Current Role of Emergency US in Patients with Major Trauma[1]

TEACHING POINTS
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In patients with major trauma, focused abdominal ultrasonography (US) often is the initial imaging examination. US is readily available, requires minimal preparation time, and may be performed with mobile equipment that allows greater flexibility in patient positioning than is possible with other modalities. It also is effective in depicting abnormally large intraperitoneal collections of free fluid, which are indirect evidence of a solid organ injury that requires immediate surgery. However, because US has poor sensitivity for the detection of most solid organ injuries, an initial survey with US often is followed by a more thorough examination with multidetector computed tomography (CT). The initial US examination is generally performed with a FAST (*f*ocused *a*ssessment with *s*onography in *t*rauma) protocol. Speed is important because if intraabdominal bleeding is present, the probability of death increases by about 1% for every 3 minutes that elapses before intervention. Typical sites of fluid accumulation in the presence of a solid organ injury are the Morison pouch (liver laceration), the pouch of Douglas (intraperitoneal rupture of the urinary bladder), and the splenorenal fossa (splenic and renal injuries). FAST may be used also to exclude injuries to the heart and pericardium but not those to the bowel, mesentery, and urinary bladder, a purpose for which multidetector CT is better suited. If there is time after the initial FAST survey, the US examination may be extended to extraabdominal regions to rule out pneumothorax or to guide endotracheal intubation, vascular puncture, or other interventional procedures.

Abbreviation: FAST = focused assessment with sonography in trauma

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See the commentary by Mirvis following this article.

Introduction

Major trauma, also referred to as multiple trauma or polytrauma, is defined as potentially fatal injuries to more than one body region (eg, head, chest, or abdomen and extremities), with a suspected injury severity score of 15 or higher. In patients with major trauma, the prompt, accurate diagnosis of injuries has the highest priority after admission. Before whole-body multidetector computed tomography (CT) became the imaging modality of choice in the late 1990s (1–6), ultrasonography (US) was the only cross-sectional method available for use in patients with major trauma. US has obvious advantages in that it is widely available, easy to perform, and low cost. Although it is operator dependent and lacks accuracy, US is often used in conjunction with multidetector CT for the urgent evaluation of patients who have sustained major trauma, particularly in Europe.

The article is focused on the current role of US in evaluating patients in the setting of major trauma. We survey intra- and extraabdominal indications for US, describe proper procedures for performing urgent examinations, and illustrate the applicability and limitations of US in the trauma setting.

Indications and Technique

The main use of US in patients with blunt or penetrating trauma is in screening for abdominal injuries. At our level I trauma hospital, approximately one-fourth of patients with an Injury Severity Score of 15 or higher have abdominal injuries that are rated 3 or higher on the Abbreviated Injury Scale. Because of the relatively high incidence of abdominal injuries among patients with major trauma and because those injuries often are fatal, such screening is essential. During the so-called golden hour in patients with trauma and shock, if there is intraabdominal bleeding, the probability of death increases by about 1% for every 3 minutes that elapses before treatment (7). In hypotensive patients and those whose condition is unstable, US can help determine whether immediate surgery is needed before the patient undergoes a further evaluation with CT (8,9).

Teaching Point

Abdominal US in cases of major trauma is usually performed with a FAST (*f*ocused *a*ssessment with *s*onography in *t*rauma) examination. This type of examination provides a quick overview of the intraperitoneal cavity to detect free fluid, which is an indirect sign of acute hemorrhage and injury to visceral organs (10–12).

For a FAST examination, the patient is placed supine, if possible. Use of a mobile US machine is recommended because standard placement of the patient is not always possible. The depth of ultrasound wave penetration for abdominal US must be at least 20 cm, which usually requires the use of a 3.5–5.0-MHz convex transducer.

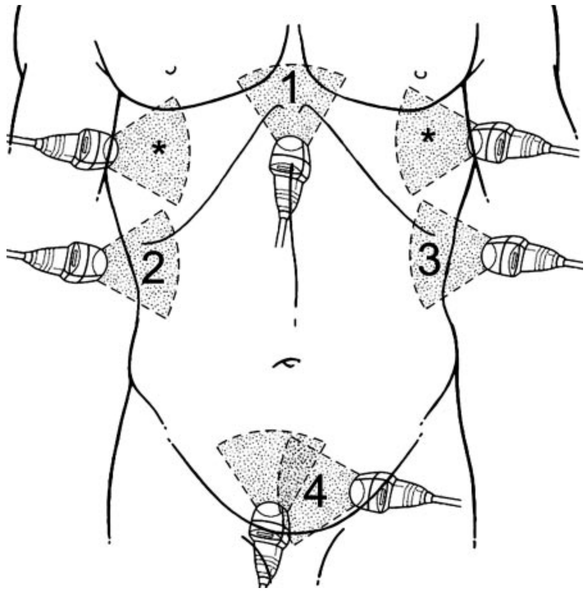


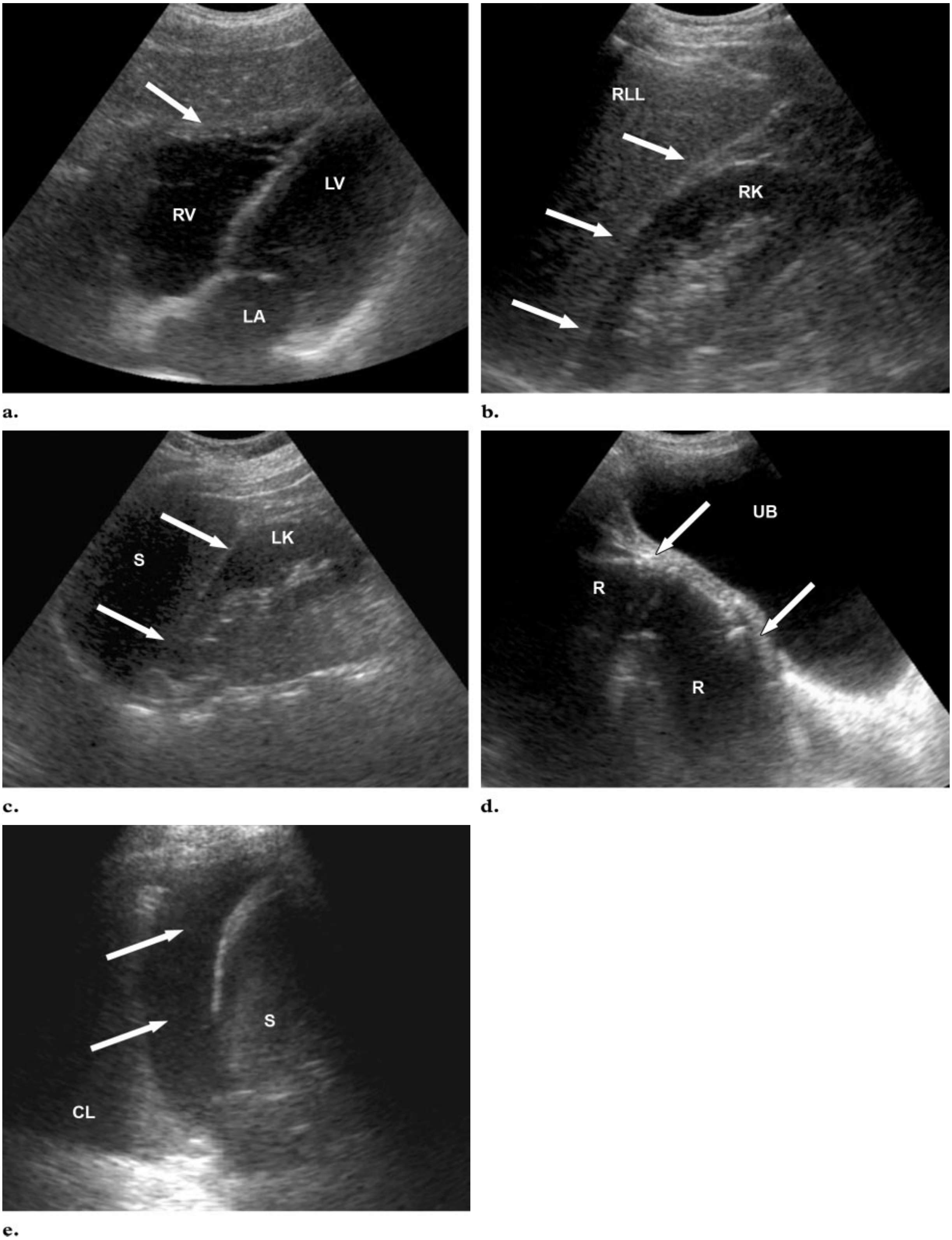
Figure 1. Diagram shows the standard projections routinely obtained in a FAST examination: a transverse view of the subxiphoid region *(1)*, longitudinal views of the right *(2)* and left *(3)* upper quadrants, and transverse and longitudinal views of the suprapubic region *(4)*. In addition to these projections, right and left longitudinal thoracic views (*) may be obtained.

