Focused Assessment with Sonography for Trauma

Nira Beck-Razi, MD*, Diana Gaitini, MD

KEYWORDS

- Focused assessment with sonography for trauma
- Multiple casualty incidents • Diagnosis • Triage
- Ultrasonography

The use of ultrasound (US) in trauma to detect abdominal parenchymal injuries, specifically traumatic splenic hematomas, was described by Kristensen and colleagues[1] back in 1971. In 1976, Asher and colleagues[2] reported a sensitivity of 80% for the detection of splenic injury from blunt abdominal injuries. US for trauma evaluation was then abandoned but resurfaced in 1990, especially for blunt abdominal injuries.[3]

SONOGRAPHIC TECHNIQUE

The US examination in the emergency room differs from the examination conducted in the US suite. The emergency examination is brief and highly focused, and typically seeks to answer a single clinically relevant question: ''Is there a hemoperitoneum?''

The protocol of the focused assessment with sonography for trauma (FAST) examination includes evaluation of the right upper quadrant, the left upper quadrant, and the pelvis for free fluid. It is desirable that the bladder be filled, thus creating an acoustic window, needed to detect small amounts of hemoperitoneum and to displace bowel loops.[4]

The rest of the protocol may differ between institutions. McGahan and colleagues[4] report that their protocol includes scanning the right upper quadrant; the hepatorenal fossa, including the right kidney, checking the liver for parenchymal anomalies; the right flank; and the pelvis; and evaluation of the epigastrium; the left upper quadrant; the spleen; the left kidney; and the left flank. They incorporated a subxiphoid view, to check the heart for pericardial fluid, and pleural views. These additions to the classic protocol are part of the extended FAST.

The authors' protocol includes scanning of the right (Morison's pouch) and left upper quadrants, the right and left gutters, and the pelvis for the evaluation of free fluid, in transverse and longitudinal planes; a subxiphoid or transthoracic view of the pericardium for the evaluation of hemopericardium; and an evaluation of the pleurae for pneumothorax (**Figs. 1–4**).

Although FAST was defined by international consensus as ''an examination to detect free intra peritoneal fluid as a marker of injury'',[5] the role of FAST has been extended to the diagnosis of hemopericardium and, lately, to pneumothorax (extended FAST). FAST is not expected to detect injuries to abdominal organs, associated or not with intraperitoneal fluid, such as hollow viscous tear, mesenteric tear, intraparenchymal or subcapsular bleeding, and retroperitoneal injuries.[6,7]

Free fluid will usually appear anechogenic to homogenously hypoechogenic, sometimes with low-level echoes. At the site of an injured solid organ, one may find echogenic blood forming a subcapsular hematoma, which may be less obvious than the hypoechoic free fluid.

Richards and colleagues[8] evaluated the US appearance of blunt liver injuries. Parenchymal injuries were documented in only 12% of patients, and three different patterns were observed. The most common pattern was a discrete hyperechogenic area; other patterns included a diffuse hyperechogenic pattern or a discrete hypoechoic pattern (**Fig. 5**). An echogenic clot was often

Unit of Ultrasound, Department of Medical Imaging, Rambam Medical Center, Ha'aliya Hashniya 8, 31096, POB 9602, Haifa, Israel
* Corresponding author.
E-mail address: n_beck_razi@rambam.health.gov.il (N. Beck-Razi).

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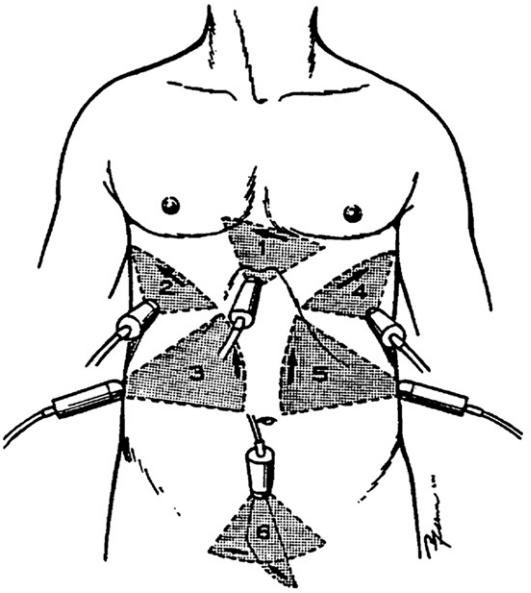

