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Ultrasound in abdominal trauma

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Ultrasound in the evaluation of abdominal trauma has evolved over the past 30 years. The use of ultrasound for abdominal trauma was described initially by Kristensen and colleagues [1] in 1971. In 1976, Ascher and colleagues [2] first reported the accuracy of ultrasound in *Radiology*, with 80% sensitivity for the detection of splenic injury. In a study of 808 patients, Tiling and colleagues [3] in 1990 reported a sensitivity of 89%, a specificity of 100%, and an accuracy of 98%. This same group also was first to comment on the effect of training and experience and reported that surgeons with extensive ultrasound experience could diagnose intra-abdominal fluid with a sensitivity of 96% and an accuracy of 99%. Interest and experience with ultrasound for trauma grew steadily around the world among surgeons and emergency physicians during the early 1990s [4–7]. During this period, ultrasound technology was improving with regard to price, portability, and resolution, allowing its use during resuscitation. At the same time, in the United States, there was continuing reliance on diagnostic peritoneal lavage (DPL) and CT and much less interest in sonography for abdominal trauma. This all changed when emergency physicians and surgeons in the United States began to publish their experience with ultrasound [4,8,9]. The term *Focused Assessment with Sonography for Trauma* (FAST) was coined by Rozycki et al [10] in 1996 and has persisted as the accepted acronym for the trauma ultrasound evaluation. The basic four-view examination (perihepatic, perisplenic, pelvic, and pericardial views) has become the foundation of the FAST examination. The rapid, noninvasive, and practical nature of ultrasound for bedside evaluation of critically injured patients has changed the evaluation of blunt abdominal trauma.

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Technique

In the supine patient, the hepatorenal space is the most dependent area and the least obstructed for fluid flow. Fluid in the abdomen can move freely up the right pericolic gutter into this space. The left pericolic gutter is higher and the phrenicocolic ligament blocks the flow; consequently, fluid tends to flow to the right pericolic area. On the right, fluid flows into Morison's pouch, the potential space in the hepatorenal recess (Figs. 1 and 2). On the left, fluid flows preferentially into the subphrenic area and not into the splenorenal area (Fig. 3), which is important because the subphrenic area may be difficult to visualize due to bowel gas and splenic flexure gas. Fluid in the pelvic region flows to the retrovesicular area in the male patient and to the pouch of Douglas in the female patient because these areas are the most dependent areas of the pelvis. Given these anatomic relationships, the FAST examination has evolved into three to five intraperitoneal views and one cardiac view.

The FAST scan can be completed in less than 5 minutes and may involve up to six views (Fig. 4), depending on examiner preference. These views include (1) a subxiphoid or parasternal view to detect pericardial fluid; (2) a right upper quadrant view to assess the hepatorenal interface (Morison's pouch) and right chest; (3) the right paracolic gutter; (4) a left upper quadrant view to assess the splenorenal interface and left chest; (5) the left paracolic gutter; and (6) longitudinal and transverse pelvis views to look for free fluid adjacent to the bladder [11]. Although the bladder is not a peritoneal organ, a full bladder greatly enhances the detection of free fluid for the pelvis view (Fig. 5) by giving readily identifiable landmarks and providing an acoustic window. The pericolic gutter views

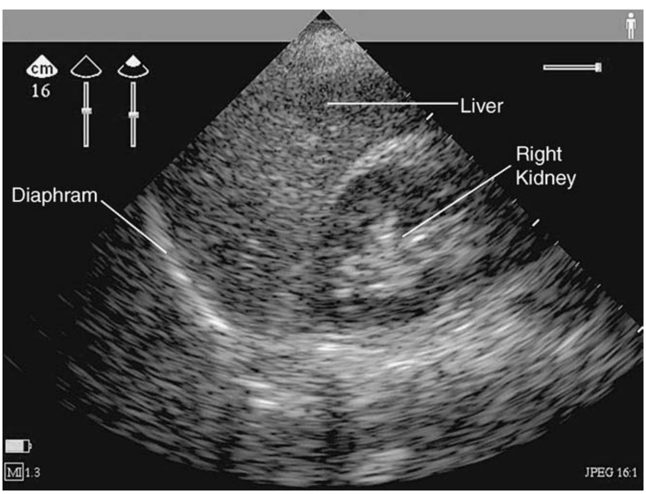

Fig. 1. Normal view of hepatorenal interface (Morison's pouch).