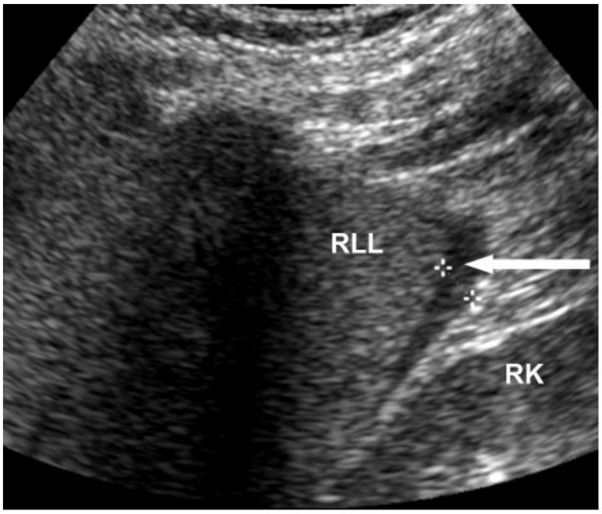
Teaching Point

The following four standard views should be obtained (Fig 1): *(a)* transverse view of the subxiphoid region to diagnose pericardial effusion and injuries to the left lobe of the liver; *(b)* longitudinal view of the right upper quadrant to show the right lobe of the liver, the right kidney, and the space between the two (the Morison pouch), which may fill with peritoneal fluid when the patient is supine; *(c)* longitudinal view of the left upper quadrant to show the left kidney, the spleen, and the space between them, which also may contain free intraperitoneal fluid; and *(d)* transverse and longitudinal views of the suprapubic region to depict the urinary bladder and rectouterine or retrovesical pouch, a recess formed by a fold of the peritoneum that descends between the rectum and uterus in women or the rectum and bladder in men. This recess is called the pouch of Douglas. Like the Morison pouch, it is a space in which free intraperitoneal fluid may collect.

In addition to these four standard views, a right and a left longitudinal thoracic view may be acquired to rule out pleural effusion (Fig 1). Because these views can be obtained quickly, they should be included in routine FAST acquisitions in all patients with trauma to the chest. Images from typical FAST examinations are shown in Figure 2.

Figure 2. US images obtained with FAST examinations in a healthy volunteer **(a–d)** and a patient with chest trauma **(e)**. **(a)** Transverse view of the subxiphoid region (*1* in Fig 1), obtained with cranial angulation of the transducer, shows a normal pericardium, without effusion. *LA* = left atrium, *LV* = left ventricle, *RV* = right ventricle. **(b)** Longitudinal view of the right upper quadrant (*2* in Fig 1) shows a normal Morison pouch (arrows) with no free fluid. *RK* = right kidney, *RLL* = right lobe of liver. **(c)** Longitudinal view of the left upper quadrant (*3* in Fig 1) shows a normal splenorenal fossa (arrows). This is another intraperitoneal recess in which abnormal fluid might collect. *LK* = left kidney, *S* = spleen. **(d)** Longitudinal view of the suprapubic region (*4* in Fig 1) shows a normal pouch of Douglas (arrows), the space between the rectum *(R)* and the urinary bladder *(UB)*. The fluid-distended rectum should not be mistaken for free fluid. **(e)** Longitudinal view of the left thoracic region (∗ at right in Fig 1) shows the pleural space, which is not normally visible at US but is so in this case because of a pleural effusion (arrows). *CL* = collapsed lung, *S* = spleen.

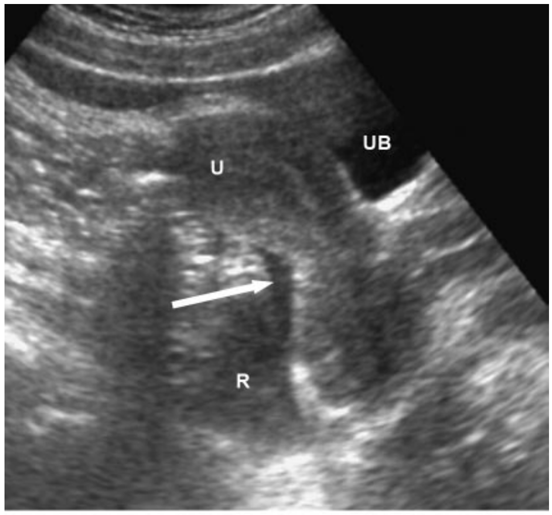




a.

b.

Figure 3. US images obtained with FAST examinations in patients with abdominal trauma show accumulations of free fluid. **(a)** Longitudinal view of the right upper quadrant shows a small amount of free intraperitoneal fluid in the Morison pouch (arrow). *RK* = right kidney, *RLL* = right lobe of liver. **(b)** Longitudinal view of the left upper quadrant shows free fluid in the perisplenic region (white arrow) with signal amplification dorsal to the fluid (black arrows). *S* = spleen. **(c)** Longitudinal view of the suprapubic region shows a small amount of free fluid in the pouch of Douglas (arrow). *R* = rectum, *U* = uterus, *UB* = urinary bladder.



c.

When the FAST examination is performed correctly by an experienced sonographer, it ordinarily takes no more than 5 minutes. However, in some cases, it may be difficult to obtain the standard views, and the examination then will be prolonged. The operator should not waste too much time with the FAST examination if there is any suspicion of hemorrhage.

Detection of Intraabdominal Injuries

A number of studies of the diagnostic value of FAST and US in major trauma have been reported in the literature. In most of them, the sensitivity and specificity of these diagnostic imaging methods were demonstrated. The results understandably varied, in view of differences in the US devices and methods used, in the levels of experience and specialization of the operators, and in the reference standards. US was not performed with the FAST technique in all of these studies; in some cases, a standard (detailed) abdominal US protocol was used.

As mentioned earlier, the primary goal of abdominal US in the major trauma setting, and of the FAST examination in particular, is to detect any intraabdominal accumulation of free fluid and other features that may be suggestive of injury to one or more organs.

Free Fluid

Typical sites of free fluid accumulation are the Morison pouch, the pouch of Douglas, and the

Table 1
Sensitivity and Specificity of US for the Detection of Free Intraperitoneal Fluid

First Author and Reference No.	Year of Publication	Sensitivity	Specificity	Diagnostic Reference Standard
Abu-Zidan (31)	1999	0.94	0.86	CT
Ballard (14)	1999	0.28	0.99	Laparotomy, DPL, CT
Boulanger (17)	1996	0.81	0.97	DPL, CT
Brenchley (18)	2006	0.78	0.99	DPL, laparotomy, CT, autopsy
Chiu (19)	1997	0.71	1.00	Laparotomy, DPL, CT, observation
Coley (15)	2000	0.38	0.97	CT
Hsu (20)	2006	0.78	0.98	CT, DPL
Ingeman (21)	1996	0.75	0.96	Laparotomy, DPL, CT, observation
Kern (22)	1997	0.73	0.98	Laparotomy, DPL, CT, observation
Kirkpatrick (10)	2005	0.77	0.99	CT, laparotomy, serial examinations
McElveen (23)	1997	0.88	0.98	Laparotomy, DPL, CT
McKenney (24)	1996	0.88	0.99	Laparotomy, DPL, CT
Miller (16)	2003	0.42	0.98	CT
Ollerton (25)	2005	0.64	1.00	CT, laparotomy
Röthlin (32)	1993	0.98	1.00	CT, observation, outcome
Rozycki (26)	1998	0.78	1.00	Laparotomy, DPL, CT, observation
Shackford (27)	1999	0.69	0.98	Laparotomy, DPL, CT, observation
Thomas (28)	1997	0.81	0.99	Laparotomy, DPL, CT, observation
Wherrett (29)	1996	0.85	0.90	DPL, CT
Yeo (30)	1999	0.67	0.97	Laparotomy, DPL, CT, observation

Note.—CT = computed tomography, DPL = diagnostic peritoneal lavage.

splenorenal fossa (Fig 3). In 30%–40% of women of reproductive age, fluid collections of up to 50 mL in the pouch of Douglas are considered physiologic, although the exact underlying mechanism of accumulation is not clear (13). Amounts of free fluid that exceed 100 mL should always be regarded as pathologic.

Although some investigators reported a poor sensitivity of FAST for the detection of free fluid (14–16), in most studies the sensitivity of FAST for the detection of free intraperitoneal fluid was 0.64–0.98 (10,17–32) (Table 1). Overall, the specificity of FAST was high, at 0.86–1.00. These widely ranging results may be explained by differences in the levels of experience among observers (dedicated sonographers, radiologists, surgeons, and residents) and in the reference standards used.

Teaching Point

The detectability of free fluid during the FAST examination is strongly dependent on the volume of fluid present. Branney et al found a minimum detectable fluid volume of about 200 mL. The sensitivity of FAST increased with larger volumes of free fluid (33). However, it is unknown whether these values are representative, because only the Morison pouch was scanned for free fluid. The distribution of free intraperitoneal fluid is influenced by anatomic and pathologic structures and by postoperative features such as scars and adhesions (33). Because of these varying morphologic characteristics, the sensitivity of FAST for the detection of free fluid might be reduced if not all regions predisposed to collect fluid are scanned.

Solid Organ Injuries

The detection of injury to a solid organ is an important purpose of abdominal US in the trauma setting. Patients who need immediate surgical or other intervention thus can be identified (29). Moreover, patients who are in stable condition and who do not require urgent intervention may be excluded from further diagnostic imaging if the

Table 2
Sensitivity and Specificity of US for the Detection of Traumatic Injury to Solid Organs

First Author and Reference No.	Year of Publication	Sensitivity	Specificity	Diagnostic Reference Standard
Akgür (39)	1997	0.84	0.99	Laparotomy, CT, observation
Bode (3)	1999	0.90	1.00	CT, US, laparotomy, outcome, autopsy
Healey (40)	1996	0.88	0.98	Laparotomy, DPL, CT, observation
Katz (41)	1996	0.91	0.84	CT, observation
Kirkpatrick (10)	2005	0.52	0.97	CT
Krupnick (42)	1997	0.62	0.98	CT
Lingawi (34)	2000	0.94	0.98	CT, US, observation
McGahan (43)	1997	0.63	0.95	Laparotomy, DPL, CT
McKenney (24)	1998	0.86	0.99	Laparotomy, DPL, CT, observation
Nural (44)	2005	0.87	0.95	CT, DPL, laparotomy, outcome
Richards (45)	2004	0.69	0.98	Laparotomy, DPL, CT
Röthlin (32)	1993	0.44	1.00	Laparotomy, CT, observation
Singh (46)	1997	0.74	0.87	DPL, observation
Yoshii (47)	1998	0.95	0.95	Laparotomy, CT, US, angiography

Note.—CT = computed tomography, DPL = diagnostic peritoneal lavage.

initial US images are of sufficient diagnostic quality (3,19,24,34,35). It is particularly important to avoid unnecessary imaging studies in children and pregnant women (36).