Fig. 1. Components of the modified assessment with sonography for trauma, including a subxiphoid view to evaluate possible pericardial blood (**1**); a right upper quadrant view to evaluate Morison's pouch (**2**); a right paracolic gutter view (**3**); a left upper quadrant view to evaluate the splenorenal recess (**4**); a left paracolic gutter view (**5**); a suprapubic view of the pouch of Douglas/retrovesical pouch (**6**). (*From* Yen K, Gorelick MH. Ultrasound applications for the pediatric emergency department: a review of the current literature. Pediatr Emerg Care 2002;18(3): 226–34; with permission.)

seen surrounding the liver. Of course, hypoechogenic fluid may be seen in other portions of the abdomen. The appearance of hepatic lacerations changes with time, as is the case in other solid organs. The laceration may be difficult to recognize or may appear slightly echogenic. Hepatic lacerations appear more hypoechoic or cystic when scanned days after the initial injury.[4] Richards and colleagues[9] identified parenchymal injuries of the spleen in 31 of 162 patients. The most common pattern was a diffuse heterogeneous appearance, a pattern that may be difficult to recognize (**Fig. 6**).

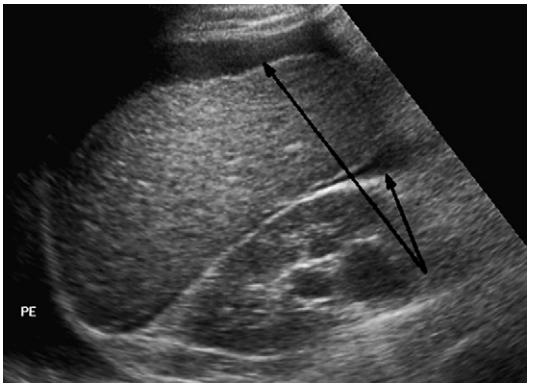

Fig. 2. A longitudinal view of the hepatorenal space (Morrison's pouch), illustrating free fluid (*short arrow*). Perihepatic fluid (*long arrow*) is also shown, as is an appreciable amount of pleural effusion (PE).

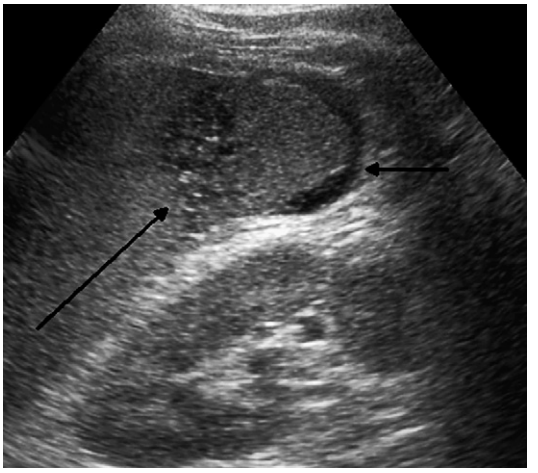

Fig. 3. A longitudinal view of the splenorenal space, illustrating free fluid (*short arrow*). A diffuse heterogeneous area is shown (*long arrow*) at the lower pole of the spleen, representing a parenchymal traumatic injury.

McGahan and associates[10] found that US discovered only 8 injured kidneys from a total of 37. If a kidney was severely injured, the sonographic appearance was that of a large, mixed, anechogenic renal fossa with loss of normal renal shape. Mild renal lacerations were difficult to detect with US.

WHOSE TURF IS IT?

Accurate training and experience are crucial to accurate US evaluation.