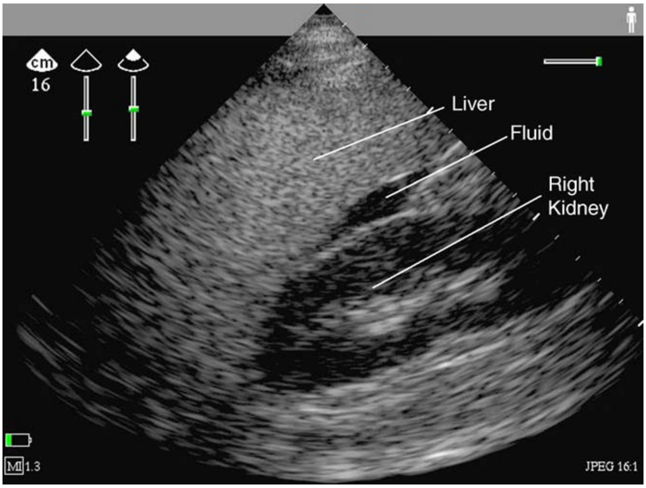

Fig. 2. Free fluid in hepatorenal interface.

are optional views that some providers use (Fig. 6). Their role in improving the accuracy of the FAST scan has not been studied. The focus of the FAST examination is the detection of free fluid; however, during the procedure, specific organs occasionally may be visualized, providing potential injury localization.

Given the flow of fluid in the abdomen and free flow toward the right, the utility of a single right-sided view has been examined. Ma and

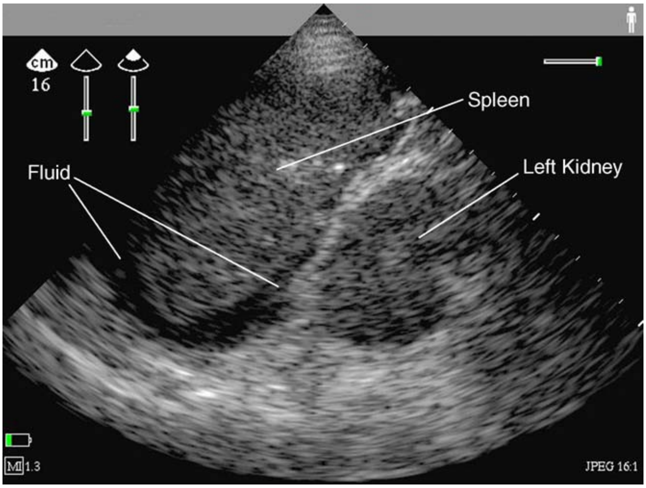

Fig. 3. Fluid in splenorenal interface. Note that fluid in the subphrenic space is larger than in the splenorenal space due to the phrenciocolic ligament.

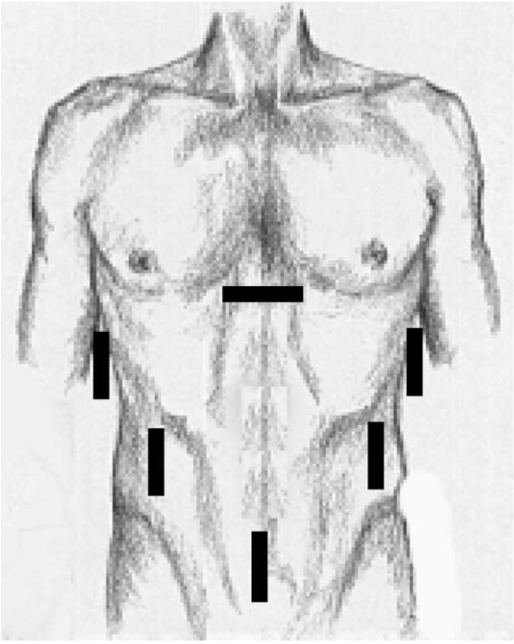

Fig. 4. FAST examination views.

colleagues [12] compared a single view of Morison's pouch with a standard five-view FAST examination for the detection of hemoperitoneum. Sensitivity of the complete FAST examination versus the single view for hemoperitoneum was 87% and 51% respectively. In a blinded prospective

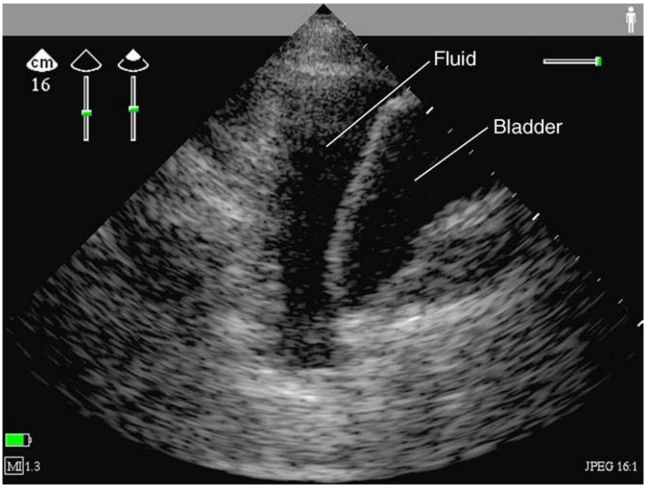

Fig. 5. Longitudinal pelvic view with intraperitoneal fluid seen outside of the bladder.