Teaching Point

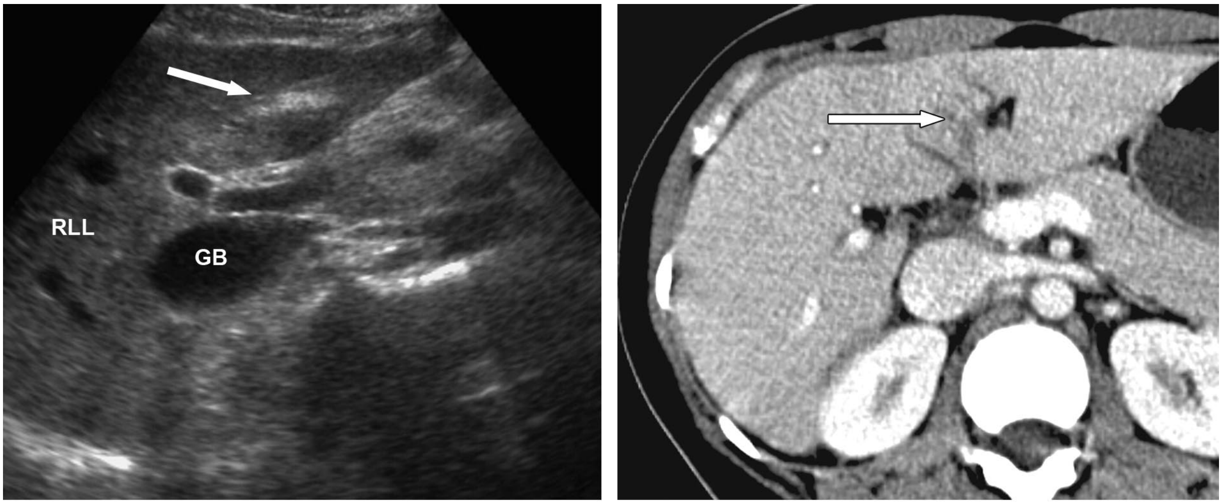
Although FAST is the most commonly used diagnostic imaging method in patients after major trauma, its role in the diagnosis of injuries to solid organs is limited. In three previously published studies, solid organ injuries without concomitant hemoperitoneum were frequently missed at FAST examinations. These results are indicative of the difficulties of screening visceral organs with this technique (16,37,38).

The reported sensitivity of FAST for the detection of all reported organ injuries ranges from 0.44 to 0.95, with high specificity of 0.84–1.00. The disparate results reflect variations in study design (3,10,24,32,34,39–47) (Table 2). Results also vary according to the organ examined. In the next section, the usefulness of FAST for detecting injuries in particular solid organs is considered.

The severity of solid organ injury is scored according to the organ injury scale established by Moore et al (48).

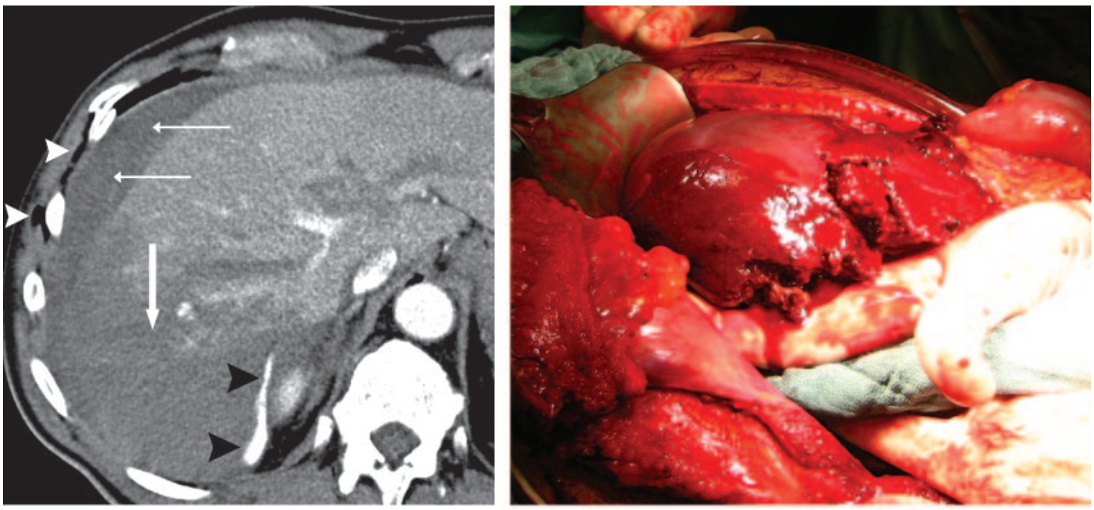
Liver.—The appearance of traumatic hepatic lesions varies greatly (Fig 4). McGahan et al described widely differing US appearances of liver lacerations, ranging from hypoechoic to hyperechoic (43). In general, lacerations become hypoechoic or even cystic over time. The lack of a uniform pattern of echogenicity makes the detection of hepatic injuries difficult at US, particularly for beginners. Extensive scanning for subtle parenchymal abnormalities would take too much time in an acute trauma setting. Alterations of the liver parenchyma caused by entities such as steatosis, regenerative nodules, or focal changes in fat distribution also may complicate the detection of injuries.

Reported values for the sensitivity of FAST in the detection of liver injuries range from 0.15 to 0.88, with high specificity of 0.99–1.00 (31,32, 49–51). These results are indicative of wide variability in the diagnostic value of FAST (Fig 5).



a. b.

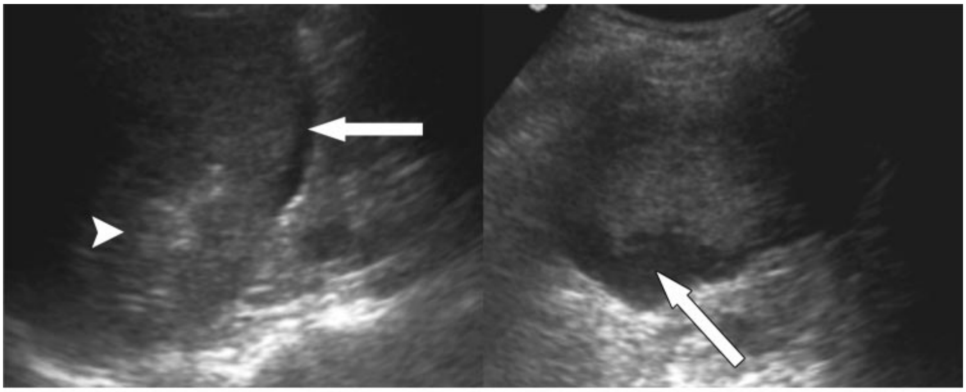
Figure 4. Images from a 24-year-old woman who was struck by a car while riding a bicycle. **(a)** Transverse US view of the subxiphoid region, obtained at an initial FAST examination, shows an area of slight hyperechogenicity in the left lobe of the liver (arrow), a finding suggestive of a laceration. A small collection of free fluid also was visible in the pouch of Douglas. *GB* = gallbladder, *RLL* = right lobe of liver. **(b)** Abdominal CT image shows an area of decreased attenuation (arrow) in the liver, a finding that helped confirm the diagnosis of liver laceration.



a. b.

Figure 5. Severe abdominal trauma in a 63-year-old man after a motor vehicle collision. Images from the initial FAST examination were reported to be of poor quality and not diagnostically adequate for all regions examined, yet gross injuries were excluded. **(a)** Contrast-enhanced abdominal CT image, obtained after the FAST examination, shows a grade IV laceration of the right liver lobe (large arrow) with active contrast material extravasation (black arrowheads). A large subcapsular hematoma (small arrows) also is visible. Injuries of that grade of severity require urgent surgical intervention, which would not have been performed on the basis of the initial US findings. The poor quality of images from the FAST examination was retrospectively considered to have been caused by serial rib fractures on the right side, with concomitant pneumothorax and massive cutaneous emphysema in the right flank (white arrowheads). **(b)** Intraoperative photograph shows the grade IV liver laceration with a massive active hemorrhage.

Figure 6. Images from a 68-year-old woman who jumped from a rooftop. **(a)** Longitudinal (right) and transverse (left) views of the left upper quadrant, obtained at the initial FAST examination, show parenchymal hyperechogenicity (arrowhead) and a small free perisplenic fluid collection (arrow). In the transverse plane, the caudal splenic edge is irregular in contour. The injury was rated grade II by the sonographer. Because other severe injuries to the head, chest, and pelvis were suspected, the patient subsequently underwent whole-body CT. **(b)** CT image shows a completely shattered spleen with massive active bleeding in the perisplenic and perihepatic regions (arrows) and extravasation of contrast material (arrowhead), findings that resulted in upgrading of the severity of injury to grade V, an indication for immediate surgery. If the diagnosis had been based on US findings alone, the extent of the lesion would have been dramatically underestimated and treatment would have been delayed. The findings were confirmed at laparotomy, and a splenectomy was performed.



a.