US is first and foremost an operator-dependent examination; this fact should be especially emphasized when surgeons or emergency physicians with

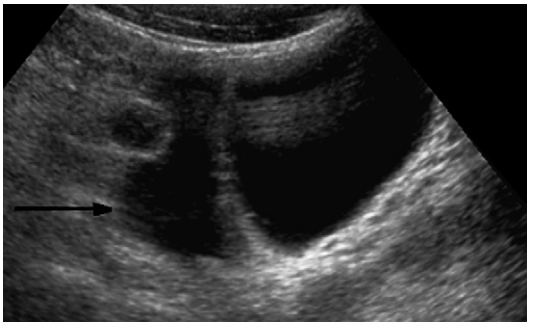

Fig. 4. A longitudinal view of the pelvis, illustrating free fluid in the retrovesical space (*arrow*).

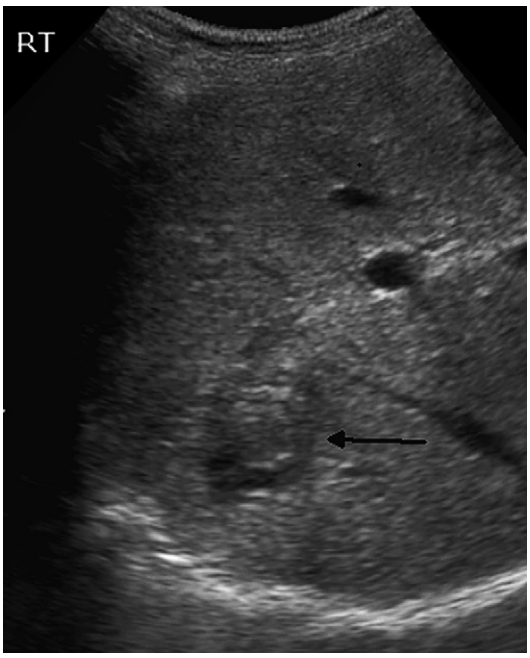

Fig. 5. A transverse view of the right lobe of the liver, showing a hypoechogenic round area, representing a posttraumatic hematoma (*arrow*).

limited training perform the examination.[11] The reported sensitivities for FAST examination vary among institutions and studies, and among studies in which the examiners were either radiologists/sonographers or nonradiologists. This variability can be attributed to the differences in methods and patient population. Some studies screen not only for fluid but also for abdominal injuries, a fact that lowers sensitivity (**Table 1**).

Brown and colleagues[11] reported an 84% sensitivity and a negative predictive value of 99%. The FAST examinations were performed by a staff or resident radiologist. In this study, it must be emphasized that US findings were considered

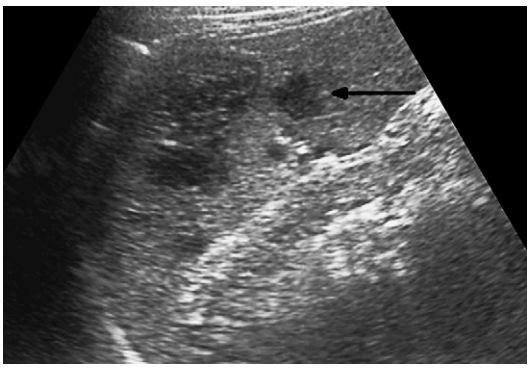

Fig. 6. A longitudinal view of the spleen, showing a heterogeneous diffuse appearance of the spleen parenchyma, representing a parenchymal traumatic injury (*arrow*).

Table 1
Sensitivity of the focused assessment with sonography for trauma examination, in different studies, comparing radiologists and nonradiologists

	Sensitivity	Operator	Including Parenchymal Injuries	Pediatric Patients Only	Stable Patients Only
Brown et al	84%	Radiologists	+	–	–
Nural et al	86%	Radiologists	+	–	–
Soudack et al	92%	Radiologists	–	+	–
Brenchley et al	78%	Emergency physicians after a brief training period	–	–	–
Brooks et al	100%	Trained nonradiologists	–	–	–
Miller et al	42%	Attending trauma staff	–	–	+

false-negative if a subsequent study revealed either free fluid (hemoperitoneum) or any visceral abdominal injury, also a fact lowering sensitivity. Nural and colleagues[12] reported a sensitivity of 86%. The examinations were performed by radiology residents and, again, the sensitivity calculated was that of intra-abdominal fluid or organ damage in detecting intra-abdominal injury.