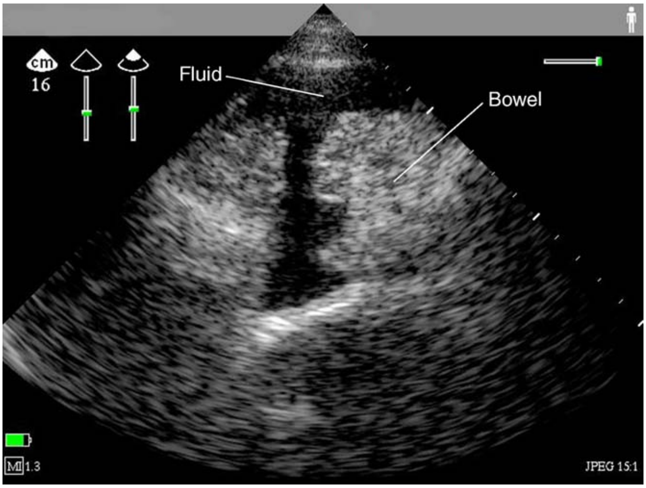

Fig. 6. Fluid in pericolic gutter. Note floating bowel loops.

study, Ingeman and associates [13] demonstrated that for single views of the abdomen for hemoperitoneum, the hepatorenal view was superior to the splenorenal or pelvic views with regard to sensitivity. In a multicenter prospective trial, Rozycki et al [14] found that the hepatorenal interface was the most common location of free fluid in blunt abdominal trauma associated with significant parenchymal injuries. Although a single hepatorenal view has been advocated in certain situations [15], a multiple-view FAST examination is still recommended because the sensitivity is higher [11,12].

The role of the FAST examination for detecting pericardial fluid also is very important. Work originally done by Plummer [16] in 1992 demonstrated the value of bedside ultrasound in the evaluation of penetrating cardiac injuries. In this study, focused bedside echocardiography was performed on 49 patients with penetrating cardiac injuries who were compared with a control group of patients who did not undergo ultrasonography. The ultrasound group had a significantly faster rate of diagnosis and disposition and higher survival rates (100% versus 57%). A multicenter trial by Rozycki et al [17] in 1999 demonstrated similar results. In 261 patients, ultrasound was found to have a sensitivity of 100% and a specificity of 97% for penetrating cardiac injuries. Thus, bedside echocardiographic evaluation as a component of the FAST examination has proved its diagnostic role for penetrating cardiac injuries. The role of bedside ultrasound in blunt chest trauma patients for evaluating myocardial contusion, rupture, and valve injury is much less clear and involves an echocardiographic examination that is beyond the scope of the limited bedside ultrasound examination and this article.

Clinical implications of the focused assessment with sonography for trauma examination results

Much of the initial research into the use of ultrasound in trauma focused on the test characteristics of ultrasound for detecting hemoperitoneum and on establishing its role in blunt abdominal trauma. Indeed, when describing the history of the FAST examination, sensitivity and specificity define its usefulness compared with DPL and CT. From a purely statistical sense, sensitivity and specificity calculations rely on all injuries being confirmed or excluded by a "gold standard" test; however, this is impractical in much of clinical research. A significant number of trauma ultrasound studies have used these clinical outcomes and, thus, sensitivity and specificity have been calculated using different outcomes and "gold standards," depending on the study. For example, a false negative in one study may be a true negative in another if the patient required no operative intervention for the injury. This situation is exemplified by a study performed by McGahan et al [18] that evaluated the use of ultrasound in 500 blunt trauma patients. This group compared ultrasound findings to CT or laparotomy findings as the "gold standard," not clinical observation. They reported a sensitivity of 63%, a specificity of 95%, and an accuracy of 85% for the detection of hemoperitoneum and organ injury. This calculation was based on very conservative positive and negative criteria, defined as the presence of any injury regardless of whether a therapeutic procedure was performed. If a study endpoint like clinical outcome or observation was used, however, then their reported sensitivity would have increased to greater than 90%. When assessing ultrasound in the evaluation of the blunt trauma patient, calculations such a sensitivity and specificity may be misleading. Consequently, the question should be, How does this ultrasound result affect the patient for whom I am caring right now?