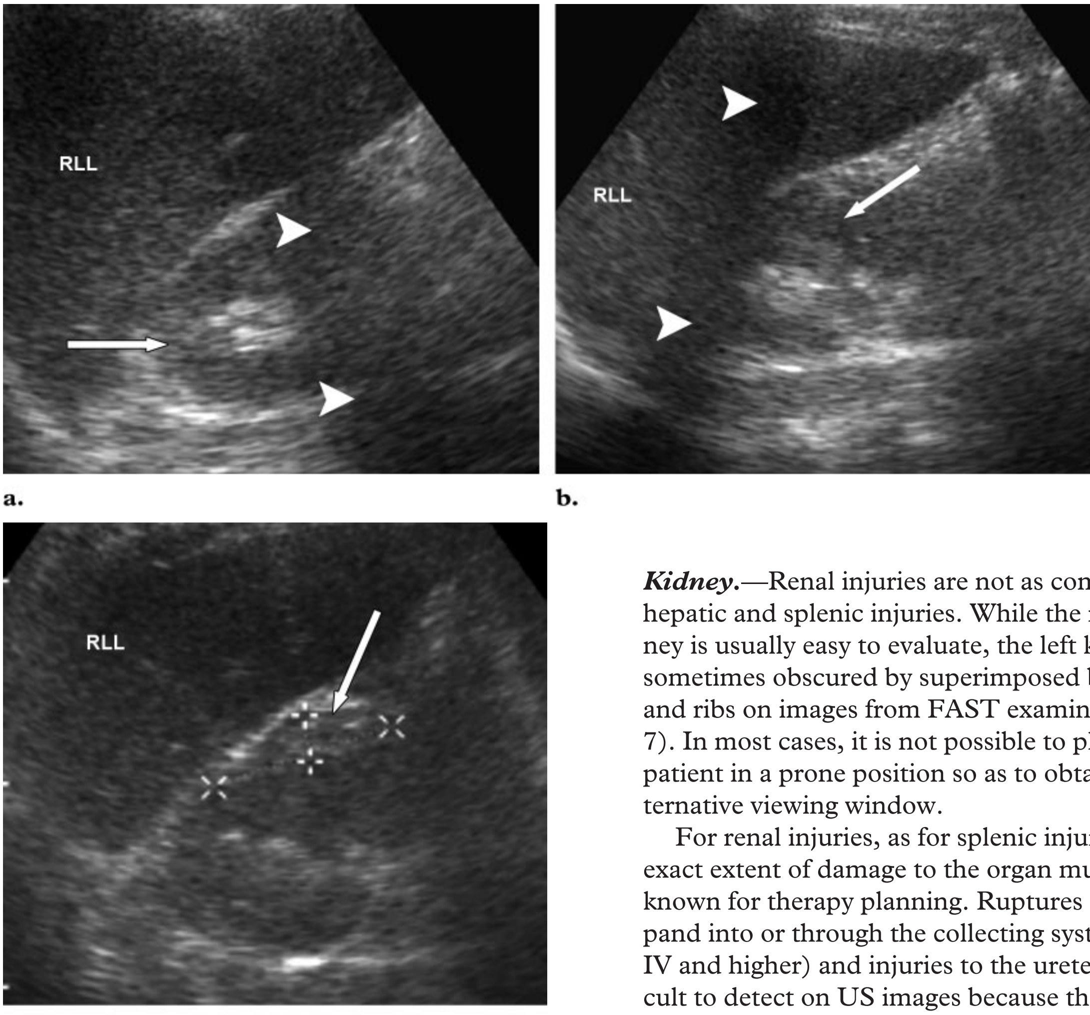
b.

Spleen.—In blunt abdominal trauma, the spleen is the most commonly injured organ; splenic injuries account for about 30% of all intraabdominal injuries (45,52). Because of its position, with overlay by the left lung during inspiration, the spleen is not always depicted in its entirety at US. Artifacts from the caudal ribs also may reduce the visibility of the spleen.

Typical findings in patients with major trauma include subcapsular hematoma and laceration of splenic tissue. The latter has a US appearance similar to that of the liver, with no specific pattern of echogenicity. Technically speaking, it is also possible to detect lesions such as pseudoaneurysms with color Doppler US; however, that method is not included in the FAST examination and, therefore, those kinds of injuries are likely to be missed (52).

Therapeutic options for splenic injury include conservative treatment, control of bleeding with embolization, and surgery. To allow appropriate therapeutic decision making, the exact extent of the injury must be known (Fig 6). As was established by an international consensus conference for FAST, there is no evidence that US alone is generally sufficient for organ injury grading and

Figure 7. US images from consecutive examinations in a 29-year-old pregnant woman who was struck by a car. **(a)** Longitudinal view from an initial FAST examination shows only the cranial pole of the right kidney (arrow); the rest of the organ was obscured by an artifact from a rib (arrowheads). **(b)** A second longitudinal view from the same examination as **a** shows the caudal part of the kidney (arrow) as well as a rib artifact (arrowheads). On the basis of these findings, significant injury was excluded. **(c)** Image from a second US examination performed by an attending radiologist half an hour later shows a small subcapsular hematoma (arrow) that is not obscured by artifact. The lesion was rated grade I.

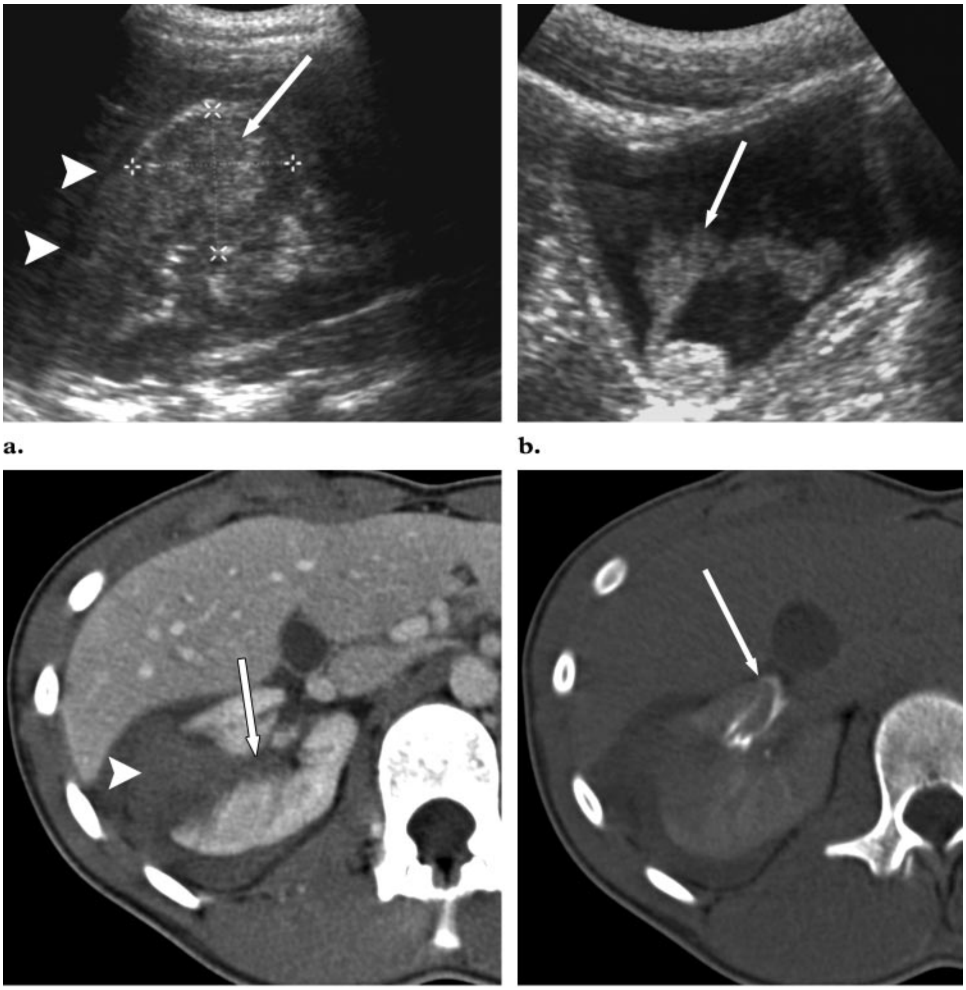


a. b. c.

planning of treatment; a more sophisticated imaging evaluation is necessary (11). The reported sensitivity of FAST for the detection of splenic injury is 0.37–0.85, with high specificity of 0.99–1.00 (31,32,49,50).

Kidney.—Renal injuries are not as common as hepatic and splenic injuries. While the right kidney is usually easy to evaluate, the left kidney is sometimes obscured by superimposed bowel gas and ribs on images from FAST examinations (Fig 7). In most cases, it is not possible to place the patient in a prone position so as to obtain an alternative viewing window.

For renal injuries, as for splenic injuries, the exact extent of damage to the organ must be known for therapy planning. Ruptures that expand into or through the collecting system (grade IV and higher) and injuries to the ureters are difficult to detect on US images because there is no visible evidence of urinary leakage. Renal excretory phase images from contrast-enhanced CT performed 10 minutes after contrast material injection help by depicting extravasation from the collecting system and the ureters and, thus, indicate the exact location and extent of rupture (Fig 8).



a. b. c. d.