Soudack and colleagues[13] reported a sensitivity of 92% for a pediatric population; false-negative results were considered to pertain to free fluid alone, and not parenchymal injuries.

Brenchley and colleagues[14] reported a sensitivity of 78% for free fluid. In this study, emergency physicians performed the FAST after a brief training period. Books and colleagues[15] reported a sensitivity of 100% for free fluid; the FAST examinations were performed by trained nonradiologists. Miller and colleagues[16] evaluated 372 hemodynamically stable patients who had suspected blunt abdominal injury. FAST examination had a sensitivity of 42% for free fluid. The examination was performed by attending trauma staff.

McGahan and colleagues[17] suggested that trauma sonography has a definite learning curve and this examination should be performed only by US technologists with more than 3 years of experience, and interpreted only by radiologists with more than 3 years of training in sonographic techniques.

The American Institute of Ultrasound in Medicine has recommended that at least 500 abdominal US examinations be performed with supervision before physicians are allowed to perform sonography independently.[18]

Smith and colleagues[19] concluded that senior surgical residents are capable of performing the focused US examination for trauma with a high level of skill after a concise introductory course. A learning curve was not apparent in their study, indicating that the criteria for being permitted to perform trauma sonography that include the requirement of a large number of examinations or extensive proctoring should be reassessed. They reported a sensitivity of 73% for detecting free fluid, commenting that they believe that it appears that many recommendations are influenced by emotional ''turf battles'' and fear of lost practice domain.

The authors believe that because one of sonography's main limitations is experience and operator dependency, it cannot be ignored that sonographers and radiologists are capable, in principle, of achieving higher accuracies.

The authors' radiology department is able to give 24-hour coverage of FAST examination in the trauma room. They believe that 24-hour coverage should be the case if a radiology department in a specific institution can give such service.

FOCUSED ASSESSMENT WITH SONOGRAPHY FOR TRAUMA IN THE ADULT AND PEDIATRIC POPULATION

In the pediatric patient, physical examination is frequently unreliable and imaging studies are required.[20] Because children differ from adults not only in size but also in their physiologic response to trauma, the effectiveness of FAST in children cannot be extrapolated from studies in adults.[13]

The management of solid visceral abdominal injuries in children differs from that of adults. In children, parenchymal injury generally does not require surgery. Surgical treatment of hepatic injuries in children is associated with high morbidity and mortality. Splenectomy is associated with sepsis and thus, a high risk of fatality.[13] According to Taylor and Sivit,[21] abdominal injury was not associated with free peritoneal fluid in 37% of children, compared with 22% in the adult population.[22] Furthermore, sonography is repeatable; thus, serial follow-up scans can be performed in cases of conservative management or when a case is not conclusive.

Several reports on the usefulness of FAST in children have been published, with conflicting results.[23–25] In the literature, reported sensitivity ranges from 33%,[24] to 81%,[26] to 97%.[13] Soudack and colleagues'[13] results showed a sensitivity of 92.5% and a specificity of 97.2%, thus concluding that FAST can be used in pediatric patients as an effective screening tool adjunct to the clinical evaluation. In contrast to this study, Richards and colleagues[27] showed a sensitivity of 56% for the detection of abdominal injuries (hemoperitoneum and solid organ injury) in pediatric blunt abdominal trauma.

In contrast to sonography, CT involves ionizing radiation, which is potentially harmful, especially to pediatric patients. Sonography produces no ionizing radiation, is quick and relatively inexpensive, and thus is appropriate as a screening test.