In detecting intra-abdominal injuries in trauma patients, the governing paradigm always has been to quickly recognize those patients who require laparotomy and to prevent further morbidity or mortality. Underlying this paradigm is the understanding that ongoing evaluation through serial examinations or other imaging will be needed to determine whether a patient has any intra-abdominal injury. Most experts would concur that ultrasound has performed best when limited to detecting free intraperitoneal fluid [10,11,19]. Historically, the presence of any intraperitoneal fluid indicated a significant intra-abdominal injury and warranted an immediate exploratory laparotomy. Over the past decade, however, the practice of non-operative management for intra-abdominal injuries in adults and children has increased [20–22]. This changing practice has relied on the increasing use of high-performance CT to image the abdomen. The availability of rapid CT scanners has allowed many trauma centers to develop criteria for obtaining abdominal CT scans during the resuscitative phase [23,24]. Thus, patients who previously would have had an ultrasound and serial examinations as the primary means of detecting abdominal injuries now are taken quickly to a high-speed CT scanner and undergo extensive body imaging. Given this practice, the question of sensitivity and specificity is a question not only of detecting an intra-abdominal injury with ultrasound but also of detecting intra-abdominal injuries that require laparotomy. The more important question is, What is the role of ultrasound in determining the need for laparotomy? The presence of free fluid is only one surrogate indicator of serious intra-abdominal injury [25]. A small amount of fluid in a stable patient with a small liver laceration is much different than a large amount of fluid in an unstable patient with a high-grade splenic disruption. Both examinations are positive, but each patient falls into a very different management category.

A 1999 consensus conference on the performance of ultrasound in trauma examined the question of the positive and negative studies and how they apply to clinical practice. This report suggested the following guidelines [11]: in hemodynamically unstable patients, a positive FAST examination generally should be followed by a laparotomy, and a negative FAST examination warrants examination for an extra-abdominal source of hemorrhage. In hemodynamically stable patients, a positive FAST examination should be followed by an abdominal CT scan to better define the injury, and a negative FAST examination should be followed with serial exams for 6 hours and a follow-up ultrasound or abdominal CT scanning, depending on the clinical scenario.

Although this practice paradigm has not been validated, it represents a consensus among experts. Variations in this practice, however, are commonplace. For example, given a significant mechanism and a negative FAST examination, a stable patient may still undergo CT scanning [25]. An unconscious patient with severe head trauma requiring operative intervention who has a negative FAST examination still may undergo CT scanning to provide preoperative clearance. Suffice it to say that stable patients with a negative FAST examination define a more ambiguous population. Patients can have significant intra-abdominal injuries and not have free fluid or they may have delayed fluid accumulation, especially if the examination is performed shortly after the injury. Does the FAST examination add much if the patient is going to undergo an abdominal CT anyway? Given the speed of the average FAST scan, it likely would not delay care. One could make an argument that the FAST examination allows for better resource use in multipatient scenarios or in situations where a single emergency physician is managing the trauma patients alone. In addition, smaller hospitals may not have CT as readily available; consequently, ultrasound would be important. Branney et al [26] developed a key clinical decision pathway using ultrasound in blunt trauma patients that reduced CT and DPL use and cost, without an increase in missed injuries. In addition, recent evidence in a randomized trial demonstrated that when ultrasound is absent, more abdominal CT scans were ordered, suggesting that some abdominal CT scans are being performed as "screening" tests, especially in patients with a low clinical probability of intra-abdominal injury [27].

Likewise, a positive FAST examination in a stable patient also is somewhat ambiguous. The consensus document recommends CT imaging in this population, which is somewhat different from the 1995 American College of Surgeons Committee on Trauma recommendation [28] for a DPL, abdominal CT, or laparotomy to further evaluate for intra-abdominal injuries. The amount of fluid and its location become more important when examining this population. In addition, there is some preliminary evidence that there may be criteria in this population that allow for the development of a clinical decision rule, including right upper quadrant fluid, hypotension, femur fracture, abdominal tenderness, and age >60 years [29].

Fluid volume and scoring systems

Fluid in the abdomen appears as an anechoic signal. Fluids such as unclotted blood, ascites, urine, and bowel fluid may have a similar appearance. In 1970, Goldberg [30] demonstrated that with ultrasound, as little as 100 mL of intraperitoneal fluid could be visualized in a right lateral decubitus position. Using the single view of Morison's pouch, Branney and coworkers [7] scanned supine patients undergoing DPL and found, on average, that a minimum of 619 mL was needed before free fluid could be visualized in Morison's pouch by most examiners. When 1 L of crystalloid was infused, the sensitivity was 97% using the single view in their study. It is likely that most of the infused fluid localized to the gravity-dependent pelvis. Current evidence suggests that in lower volumes, fluid accumulates in the pelvis or near the site of injury. The acoustic window created by a full bladder enhances detection of fluid in the pelvis [18]. It is not until there are larger intraperitoneal fluid volumes (> 500 mL) that fluid is detectable in the perihepatic and perisplenic spaces [31]. A study by Abrams and colleagues [32] confirmed these findings and, further, determined that 5° of Trendelenberg positioning resulted in the detection of free fluid in Morison's pouch (668 mL in the supine position and 443 mL in Trendelenberg's position). The available data suggest that the average volume of fluid detectable by the FAST scan ranges from approximately 250 mL to 620 mL [7,33]. A confounder associated with fluid detection is the learning curve. As examiners gain more experience, their sensitivity improves. Gracias et al [33] demonstrated that examiners who had performed over 100 examinations were significantly better at diagnosing smaller fluid volumes.