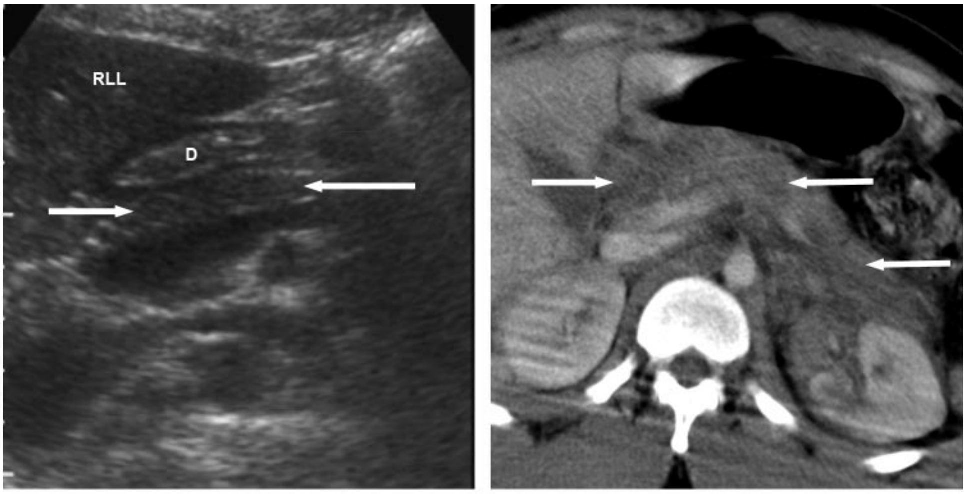
Figure 8. Images from a 16-year-old male soccer goalkeeper who was struck in the right flank by a field player's foot. **(a)** Longitudinal view of the hepatorenal fossa, from an initial FAST examination, shows an intraparenchymal subcapsular area of hyperechogenicity (arrow), a finding indicative of hematoma, as well as a discrete band of free fluid in the Morison pouch (arrowheads). **(b)** Longitudinal view of the suprapubic region, from the same examination as **a**, shows a focus of hyperechogenicity (arrow) in the urinary bladder, adjacent to the ureteric ostium. The finding was indicative of macrohematuria. **(c)** Abdominal CT image helps confirm the renal laceration and perirenal fluid collection (arrowhead). The lesion would have been rated grade III, but the parenchymal rupture seemed to extend into the collecting system (arrow). **(d)** Delayed phase CT image, obtained 10 minutes after intravenous administration of contrast material, shows extravasation (arrow), a finding indicative of a rupture of the collecting system. The lesion thus was rated grade IV.

In several studies, the sensitivity of FAST for the detection of renal lesions (0.23–1.00) was lower than that for the detection of hepatic and renal injuries. However, the specificity of FAST was high, at 0.98–1.00 (31,32,49,50).

Pancreas.—Pancreatic injuries are not common in abdominal trauma; they occur in fewer than 2% of patients (53). However, because they result in high morbidity and mortality, it is crucial that they be accurately and promptly diagnosed. The pancreas is difficult to see at US because of superimposed bowel gas. In addition, the pancreatic region is not part of the routine FAST examination. Although a part of the pancreas can sometimes be seen on US images obtained with a FAST examination, subtle injuries such as a contusion or a small rupture frequently are overlooked (Fig 9).

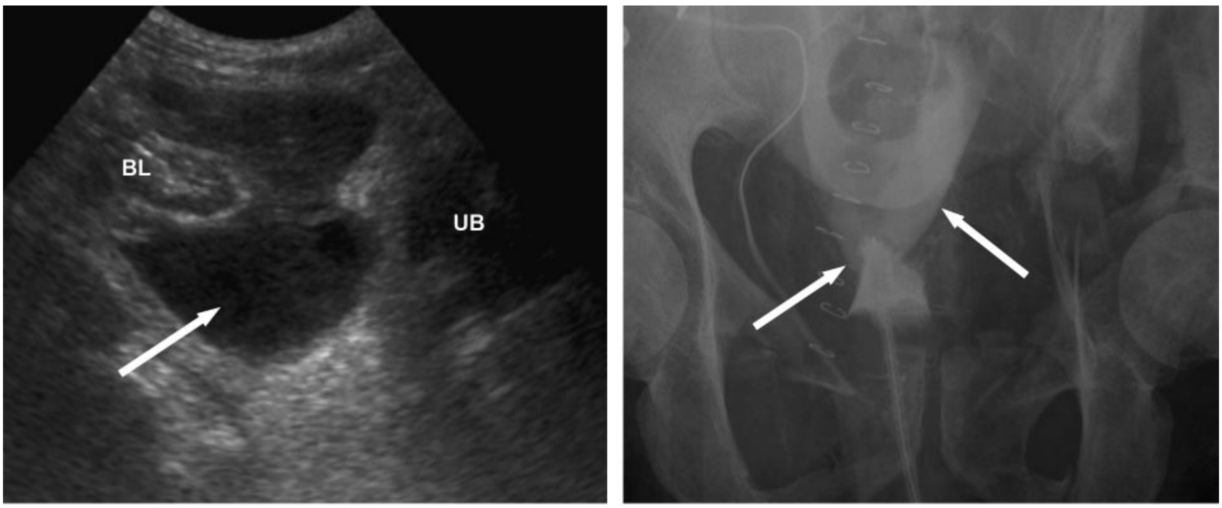
Sensitivity and specificity of US for detection of pancreatic injuries were reported in only two published studies (47,50). Sensitivity was poor, at 0.71 and 0.44, respectively; however, a specificity of 1.00 was found in both studies.

Bowel, Mesentery, and Urinary Bladder.—Injuries to the bowel and mesentery are difficult to detect with US. Characteristic findings include thickening of the bowel wall, pneumoperitoneum,



a. b.

Figure 9. Images from a 26-year-old man who was involved in a motor vehicle collision while riding a motorcycle. **(a)** Transverse US view of the subxiphoid region shows a normal pancreatic head and corpus (arrows). *D* = duodenum, *RLL* = right lobe of liver. **(b)** CT image shows an area of edema (arrows) in the pancreatic parenchyma, a finding indicative of a grade II pancreatic contusion. Laboratory test results showed highly elevated amylase and lipase values that were indicative of pancreatic injury.

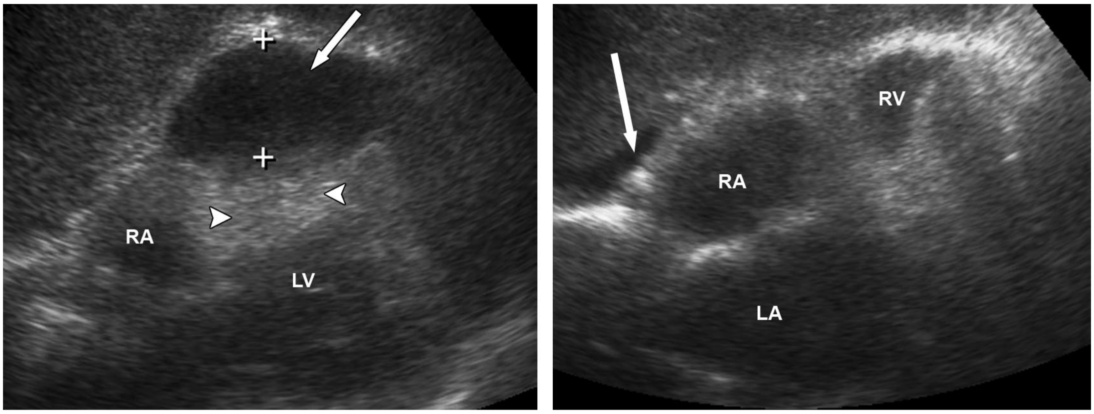


a. b.

Figure 10. Images from a 64-year-old man with major trauma to the pelvis and chest after being struck by the trunk of a falling tree. **(a)** Longitudinal US view of the suprapubic region shows a large collection of free fluid in the pouch of Douglas (arrow). Note the bowel loop *(BL)* "swimming" in the fluid. An emergency laparotomy was performed. *UB* = urinary bladder. **(b)** Anteroposterior pelvic radiograph, obtained after filling of the urinary bladder with contrast material, shows the extravasation of contrast material into the abdominal cavity (arrows). Note the massive fractures on both sides of the pelvic girdle.

and focal free fluid (43,54). Because a typical FAST examination omits large portions of the abdomen, the reliable exclusion of those injuries is impossible with FAST alone. In three studies (32,47,54), sensitivity of FAST was found to be poor (0.35, 0.38, and 0.44, respectively). In a study by Abu-Zidan et al, all bowel injuries in the series were missed at US but detected at CT (31).

To our knowledge, there are no published reports about the usefulness of US for dedicated evaluation of injuries to the urinary bladder. In an intraperitoneal bladder rupture, free fluid collects in the pouch of Douglas, with the exact volume of fluid depending on the extent of bladder filling before rupture (Fig 10). An extraperitoneal rupture produces no free intraabdominal fluid. Because the integrity of the bladder wall can be evaluated only if the bladder is full of fluid, retrograde filling via a Foley catheter may be necessary. However, intravesical air collections after catheterization may limit the quality of US images.



a. b.

Figure 11. Images from a 78-year-old woman with severe thoracic trauma after an automobile collision. **(a)** Transverse US view of the subxiphoid region, obtained during the initial FAST examination with cranial angulation of the transducer, shows a large pericardial effusion (arrow) with nearly total compression of the right ventricle (arrowheads). *LV* = left ventricle, *RA* = right atrium. **(b)** Transverse US view obtained after an emergency thoracotomy and decompression, during which approximately 500 mL of blood was removed from a hematoma, shows refilling of the right ventricle. A small pericardial effusion is still present (arrow). *LA* = left atrium, *RA* = right atrium, *RV* = right ventricle.

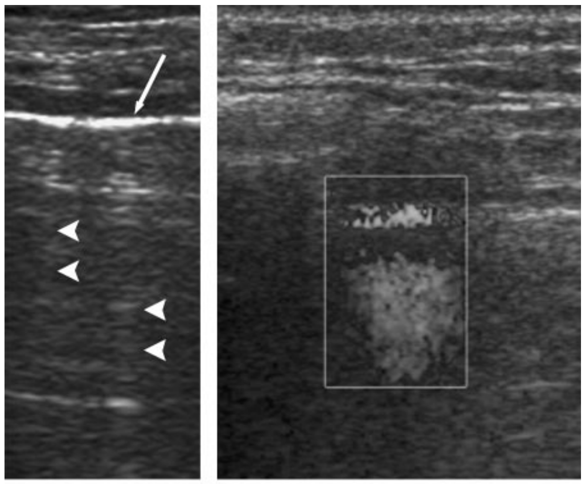
Heart and Pericardium.—Injuries to the heart are more common in penetrating trauma than in blunt trauma. Massive damage to the heart results in exsanguination and rapid death. Patients with subtle closed injuries to the pericardium or with occult cardiac injuries may seem stable at admission; however, if there is increasing compression of the heart chambers because of a pericardial effusion, the patient's condition is likely to deteriorate suddenly (Fig 11). In such a situation, immediate decompression must be performed.