Sonography is a valuable tool as an adjunct to physical examination in cases of pediatric blunt abdominal trauma.[13]

FOCUSED ASSESSMENT WITH SONOGRAPHY FOR TRAUMA IN BLUNT AND PENETRATING TRAUMA

FAST is rapidly establishing its place in the evaluation of blunt abdominal trauma. However, few articles have been published concerning its role in penetrating abdominal trauma. Udobi and colleagues[28] concluded in their study that FAST

can be a useful initial diagnostic study after penetrating abdominal trauma; furthermore, they concluded that a positive FAST is a strong predictor of injury, and these patients should proceed directly to laparotomy. If negative, additional diagnostic studies should be performed to rule out occult injury, because their results showed a low sensitivity of 46%.

Rapid diagnosis and treatment of abdominal injury is an important factor in decreasing mortality in patients who have blunt abdominal trauma. Physical examination is frequently unreliable in the setting of acute trauma.[29]

Diagnostic peritoneal lavage has been used successfully to aid in the diagnosis of abdominal injury and to determine the need for laparotomy.[30]

When CT emerged in clinical practice, it allowed a more accurate decision-making process and a better triage of these patients.[31,32] Today, US is used in many centers of the world in the evaluation of blunt abdominal trauma.[33–35]

Most studies in the literature report a high sensitivity and a high negative predictive value for FAST in blunt abdominal injury, thus making the examination an excellent screening test.

Lingawi and colleagues reported a sensitivity of 94%, and a 100% negative predictive value in blunt abdominal injuries.[6] Rothlin and associates [36] reviewed the European literature about US of blunt abdominal trauma and cited reports of sensitivities of 85% to 100% and specificities of 98% to 100%. Their study showed an overall sensitivity and specificity of the US examination of 90% and 99.5%, respectively.

Brown and colleagues[11] reported a slightly lower sensitivity of 84%, probably because they screened patients for abdominal injury and not for free fluid alone. US in the emergency room is not expected to detect abdominal injuries not associated with free fluid, such as hollow viscous injuries or parenchymal injuries.

McGahan and colleagues[17] reported a low sensitivity of 63% of US in detecting free fluid, in comparison to CT, diagnostic peritoneal lavage and surgery. They explained their results by the fact that the bladder was not filled during the examination and small amounts of fluid in the pelvis were undetected.

The authors believe that FAST plays an important part in the evaluation of all trauma injuries, whether blunt or penetrating, and should be performed on all of them during the resuscitation phase. US is fast and noninvasive, does not involve radiation, is portable, and can be integrated into the resuscitation process in the trauma bay without disrupting it.

A negative FAST should be received with caution, especially in penetrating abdominal injury, because in such injuries it takes time to develop appreciable hemoperitoneum that can be detected by US.

FOCUSED ASSESSMENT WITH SONOGRAPHY FOR TRAUMA IN STABLE AND UNSTABLE PATIENTS

In a setting of a blunt abdominal trauma, determining which patients should be triaged to laparotomy is important, even more so when these patients are unstable; rapid and accurate triage is crucial because delayed treatment is associated with increased morbidity and mortality.[37] In such a setting, clinical history, laboratory test, and a physical examination are often not reliable in the evaluation of the patient.[38]

Brett and colleagues[34] evaluated the usefulness of FAST performed by experienced sonographers in a setting of a blunt abdominal trauma, comparing hypotensive and normotensive patients. They found a statistically significant difference between hypotensive and normotensive patients with small amounts of free fluid, which reflects the greater significance of small amounts of fluid in hypotensive patients and the higher associated therapeutic laparotomy rate. They concluded that FAST is an effective screening tool when performed by experienced sonographers. In hypotensive patients, in whom a moderate to large amount of fluid is found, immediate triage to laparotomy, obviating CT, is warranted.

Miller and colleagues[16] evaluated 372 hemodynamically stable patients who had suspected blunt abdominal injury. FAST examination had a sensitivity of 42% and a negative predictive value of 98%. They concluded that the use of FAST examination in hemodynamically stable trauma patients results in underdiagnosis of intra-abdominal injury.

Thus, FAST evaluation of stable patients who have suspected abdominal injury is perhaps less accurate than for unstable patients, but still has an important role in the triage of all trauma patients.