Despite these results, a discussion of the minimal detectable fluid volume alone is not helpful to the clinician for decision making. As stated previously, a small amount of fluid may not change clinical decision making if the patient is stable and able to undergo an abdominal CT scan. Determining which volume of intraperitoneal fluid will require surgical intervention is the next step. Applying a semiquantitative measure such as "small," "moderate," or "large" generally is not helpful clinically and is subject to significant inter-rater variability. Development of a more standardized scoring system would allow for improved transfer of clinical data and overall care.

Two scoring systems currently exist for the FAST examination. Huang and associates [34] in 1994 created a scoring system to estimate the amount of hemoperitoneum detected by ultrasound and applied this system to 442 patients in a prospective study. One point was assigned to each anatomic site in which free fluid was detected during the FAST scan, with a score ranging from 0 to 8. Fluid of more than 2 mm in depth in the hepatorenal or the splenorenal space was given 2 points instead of 1. Floating loops of bowel were given 1 point. Ninety-six percent of patients with scores $\geq$3 required exploratory laparotomy; however, 38% of patients with scores <3 still required surgery. This system was 84% sensitive and 71% specific for quantifying hemoperitoneum greater or less than 1 L compared with intraoperative findings.

McKenney et al [35,36] developed and prospectively evaluated a scoring system that measured the depth of fluid in the deepest pocket, and 1 point was added for fluid in each of the other areas (four areas maximum.) In this study, 85% of patients with a score >3 required a therapeutic laparotomy, whereas 15% of patients with a score of $\leq$2 required surgery. These investigators concluded that their scoring system was better than systolic blood pressure and base deficit in determining the need for therapeutic laparotomy.

These scoring systems are relatively reproducible and easy to apply but have yet to be validated by other centers. In addition, they rely exclusively on fluid volume scoring, without considering any clinical criteria. For example, taking the systems to an extreme, a patient could have an ultrasound score of 2 and be in hemorrhagic shock but not meet criteria for laparotomy. Although a simple scoring system would allow for reliable information transfer and could be an objective measure for serial examinations, a large trial is needed to validate such a scoring system. In addition, any useful scoring system should be easy to apply and be combined with reliable clinical variables.

Training and credentialing

The training and proficiency in performing a FAST examination has been an area of increasing research. Ultrasound training has been required in Germany since the 1970s. More recently, ultrasound training has been required in emergency medicine residencies approved by the Accreditation Council for Graduate Medical Education. In addition, the FAST examination has been adopted as a modular component of the American College of

Surgeons ultrasound training curriculum [37]. Given the increasing educational requirements of the FAST examination, data are slowly emerging outlining required experience.

The 1999 consensus document addresses this issue; its major recommendation was a 4-hour didactic component, a 4-hour practical component, and 200 supervised examinations [11]. The document referred to alternative recommendations, including a similar 1-day course followed by 50 examinations. The recent American College of Emergency Physicians Ultrasound Guideline recommendations published in 2001 recommended 25 to 40 supervised examinations [38]. As evidenced by this discrepancy, the true required number for proficiency seems ill-defined.

Assessing ultrasound competency and proficiency is important. Initial training and ongoing review is critical to the safe and effective implementation of a FAST program. Proficiency requires an adequate number of supervised examinations with a significant number of positive findings. After an initial 1-day course, which includes didactic and hands-on training, the reported sensitivity is 81% and specificity is 91%, with an overall accuracy of 98% [39]. Sensitivity is the parameter most affected by increased practice. The first 30 to 50 examinations demonstrate a rapid improvement in overall sensitivity. The learning curve appears to level off after 50 examinations, and improvement is more gradual until 200 examinations are performed. Little measured improvement in sensitivity or specificity is seen after 200 examinations [33].

The overall number of examinations is not the only issue in FAST training and proficiency. A critical part of training is the presence of an adequate number and variability of positive examinations. The positive FAST rate is reported to be 9% to 13% [27,40–42]. Thus, with 50 sequential examinations, a provider may have less than 10 positive examinations. The American College of Emergency Physicians Ultrasound Guidelines specify that 50% of examinations should be positive [38]. In 2002, Gracias et al [43] demonstrated the importance of positive examinations in overall training and proficiency with FAST scanning. They found that training with peritoneal dialysis patients increased sensitivity from 43% in their control group to 87% in the study group after a 2-hour practicum. Thus, the inclusion of peritoneal dialysis models is a recommended adjunct in FAST training.

