abroad.

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