FOCUSED ASSESSMENT WITH SONOGRAPHY FOR TRAUMA AS A TRIAGE TOOL IN MULTIPLE-CASUALTY INCIDENTS

In war zones and regions of political conflict, civilians and military personnel are exposed to serious injuries due to explosives and firearms. Injuries may be blunt or penetrating, often combined in a single patient.[39–41]

Effective initial triage, defined as the art of sorting patients according to the severity of their injury,

is the key to dealing successfully with a multiple-casualty incident.

To proceed to further triage and patient management, a quick and efficient imaging diagnosing test is needed. FAST can be performed rapidly in the admission area and is repeatable, noninvasive, nonirradiating, and inexpensive. It is widely accepted as an effective initial tool to evaluate trauma victims with suspected blunt abdominal injuries.[42]

FAST may play an important role in the work-up of trauma patients in a multiple-casualty incident because of the complexity of the injuries. Some controversies remain concerning the role of FAST in penetrating trauma.[28] Although the role of FAST in an individual trauma casualty has been reviewed in the literature, few studies have described the role of FAST in multiple-casualty incidents.

Miletic and colleagues[43] described US screening of mass war casualties as an efficient and effective means for detection and on-site triage of abdominal injuries that were mostly penetrating (90%), with a similar sensitivity and specificity in war and civil conditions.

Sarkisian and colleagues[44] described a successful application of US after a catastrophic earthquake in Armenia, which involved mostly crush injuries.

In war conflict and in terror-related injuries, patients comprise a heterogeneous group of blunt and penetrating injuries, hemodynamically stable and unstable patients, adults and children. The level of care for each casualty in a multiple-casualty incident is less than that provided under regular circumstances. Attention is given to the moderately to severely injured, because these will benefit the most from optimal care.

In a study the authors conducted on 102 soldiers and civilians during the second Lebanon war, they reported a sensitivity of 75% for hemoperitoneum detection. Injuries encountered were blunt and penetrating combined. Their results show that FAST, as the first imaging examination during continuous arrival phase in a setting of a war conflict–related multiple-casualty incident, enabled immediate triage of casualties to laparotomy, CT, or clinical observation.

Because of its moderate sensitivity and limitation in diagnosing solid organs or hollow viscous injury, a negative FAST in the presence of a strong clinical suspicion must be followed by CT or laparotomy, according to clinical judgment.[45]

ROLE OF FOCUSED ASSESSMENT WITH SONOGRAPHY FOR TRAUMA IN FOLLOW-UP

One of US's main advantages is the fact that no ionizing radiation is involved; thus, the examination can be repeated when needed. Blackbourne and colleagues[46] aimed to evaluate whether delayed, repeat US study can reveal additional intra-abdominal injuries and hemoperitoneum. They found that secondary US of the abdomen significantly increases the sensitivity of US to detecting intra-abdominal injury. The sensitivity of US to detecting intraperitoneal injury is directly related to the fact that US relies on the existence of free intraperitoneal blood and does not routinely include parenchymal imaging. Studies have shown that the sensitivity to detecting intraperitoneal fluid is relatively proportional to the amount of fluid in the peritoneal cavity, especially for inexperienced US operators.[47,48] The limited intraperitoneal blood on admission, combined with the necessity for a significant amount of intraperitoneal blood (>200 mL) for most surgical US operators to be able to detect hemoperitoneum, may limit the sensitivity of US in stable blunt trauma patients.[49]

A secondary abdominal US may allow for the duration necessary to accumulate the prerequisite amount of blood for detection by most surgical US operators. Although FAST has shown lower sensitivity for penetrating trauma,[28] a secondary US in cases of such injuries may give better results for the same reason. In the case of a multiple-casualty incident, when resources are overwhelmed, particularly CT, a secondary US can be helpful, especially when an initially stable patient who was left on clinical observation is deteriorating and CT is not yet available.