Standardizing the training experience also is important. Objective Structured Clinical Examinations (OSCEs) are used in several areas of surgical education. Sisley et al [44] used an OSCE developed for FAST training to assess knowledge and interpretation skills. The OSCE was effective in measuring improvement after a standardized FAST training course. The OSCE best measured factual knowledge improvement. Tools such as OSCEs allow for the comparison of different instruction styles and can be used to determine the efficacy of these styles in FAST education.

Salen et al [45] summarized many of the important issues surrounding FAST proficiency and training. Their review demonstrates the lack of consensus in current FAST training. After appropriate training with didactic, practical, and experiential curriculum, they recommended 25 to 50 proctored examinations. This recommendation is very different from the FAST consensus document that recommended 200 examinations [11]. To add more confusion, one series [46] could find no learning curve in a 24-month study of surgical residents.

It appears that most investigators find that sensitivity and specificity begin to plateau after 25 to 50 examinations [33,39,47]. Whether it is appropriate to label this as proficient or wait until maximal experience is achieved at 200 examinations is unclear. Central to this discussion of examination numbers is that experience with an adequate number of positive examinations in actual clinical situations is critical to true proficiency. Nothing takes the place of scanning during an actual resuscitation. Anechoic signals are seen very differently in a trauma patient who may be intubated and have a fractured femur. Seeing fluid in positive FAST examinations may be subtle and is learned only through supervised practice. This clinical experience is central to technical proficiency and reducing false-negative examinations.

Parenchymal and bowel injuries

The reported sensitivities and specificities of ultrasound for detecting parenchymal intra-abdominal injuries are much lower than for hemoperitoneum [11,48,49]. Isolated solid-organ injuries without hemoperitoneum are much more difficult to detect. Brown et al [50] reported on 2693 blunt trauma patients and found that 26% of the patients with injuries had no hemoperitoneum. They also found that they could detect subtle findings of injury in 46% of those patients, including parenchymal injuries and retroperitoneal fluid. They used very experienced sonographers and did not separate therapeutic interventions from all injuries.

Severe solid-organ injury may not produce sonographically detectable quantities of free intraperitoneal blood if the capsule remains intact [51]. These injuries, however, may be detected by ultrasound as aberrations in the normal parenchymal architecture of the spleen, liver, and kidney. Hematomas may be identified as cystic or mixed echogenic areas in a subcapsular or intraparenchymal distribution. Minor injuries may be isoechoic or present as a geographic hyperechoic pattern. Some injuries, such as subcapsular hematomas or bowel perforations, may not result in appreciable hemoperitoneum. These potentially lethal occult injuries may be missed with FAST examination alone. Detection of solid-organ injury requires greater skill in image interpretation that goes beyond simply searching for free fluid [48].

Splenic injuries have a variable appearance. The parenchymal architecture may have a disorganized appearance, with cystic or hypoechoic regions visualized. Subcapsular hematomas may appear as an echogenic or hypoechoic rim. The utility of the ultrasound for detecting free fluid has been well established, but less is known about its accuracy for detecting solid-organ injuries. Richards and associates [49] recently evaluated ultrasound for detecting splenic injuries. Free fluid and parenchymal abnormalities were assessed during FAST examinations, and the sonographic patterns of splenic injuries were reported. The overall sensitivity for all injuries was 69% but rose to 86% for grade III or higher splenic injuries. This series used radiologists for retrospective interpretation and the examinations were not read in real time during the resuscitation; consequently, the true practicality of evaluating for parenchymal injuries is uncertain from this data. It was concluded that inclusion of parenchymal abnormality without accompanying free fluid improved the sensitivity of the FAST examination. The most common sonographic parenchymal finding was a diffuse hyper- and hypoechoic pattern within the spleen. This examination, however, can be very difficult because the stomach lies close to the acoustic window of the spleen and can give a hyperechoic signal that appears to be within the spleen. This examination takes significant practice, and its real role in the era of CT scanning is unclear.

Hepatic injuries may be difficult to detect when the liver capsule remains intact. The liver has a greater volume than spleen; thus, small intraparenchymal lesions may be missed with the rapid FAST technique. In a recent study by Ohta and colleagues [52], a geographic hyperechoic liver pattern was detected with ultrasound in 33 patients and believed to represent a mild form of liver injury not requiring surgical repair.

Bowel injuries from blunt trauma notoriously are difficult to diagnose, even with CT. Ultrasound is inaccurate for detecting bowel injuries, and the most common finding is free fluid [53]. Clinical suspicion for this injury mandates further observation and laboratory tests.

Despite research into the value of ultrasound for detecting parenchymal injuries, most of the studies have used radiologists in retrospective reviews. The added time and clinical value, given the advent of high-speed CT imaging, makes for a less compelling argument for using the FAST examination to detect parenchymal organ injuries.