Teaching Point

The sensitivity of FAST for the detection of cardiac injuries with the acquisition of pericardial views was 0.97–1.00, a finding that indicates the suitability of US for detecting or excluding such injuries (55–57). The pericardial view therefore should be included routinely in any FAST examination.

Extraabdominal US Evaluations

Techniques such as color Doppler US (58) and soft-tissue US play a minor role in the trauma setting and usually are performed only after the patient's condition has stabilized or when other imaging techniques are not available. US also may be useful for the visualization of vessels and for guidance during arterial and venous punctures in patients with hypotension. If there is time after the initial FAST examination, US scanning may be extended for the detection of pneumothorax and for control of correct tube placement and ventilation in endotracheally intubated patients.



a. b.

Figure 12. Normal physiologic ventilation at thoracic US. **(a)** Longitudinal view shows vertical comet-tail artifacts (arrowheads), which derive from movement of the various pleural layers during respiration. The arrow points to the interface between the pleura and the thoracic wall. **(b)** Duplex US image shows the lung-sliding sign, which is caused by the movement of the lung along the pleural surface during respiration. The absence of the comet-tail artifact, the lung-sliding sign, or both is indirectly indicative of pneumothorax.

Detection of Pneumothorax

Several previously published articles describe the use of US to detect pneumothorax (59–67). Because air between the pleura and the lung at US cannot be distinguished directly from that in the lung during normal ventilation, the detection of pneumothorax depends on indirect US signs, two of which are shown in Figure 12a (the comet-tail

Table 3
US Features Indicative of Normal or Abnormal Lung Ventilation

Interpretation of US Feature	Lung-Sliding Sign: Right Lung	Lung-Sliding Sign: Left Lung	Comet-Tail Artifact: Right Lung	Comet-Tail Artifact: Left Lung	Power-Doppler Sign: Right Lung	Power-Doppler Sign: Left Lung
Normal ventilation	Present	Present	Present	Present	Present	Present
Abnormal ventilation						
Apnea*	Absent	Absent	Present	Present	Absent	Absent
Intubation in right main-stem bronchus	Present	Absent	Present	Present	Present	Absent

Source.—Adapted, with permission, from reference 70.
*Apnea was defined as a lung ventilation failure caused by paralysis or esophageal intubation.

artifact) and 12b (the lung-sliding sign). Both signs are clearly visible in both lungs during normal ventilation at US, although training is necessary to interpret these features properly. When the signs are absent, pneumothorax is likely. There are other signs that also may help detect pneumothorax (eg, the deep sulcus sign, the lung point sign). These are less commonly seen and are adequately described elsewhere in the literature, so they are not discussed in detail here (64).

The reported sensitivity of US for the detection of pneumothorax ranges from 0.59 to 1.00, and the specificity ranges from 0.94 to 1.00 (62–64,66,67). Although in most studies the sensitivity was high, there were some limitations. In one of the studies, the sample size was small (63). In two studies, chest radiography was used as the reference standard (62,67). The results of studies conducted by Soldati et al (64) and Zhang et al (66), who compared chest radiography with both CT and US, indicated that chest radiography alone has poor sensitivity (0.54 and 0.28 in the two studies, respectively) for the detection of pneumothorax and that US is superior to radiography.

It is unclear whether US should be used routinely for the detection of pneumothorax in patients with major trauma. However, in cases in which the patient requires surgery or another urgent intervention before undergoing CT, chest US seems applicable to rule out pneumothorax if chest radiography has not been performed or was not of sufficiently diagnostic quality.

Control of Endotracheal Intubation

Another possible use for US in patients with major trauma is control of endotracheal tube placement. Drescher et al reported the possibility of detecting esophageal intubation either directly, with depiction of the tube in the esophageal lumen, or indirectly, with the absence of specific US signs that should appear in the intubated trachea (68). Werner et al reported a sensitivity of 1.00 for the US detection of esophageal intubation (69). However, both studies were pilot studies, and the sample sizes were small.

The endotracheal tube is misdirected into a main bronchus in 5%–10% of intubations performed in hospital emergency departments, and the frequency of such malpositioning is even higher (6%–18%) in the nonhospital setting (70). Such occurrences are not directly detectable with US; however, correct placement of the tube can be verified from the US depiction of bilateral ventilation of the lungs. As in screening for pneumothorax, the lung-sliding and power-Doppler signs and the comet-tail artifact are useful for confirming correct endotracheal tube placement (Table 3) (70). In a physiologically ventilated lung at US, all three signs are seen. If there is apnea, the lung-sliding and power-Doppler signs are absent. If only one main bronchus is intubated (usually the right main stem), both signs are absent on the opposite side. The comet-tail artifact is absent only in cases of pneumothorax.

Another way to indirectly verify correct endotracheal tube placement is by using M-mode US to visualize diaphragmatic movement in the ventilated lung (Fig 13). For this purpose, the transducer is placed on either the right or the left side of the chest (71). In a ventilated lung, there is evidence of diaphragmatic motion during inspiration and expiration, whereas in the presence of apnea, that motion ceases. However, the effectiveness of this method in all patients is unclear, and further investigation is required.

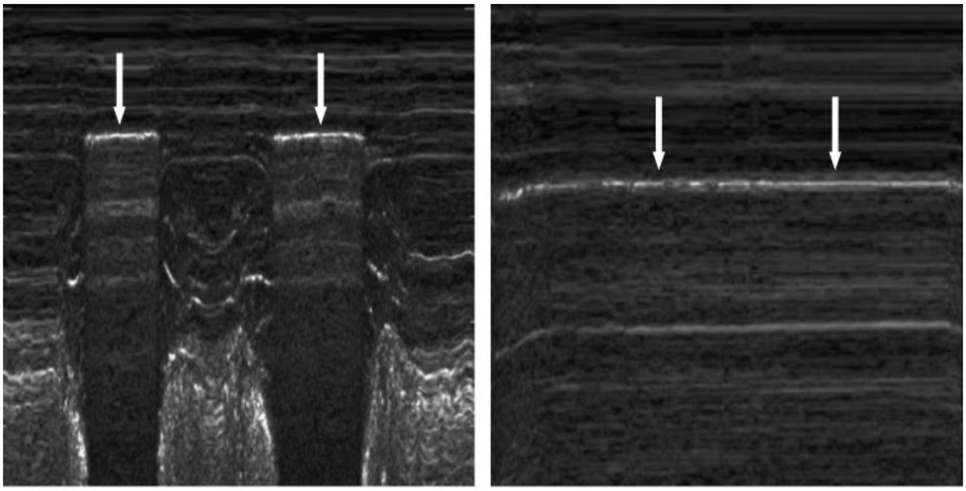


Figure 13. Diaphragmatic motion at abdominal US. **(a)** M-mode image in a patient with normal ventilation shows regular movement of the diaphragm during exhalation (arrows). **(b)** M-mode image in a patient with apnea shows no diaphragmatic motion (arrows).

Limitations of US in Major Trauma

US is useful for diagnostic imaging in patients with major trauma, but it has some limitations. As was shown by our survey of solid organ injuries, the diagnostic value of FAST and US for the detection of such injuries varies widely. In this section, the factors that influence the quality of US images are described in greater detail.

One drawback of US in the setting of major trauma is the limited availability of space and access to the patient in the emergency setting. Unless the patient is fully undressed, the sonographer has difficulty reaching all the regions of interest. Moreover, because the need to perform other diagnostic evaluations (eg, physical examination, blood sampling, or electrocardiography) may be as urgent as the need for imaging, the sonographer often must compete with or maneuver around colleagues from other departments for access to the patient.

Patient movement during the examination is another issue: In some cases, the patient is uncooperative or aggressive with the medical staff. Moreover, in patients in whom manual chest compression must be performed for cardiopulmonary resuscitation, the abdominal wall moves constantly, making it difficult to obtain accurate images.

Contamination of the patient with blood, dirt, or other substances is likely to complicate the imaging evaluation. If cutaneous emphysema is present in a region, a proper US evaluation of that region is not possible (Fig 5a). In patients with penetrating trauma, dressing material and foreign bodies may obstruct access to the patient or may obscure part of the anatomy at US.

Not all trauma suites are equipped with up-to-date US machines. Handheld devices that provide only limited resolution and that lack capabilities for color and power Doppler depiction often are used. Because of mechanical stress, the transducers have a high rate of failure. Moreover, in the trauma suite there is usually bright ambient light, which is necessary for physical examination and inspection of the patient but which limits the visibility of the US monitor.

US is strongly operator dependent, and the diagnostic sensitivity and image quality may be decreased when examinations are performed after regular hours or during the weekend, times when residents with limited US experience are often on duty. In a retrospective study of diagnostic performance with US in the trauma setting, Sato and Yoshii compared diagnostic results by dividing them, according to the level of experience of the operator, into two groups: results obtained by experienced and highly trained operators (surgeons, radiologists, and sonographers) and results obtained by resident surgeons with basic training in US (50). The comparison showed that the sensitivity of abdominal US in the detection of organ injuries in the highly experienced group was almost double that in the less experienced group. In another study, the difference between similar groups of beginners and more experienced operators was smaller, but the more experienced group also performed better (32). Catalano and Siani reported increasing sensitivity with increasing experience of the sonographer and concluded that a FAST examination is always inadequate for the exclusion of organ injuries and should be replaced by a full US examination (72).