A secondary US can be beneficial in cases of a known trauma to parenchymal organs, in most cases initially diagnosed by CT. The secondary US can evaluate the parenchymal injuries and the amount of free fluid over time. The pediatric population is more sensitive to ionizing radiation damage and CT should be limited; a follow-up US examination is most useful. In addition, treatment of such injuries takes a more conservative approach in children than in adults.

PITFALLS AND LIMITATIONS

US is first and foremost an operator-dependent examination; thus, experience plays an important role and sensitivity drops with little experience.

US showed a low sensitivity of 44% in detecting free fluid associated with bowel or mesenteric injury,[50] US has a low sensitivity for parenchymal injuries, injuries to the diaphragm and the pancreas, and vascular injuries. These specific limitations must be kept in mind when one performs the FAST examination, so that the only question that can be answered with high accuracy is the presence or absence of free fluid.

Without a full bladder, free fluid may be missed, because a full bladder creates an acoustic window that helps detect small amounts of fluid in the pelvis and displaces bowel loops.[17] On the other hand, false-positive results can be due to physiologic pelvic fluid in female patients of reproductive ages. The mechanism of fluid accumulation is unclear and is probably multifactorial.[51–53] With transabdominal imaging, physiologic fluid has been described during all stages of the menstrual cycle in up to 30% to 40% of healthy volunteers.[53] In the obstetric literature, numerous investigators have quantified the volume of fluid found surgically in the cul-de-sac and have estimated the upper limit of physiologic fluid to be about 45 mL. Although these investigators described the fluid as ranging from clear to blood tinged, physiologic fluid is generally anechoic on sonographic imaging. When fluid in the cul-de-sac contains internal echoes, it is unlikely to be physiologic. And in a patient with trauma, this fluid likely represents hemoperitoneum.[54] Because the cul-de-sac is the most dependent recess in the peritoneum in both supine and upright positions, pathologic fluid tends to collect within it.[55]

Sirlin and colleagues[54] reported in their study that fluid in the cul-de-sac was never the sole manifestation of a solid organ or enteric injury. They concluded that in a female patient of reproductive age with blunt abdominal trauma, small amounts of anechoic fluid isolated to the cul-de-sac or adjacent pelvic recesses should be considered physiologic, and further evaluation is not needed in the absence of other radiologic or clinical findings.

They emphasized that if the fluid measures at least 3 cm in depth, has internal echoes, and extends into the supravesical space or anterior to the bladder, or if the patient is past her reproductive years or her reproductive status is unknown, fluid is regarded with suspicion. US is an operator-dependent examination, which is a limitation of the examination in itself. Thus, when the examination is performed by a resident with less experience, under the stressful environment of a trauma room, his or her tendency is to overcall the findings when in doubt. A similar dilemma occurs when small amounts of fluid are found in the pelvis in children. Rathaus and colleagues[56] aimed to evaluate the significance of the US finding of pelvis fluid after blunt abdominal trauma in children as a predictor of an abdominal injury. They concluded that a normal US examination or the presence of pelvic fluid is associated with a low probability of an organ injury, but the presence of peritoneal fluid outside the pelvis indicates that the probability of an organ injury is high. Despite this conclusion, the residence tendency is again to overcall. Last but not least, the medical history of a trauma patient arriving in the trauma room is not known; thus, if the patient has ascites for any number of reasons, the examination will be positive. In addition, even if the patient's condition is known, one cannot be sure if there is hemoperitoneum on top of the known ascites.

SUMMARY

The US examination in the trauma room is brief and focused and should answer a single relevant question: "Is there a hemoperitoneum?" The presence of hemopericardium is evaluated also, as is the presence of pneumothorax.

The answer to this question enables the attending staff to perform better triage, whether dealing with an individual trauma patient or in the case of a multiple-casualty incident, thus improving patient prognosis.

Because no ionizing radiation is involved, FAST can be performed consecutively and can spare the patient from CT, an important fact to remember, especially when dealing with pediatric trauma patients.

In the authors' institution, it is acceptable that the FAST examination be performed on all trauma patients, keeping in mind the examination's limitations, including its lower sensitivity in cases of penetrating trauma and stable patients.

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