The pediatric trauma patient

Most advocates of FAST evaluation of pediatric trauma patients still recommend abdominal CT scans in hemodynamically stable children with positive ultrasound examinations [22,51,54]. As with adults, a CT scan is thought to be necessary to obtain detailed information regarding specific organ injuries that FAST examinations do not reliably provide. Although a negative FAST examination does not obviate the need for a subsequent abdominal CT scan, it likely provides enough extra information to decrease the use of abdominal CT in children at low risk of intraperitoneal injury [55]. The FAST examination may be useful for the evaluation of pediatric trauma patients in several circumstances, although these circumstances have not been studied in a controlled fashion as yet. For hemodynamically unstable pediatric trauma patients, the FAST examination can help to identify rapidly the source of hypotension and assist decision making with regard to timing of diagnostic testing versus operative intervention [56]. For children with head and abdominal trauma, the FAST examination offers important clinical information to assist in making decisions regarding the timing of head CT and abdominal CT versus laparotomy. The FAST examination also may be of use in evaluating alert pediatric trauma patients without abdominal tenderness who otherwise would not routinely undergo radiographic imaging and who, on occasion, may have intra-abdominal injuries. The FAST examination also may allow for prioritization of imaging studies after initial evaluation and resuscitation are complete. Patients with intraperitoneal fluid on ultrasound could be triaged to abdominal CT with greater expediency than those patients with no intraperitoneal fluid detected on FAST examination. The additional information offered by a negative FAST examination also may be sufficient for the clinician to decide against abdominal CT in pediatric patients with an already low likelihood of intra-abdominal injury. Thus, although the FAST examination routinely may not replace abdominal CT scanning of pediatric trauma patients, there are specific clinical scenarios in which ultrasound likely is useful and may enhance clinical efficiency [55,56].

Controversies regarding the use of ultrasound technology in the setting of trauma were highlighted in a recent survey of general emergency physicians, pediatric emergency physicians, and trauma surgeons [57]. In the case of adult trauma patients, 91% of the respondents considered ultrasound to be "somewhat to extremely useful." In the case of pediatric trauma patients, however, 73% of respondents considered ultrasound to be useful and only 57% of pediatric emergency physicians considered it useful. Only 14% of pediatric emergency departments routinely used the FAST examination for their trauma patients [57]. The investigators recommended further studies to evaluate the clinical utility of the FAST examination for pediatric trauma patients. These data suggest that the role of ultrasound in pediatric trauma patients generally is less clear than for adults. With most intra-abdominal injuries in children being managed through nonoperative management, the true role of ultrasound in children is yet to be fully clarified.

Clinical algorithms

The development of clinical algorithms for the use of ultrasound in trauma is a logical extension of its growing application. The FAST examination must be performed in the context of the resuscitation and guided by a given clinical scenario. Luks [58] described it accurately, stating, "ultrasound does not have to surpass other diagnostic modalities as long as it identifies the life-threatening conditions." Emphasis has moved away from ultrasound replacing other diagnostic modalities and moved toward incorporating it into the resuscitation of trauma patients. Clinical algorithms attempt to integrate ultrasound into trauma care.

Two algorithms that illustrate the different issues surrounding ultrasound use in abdominal trauma are shown in Fig. 7. These algorithms are derived from the FAST consensus results published in 1999. In Fig. 7A, the FAST examination is performed on every patient and then coupled with