Unfortunately, the term *experienced* is not always clearly defined. The definition developed by the FAST consensus conference specifies that 200 or more supervised examinations must be performed to attain a sufficient skill level to perform FAST reliably (11); other sources claim that 10 examinations are sufficient experience to safely rule out hemoperitoneum (27). Jang et al showed that the sensitivity of US for the detection of free intraperitoneal fluid was 0.74 for residents with previous experience of 11–20 supervised examinations (73). The sensitivity increased with increasing numbers of examinations, to 0.95 in a group of residents each of whom had performed more than 31 examinations. The authors concluded that 10 examinations did not constitute sufficient experience to rule out free fluid.

Summary and Recommendations

In a large number of studies, US, and specifically FAST, proved feasible as a primary method of diagnostic imaging in patients with major trauma (suspected injury severity score of 15 or higher). On the basis of the reported results in these studies, the following conclusions may be drawn about US with the FAST protocol:

a) The examination is widely available and may be performed quickly for a "first look."

b) It has acceptable sensitivity for the detection of free fluid.

c) It has poor sensitivity for the diagnosis of injury to solid organs.

d) It has high specificity for the detection of free fluid and solid organ injury.

e) It often leads to underestimation of the severity of solid organ injury.

f) It is strongly dependent on the operator's skill and experience.

g) It cannot always be performed in a standard way.

On the basis of our experience, we recommend using FAST in patients with major trauma to rule out severe intraperitoneal hemorrhage, which requires immediate surgery before further examinations such as CT can be performed (8,9). If acute intraperitoneal hemorrhage has been ruled out, either a whole-body or a focused CT examination—with the choice depending on the suspected injury patterns—should be performed for definitive diagnosis. Our recommendations for the reasonable use of FAST in patients with major trauma are as follows:

1. Don't waste time.
2. Scan for free fluid and pericardial effusion first.
3. If there is time, look for injuries to solid organs.
4. If you are skilled, look for pneumothorax, but only in patients at risk.
5. Use FAST for an overview, not for a definitive diagnosis.
6. Move the patient on to CT or the operating room as quickly as possible.

References

1. Freshman SP, Wisner DH, Battistella FD, Weber CJ. Secondary survey following blunt trauma: a new role for abdominal CT scan. J Trauma 1993; 34:337–340; discussion 340–341.
2. Leidner B, Adiels M, Aspelin P, Gullstrand P, Wallen S. Standardized CT examination of the multitraumatized patient. Eur Radiol 1998;8: 1630–1638.
3. Bode PJ, Edwards MJ, Kruit MC, van Vugt AB. Sonography in a clinical algorithm for early evaluation of 1671 patients with blunt abdominal trauma. AJR Am J Roentgenol 1999;172:905–911.
4. Novelline RA, Rhea JT, Rao PM, Stuk JL. Helical CT in emergency radiology. Radiology 1999;213: 321–339.
5. Poletti PA, Wintermark M, Schnyder P, Becker CD. Traumatic injuries: role of imaging in the management of the polytrauma victim (conservative expectation). Eur Radiol 2002;12:969–978.
6. Linsenmaier U, Krotz M, Hauser H, et al. Whole-body computed tomography in polytrauma: techniques and management. Eur Radiol 2002;12: 1728–1740.
7. Clarke JR, Trooskin SZ, Doshi PJ, Greenwald L, Mode CJ. Time to laparotomy for intra-abdominal bleeding from trauma does affect survival for delays up to 90 minutes. J Trauma 2002;52:420–425.
8. Farahmand N, Sirlin CB, Brown MA, et al. Hypotensive patients with blunt abdominal trauma: performance of screening US. Radiology 2005;235: 436–443.
9. Lee BC, Ormsby EL, McGahan JP, Melendres GM, Richards JR. The utility of sonography for the triage of blunt abdominal trauma patients to exploratory laparotomy. AJR Am J Roentgenol 2007;188:415–421.
10. Kirkpatrick AW, Sirois M, Laupland KB, et al. Prospective evaluation of hand-held focused abdominal sonography for trauma (FAST) in blunt abdominal trauma. Can J Surg 2005;48:453–460.
11. Scalea TM, Rodriguez A, Chiu WC, et al. Focused Assessment with Sonography for Trauma (FAST): results from an international consensus conference. J Trauma 1999;46:466–472.
12. Von Kuenssberg Jehle D, Stiller G, Wagner D. Sensitivity in detecting free intraperitoneal fluid with the pelvic views of the FAST exam. Am J Emerg Med 2003;21:476–478.
13. Sirlin CB, Casola G, Brown MA, et al. US of blunt abdominal trauma: importance of free pelvic fluid in women of reproductive age. Radiology 2001;219:229–235.
14. Ballard RB, Rozycki GS, Newman PG, et al. An algorithm to reduce the incidence of false-negative FAST examinations in patients at high risk for occult injury: Focused Assessment for the Sonographic Examination of the Trauma patient. J Am Coll Surg 1999;189:145–150; discussion 150–151.
15. Coley BD, Mutabagani KH, Martin LC, et al. Focused abdominal sonography for trauma (FAST) in children with blunt abdominal trauma. J Trauma 2000;48:902–906.

16. Miller MT, Pasquale MD, Bromberg WJ, Wasser TE, Cox J. Not so FAST. J Trauma 2003;54:52–59; discussion 59–60.
17. Boulanger BR, McLellan BA, Brenneman FD, et al. Emergent abdominal sonography as a screening test in a new diagnostic algorithm for blunt trauma. J Trauma 1996;40:867–874.
18. Brenchley J, Walker A, Sloan JP, Hassan TB, Venables H. Evaluation of focussed assessment with sonography in trauma (FAST) by UK emergency physicians. Emerg Med J 2006;23:446–448.
19. Chiu WC, Cushing BM, Rodriguez A, et al. Abdominal injuries without hemoperitoneum: a potential limitation of focused abdominal sonography for trauma (FAST). J Trauma 1997;42:617–623; discussion 623–625.
20. Hsu JM, Joseph AP, Tarlinton LJ, Macken L, Blome S. The accuracy of focused assessment with sonography in trauma (FAST) in blunt trauma patients: experience of an Australian major trauma service. Injury 2007;38(1):71–75.
21. Ingeman JE, Plewa MC, Okasinski RE, King RW, Knotts FB. Emergency physician use of ultrasonography in blunt abdominal trauma. Acad Emerg Med 1996;3:931–937.
22. Kern SJ, Smith RS, Fry WR, Helmer SD, Reed JA, Chang FC. Sonographic examination of abdominal trauma by senior surgical residents. Am Surg 1997;63:669–674.
23. McElveen TS, Collin GR. The role of ultrasonography in blunt abdominal trauma: a prospective study. Am Surg 1997;63:184–188.
24. McKenney MG, Martin L, Lentz K, et al. 1,000 consecutive ultrasounds for blunt abdominal trauma. J Trauma 1996;40:607–610; discussion 611–612.
25. Ollerton JE, Sugrue M, Balogh Z, D'Amours SK, Giles A, Wyllie P. Prospective study to evaluate the influence of FAST on trauma patient management. J Trauma 2006;60:785–791.
26. Rozycki GS, Ballard RB, Feliciano DV, Schmidt JA, Pennington SD. Surgeon-performed ultrasound for the assessment of truncal injuries: lessons learned from 1540 patients. Ann Surg 1998;228:557–567.
27. Shackford SR, Rogers FB, Osler TM, Trabulsy ME, Clauss DW, Vane DW. Focused abdominal sonogram for trauma: the learning curve of nonradiologist clinicians in detecting hemoperitoneum. J Trauma 1999;46:553–562; discussion 562–564.
28. Thomas B, Falcone RE, Vasquez D, et al. Ultrasound evaluation of blunt abdominal trauma: program implementation, initial experience, and learning curve. J Trauma 1997;42:384–388; discussion 388–390.
29. Wherrett LJ, Boulanger BR, McLellan BA, et al. Hypotension after blunt abdominal trauma: the role of emergent abdominal sonography in surgical triage. J Trauma 1996;41:815–820.
30. Yeo A, Wong CY, Soo KC. Focused abdominal sonography for trauma (FAST). Ann Acad Med Singapore 1999;28:805–809.
31. Abu-Zidan FM, Sheikh M, Jadallah F, Windsor JA. Blunt abdominal trauma: comparison of ultrasonography and computed tomography in a district general hospital. Australas Radiol 1999;43:440–443.
32. Rothlin MA, Naf R, Amgwerd M, Candinas D, Frick T, Trentz O. Ultrasound in blunt abdominal and thoracic trauma. J Trauma 1993;34:488–495.
33. Branney SW, Wolfe RE, Moore EE, et al. Quantitative sensitivity of ultrasound in detecting free intraperitoneal fluid. J Trauma 1995;39:375–380.
34. Lingawi SS, Buckley AR. Focused abdominal US in patients with trauma. Radiology 2000;217:426–429.
35. Ma OJ, Gaddis G, Steele MT, Cowan D, Kaltenbronn K. Prospective analysis of the effect of physician experience with the FAST examination in reducing the use of CT scans. Emerg Med Australas 2005;17:24–30.
36. Brown MA, Sirlin CB, Farahmand N, Hoyt DB, Casola G. Screening sonography in pregnant patients with blunt abdominal trauma. J Ultrasound Med 2005;24:175–181.
37. Bakker J, Genders R, Mali W, Leenen L. Sonography as the primary screening method in evaluating blunt abdominal trauma. J Clin Ultrasound 2005;33:155–163.
38. Poletti PA, Mirvis SE, Shanmuganathan K, et al. Blunt abdominal trauma patients: can organ injury be excluded without performing computed tomography? J Trauma 2004;57:1072–1081.
39. Akgur FM, Aktug T, Olguner M, Kovanlikaya A, Hakguder G. Prospective study investigating routine usage of ultrasonography as the initial diagnostic modality for the evaluation of children sustaining blunt abdominal trauma. J Trauma 1997;42:626–628.
40. Healey MA, Simons RK, Winchell RJ, et al. A prospective evaluation of abdominal ultrasound in blunt trauma: is it useful? J Trauma 1996;40:875–883; discussion 883–885.
41. Katz S, Lazar L, Rathaus V, Erez I. Can ultrasonography replace computed tomography in the initial assessment of children with blunt abdominal trauma? J Pediatr Surg 1996;31:649–651.
42. Krupnick AS, Teitelbaum DH, Geiger JD, et al. Use of abdominal ultrasonography to assess pediatric splenic trauma: potential pitfalls in the diagnosis. Ann Surg 1997;225:408–414.
43. McGahan JP, Wang L, Richards JR. From the RSNA refresher courses: focused abdominal US for trauma. RadioGraphics 2001;21(Spec Issue):S191–S199.
44. Nural MS, Yardan T, Guven H, Baydin A, Bayrak IK, Kati C. Diagnostic value of ultrasonography in the evaluation of blunt abdominal trauma. Diagn Interv Radiol 2005;11:41–44.
45. Richards JR, McGahan PJ, Jewell MG, Fukushima LC, McGahan JP. Sonographic patterns of intraperitoneal hemorrhage associated with blunt splenic injury. J Ultrasound Med 2004;23:387–394.
46. Singh G, Arya N, Safaya R, Bose SM, Das KM, Khanna SK. Role of ultrasonography in blunt abdominal trauma. Injury 1997;28:667–670.
47. Yoshii H, Sato M, Yamamoto S, et al. Usefulness and limitations of ultrasonography in the initial evaluation of blunt abdominal trauma. J Trauma 1998;45:45–50; discussion 50–51.
48. Moore EE, Cogbill TH, Malangoni MA, et al. Organ injury scaling. Surg Clin North Am 1995;75:293–303.
49. Marco GG, Diego S, Giulio A, Luca S. Screening US and CT for blunt abdominal trauma: a retrospective study. Eur J Radiol 2005;56:97–101.