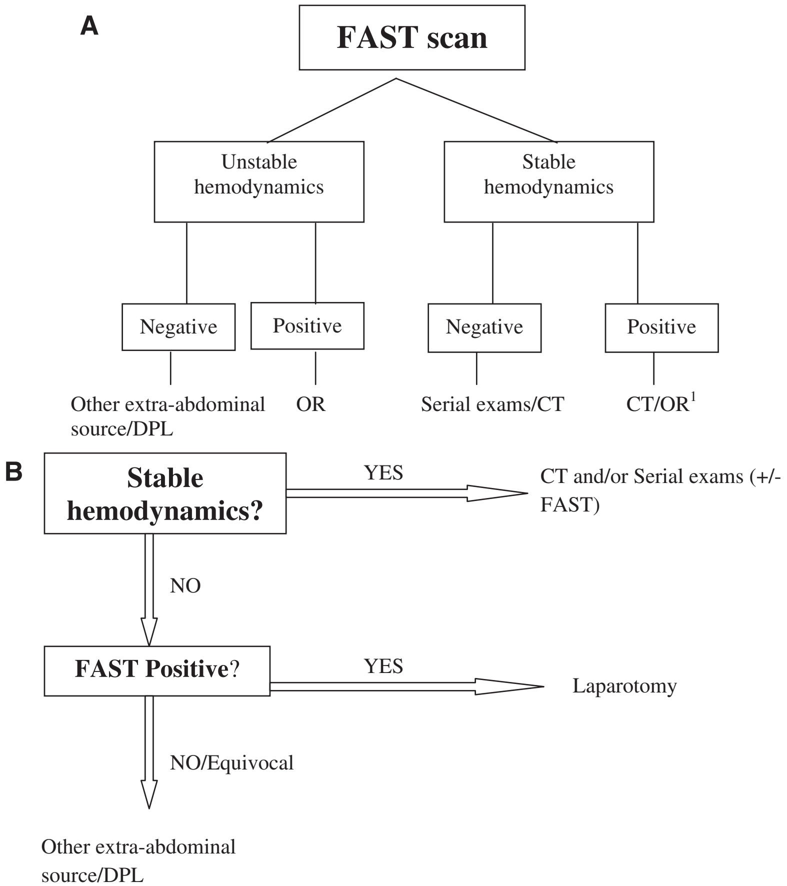

Fig. 7. (*A*) FAST-oriented algorithm. (*B*) Hemodynamics-oriented FAST algorithm. (*Adapted from* Scalea TM, Rodriguez A, Chiu WC, Brenneman FD, Fallon WF Jr, Kato K, et al. Focused Assessment with Sonography for Trauma (FAST): results from an international consensus conference. J Trauma 1999;46(3):466–72; with permission.)

hemodynamic stability. This type of algorithm is used by centers that believe that all patients should undergo a FAST scan.

Fig. 7B illustrates a different algorithm based on the same consensus recommendations [11]. In this algorithm, hemodynamic status is the initial decision point. If stable, the patient can undergo serial physical examinations and FAST examinations or abdominal CT scanning alone, depending on the clinical scenario. If the patient is unstable, then a FAST examination is performed. If the FAST examination is positive, then the patient would go for laparotomy; if negative, then the clinician would look for an extra-abdominal source of bleeding or perform a DPL if the examination was equivocal. In this algorithm, the FAST examination plays much less of a role in the stable patient. One could argue that in this algorithm, if CT is used, a FAST examination would not be needed in the hemodynamically stable patients. Although both algorithms follow the consensus recommendations, they do so with very different emphases: one emphasizes the initial FAST and the other emphasizes hemodynamic status.

Another algorithm that is more logical and incorporates clinical and ultrasound data is the Key Clinical Pathway developed by Branney et al [26]. This pathway uses hemodynamic status first. From this point, various clinical parameters are applied to the pathway to select patients who require CT or laparotomy. This pathway then includes more relevant clinical data such as peritoneal irritation, confounding injuries, gross hematuria, or hematocrit <35% to help answer the question of whether a patient requires immediate laparotomy. Two issues arise from this pathway. First, if a patient is unstable but has no free fluid, then a DPL is recommended. Some clinicians would recommend looking for another source of bleeding and not performing a DPL. Second, if a patient has a positive FAST examination but is stable and has no peritoneal irritation, then a DPL rather than a CT scan is recommended. A patient who is severely head injured would fall into this category. This pathway gives the impression that the investigators believe the sensitivity of ultrasound is not good enough to be used in isolation.

From these pathways, even more questions are generated: Why perform a FAST examination in a stable patient? Will it change decision making? As stated earlier, given the accessibility and speed of newer-generation CT scanners, severely injured patients can be imaged effectively during the resuscitation period. This practice is an area of some debate and focuses on the overall practice paradigm of a particular institution. One could argue that determining the presence of hemoperitoneum is valuable even when CT scanning is readily available. Resource use, timing, and treatment of secondary injuries will be influenced by the FAST examination results. Algorithms that include ultrasound and CT have been developed that minimize missed injuries while limiting overuse of CT scanning [23]. Future studies are needed to examine whether there are any predictive factors present during resuscitation that help to determine whether a positive FAST scan requires a therapeutic laparotomy. Whatever pathway is chosen, understanding the overall strengths and limitations of the FAST examination is critical to its safe and effective implementation into the trauma resuscitation.

Future directions

Future research in trauma ultrasound likely will focus on integration with current diagnostic and imaging modalities. Preliminary research that is examining the role of ultrasound for detecting traumatic pneumothorax [59], evaluating portable ultrasound units [60], and evaluating transducer frequency for parenchymal injuries is revealing exciting results [61]. More important, a large, multicenter trial to evaluate previous hypotheses and clarify issues such as scoring systems and practice pathways still is needed. Certainly, the role of trauma ultrasound in the setting of a small, rural emergency department with limited backup is very different than ultrasound in a busy level I trauma center. Emergency physicians must continue to be on the forefront of this work. The role of ultrasound in pediatric trauma still needs to be clarified. Great strides, however, have been made in clarifying the advantages and disadvantages of the FAST examination. Ultrasound has been an important addition to the management of trauma patients and will continue to play an important role in trauma management into the twenty-first century.

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