50. Sato M, Yoshii H. Reevaluation of ultrasonography for solid-organ injury in blunt abdominal trauma. J Ultrasound Med 2004;23:1583–1596.
51. Soundappan SV, Holland AJ, Cass DT, Lam A. Diagnostic accuracy of surgeon-performed focused abdominal sonography (FAST) in blunt paediatric trauma. Injury 2005;36:970–975.
52. Doody O, Lyburn D, Geoghegan T, Govender P, Monk PM, Torreggiani WC. Blunt trauma to the spleen: ultrasonographic findings. Clin Radiol 2005;60:968–976.
53. Gupta A, Stuhlfaut JW, Fleming KW, Lucey BC, Soto JA. Blunt trauma of the pancreas and biliary tract: a multimodality imaging approach to diagnosis. RadioGraphics 2004;24:1381–1395.
54. Richards JR, McGahan JP, Simpson JL, Tabar P. Bowel and mesenteric injury: evaluation with emergency abdominal US. Radiology 1999;211:399–403.
55. Rozycki GS, Feliciano DV, Ochsner MG, et al. The role of ultrasound in patients with possible penetrating cardiac wounds: a prospective multicenter study. J Trauma 1999;46:543–551; discussion 551–552.
56. Rozycki GS, Feliciano DV, Schmidt JA, et al. The role of surgeon-performed ultrasound in patients with possible cardiac wounds. Ann Surg 1996;223:737–744; discussion 744–746.
57. Tayal VS, Beatty MA, Marx JA, Tomaszewski CA, Thomason MH. FAST (focused assessment with sonography in trauma) accurate for cardiac and intraperitoneal injury in penetrating anterior chest trauma. J Ultrasound Med 2004;23:467–472.
58. Kantarci F, Mihmanli I, Kara B, Bozlar U. Acute arterial emergencies: evaluation by Doppler ultrasound. Emerg Radiol 2005;11:315–321.
59. Joseph T. Does the detection of occult pneumothorax by the focused assessment with sonography trauma examination value add to the management of the trauma patient? Emerg Med Australas 2005;17:418–419.
60. Kirkpatrick AW, Nicolaou S, Rowan K, et al. Thoracic sonography for pneumothorax: the clinical evaluation of an operational space medicine spin-off. Acta Astronaut 2005;56:831–838.
61. Kirkpatrick AW, Sirois M, Laupland KB, et al. Hand-held thoracic sonography for detecting post-traumatic pneumothoraces: the Extended Focused Assessment with Sonography for Trauma (EFAST). J Trauma 2004;57:288–295.
62. Knudtson JL, Dort JM, Helmer SD, Smith RS. Surgeon-performed ultrasound for pneumothorax in the trauma suite. J Trauma 2004;56:527–530.
63. Rowan KR, Kirkpatrick AW, Liu D, Forkheim KE, Mayo JR, Nicolaou S. Traumatic pneumothorax detection with thoracic US: correlation with chest radiography and CT—initial experience. Radiology 2002;225:210–214.
64. Soldati G, Testa A, Pignataro G, et al. The ultrasonographic deep sulcus sign in traumatic pneumothorax. Ultrasound Med Biol 2006;32:1157–1163.
65. Tam MM. Occult pneumothorax in trauma patients: should this be sought in the focused assessment with sonography for trauma examination? Emerg Med Australas 2005;17:488–493.
66. Zhang M, Liu ZH, Yang JX, et al. Rapid detection of pneumothorax by ultrasonography in patients with multiple trauma. Crit Care 2006;10:R112.
67. Dulchavsky SA, Schwarz KL, Kirkpatrick AW, et al. Prospective evaluation of thoracic ultrasound in the detection of pneumothorax. J Trauma 2001;50:201–205.
68. Drescher MJ, Conard FU, Schamban NE. Identification and description of esophageal intubation using ultrasound. Acad Emerg Med 2000;7:722–725.
69. Werner SL, Smith CE, Goldstein JR, Jones RA, Cydulka RK. Pilot study to evaluate the accuracy of ultrasonography in confirming endotracheal tube placement. Ann Emerg Med 2007;49:75–80.
70. Chun R, Kirkpatrick AW, Sirois M, et al. Where's the tube? evaluation of hand-held ultrasound in confirming endotracheal tube placement. Prehospital Disaster Med 2004;19:366–369.
71. Hsieh KS, Lee CL, Lin CC, Huang TC, Weng KP, Lu WH. Secondary confirmation of endotracheal tube position by ultrasound image. Crit Care Med 2004;32:S374–S377.
72. Catalano O, Siani A. Focused assessment with sonography for trauma (FAST): what it is, how it is carried out, and why we disagree. Radiol Med (Torino) 2004;108:443–453.
73. Jang T, Sineff S, Naunheim R, Aubin C. Residents should not independently perform focused abdominal sonography for trauma after 10 training examinations. J Ultrasound Med 2004;23:793–797.

Current Role of Emergency US in Patients with Major Trauma

Markus Körner, MD, et al

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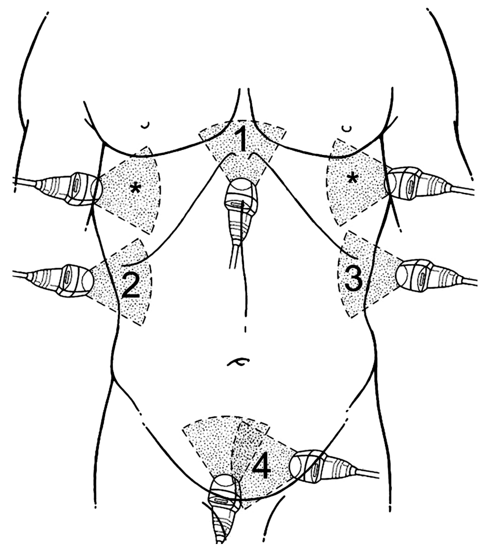
Page 226
Abdominal US in cases of major trauma is usually performed with a FAST (focused assessment with sonography in trauma) examination. This type of examination provides a quick overview of the intraperitoneal cavity to detect free fluid, which is an indirect sign of acute hemorrhage and injury to visceral organs.

Page 226
The following four standard views should be obtained (Fig 1): *(a)* transverse view of the subxiphoid region to diagnose pericardial effusion and injuries to the left lobe of the liver; *(b)* longitudinal view of the right upper quadrant to show the right lobe of the liver, the right kidney, and the space between the two (the Morison pouch), which may fill with peritoneal fluid when the patient is supine; *(c)* longitudinal view of the left upper quadrant to show the left kidney, the spleen, and the space between them, which also may contain free intraperitoneal fluid; and *(d)* transverse and longitudinal views of the suprapubic region to depict the urinary bladder and rectouterine or retrovesical pouch, a recess formed by a fold of the peritoneum that descends between the rectum and uterus in women or the rectum and bladder in men. This recess is called the pouch of Douglas. Like the Morison pouch, it is a space in which free intraperitoneal fluid may collect.



Page 229
The detectability of free fluid during the FAST examination is strongly dependent on the volume of fluid present.

Page 230
Although FAST is the most commonly used diagnostic imaging method in patients after major trauma, its role in the diagnosis of injuries to solid organs is limited.

Page 236
The sensitivity of FAST for the detection of cardiac injuries with the acquisition of pericardial views was 0.97–1.00, a finding that indicates the suitability of US for detecting or excluding such injuries. The pericardial view therefore should be included routinely in any FAST examination.

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