Prehospital and Emergency Department Ultrasound in Blunt Abdominal Trauma

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Abstract

Blunt abdominal trauma is a challenging aspect of trauma management. Early detection has a major impact on patient outcome. In contrast to physical examination, computed tomography is known to be a sensitive and specific test for blunt abdominal injuries. However, it is time-consuming and thus contraindicated in hemodynamically unstable patients. Therefore, focused assessment with sonography for trauma (FAST) offers a fast and easily applicable screening method to identify patients for urgent laparotomy without any further diagnostics. FAST detects, with high sensitivity, intraperitoneal fluid that accumulates in dependent areas indicating blunt abdominal trauma. FAST has been established as a gold standard early screening method for blunt abdominal trauma when performing trauma management in the emergency department (ED) based on the Advanced Trauma Life Support® algorithm. The development of hand-held ultrasound devices facilitated the introduction of FAST into prehospital trauma management. It was demonstrated that prehospital FAST (p-FAST) can be performed with high sensitivity and specificity, and can lead to significant changes in prehospital trauma therapy and management. Standardized training with both theoretical and hands-on modules is mandatory in order to gain the skills required to perform FAST or p-FAST well.

Key Words

FAST · Abdominal trauma · Ultrasound

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Blunt Abdominal Trauma

A major cause of death in patients with multiple injuries in the first twenty-four hours after trauma is abdominal trauma in combination with pelvic injuries [1]. In order to decrease preventable death, potential sources of hemorrhage need to be rapidly evaluated, resuscitation needs to be initiated, and specific therapy needs to be instituted. However, diagnosing blunt abdominal trauma (BAT) is a challenging task, as physical examination is frequently unreliable in the setting of acute trauma because there are often distracting injuries, altered levels of consciousness, nonspecific signs and symptoms, and large differences in the individual reactions of patients to intra-abdominal injury [2, 3]. More than 40 years ago, the introduction of diagnostic peritoneal lavage (DPL) marked a new era in the determination of the need for laparotomy [4]. DPL has been shown to be very sensitive, but it is an invasive procedure associated with complications in 0.8–1.7% of patients.

The introduction of computed tomography (CT) in the mid-1980s resulted in a revolution in the assessment of medical and surgical patients, and in fundamental changes in the management of multiply injured patients. CT is a sensitive and specific test for blunt abdominal injuries. However, this technology is expensive, time-consuming, and requires trained personnel and transport to the radiology suite [5]. Thus, CT scan is contraindicated in hemodynamically unstable patients with BAT in need of urgent laparotomy.

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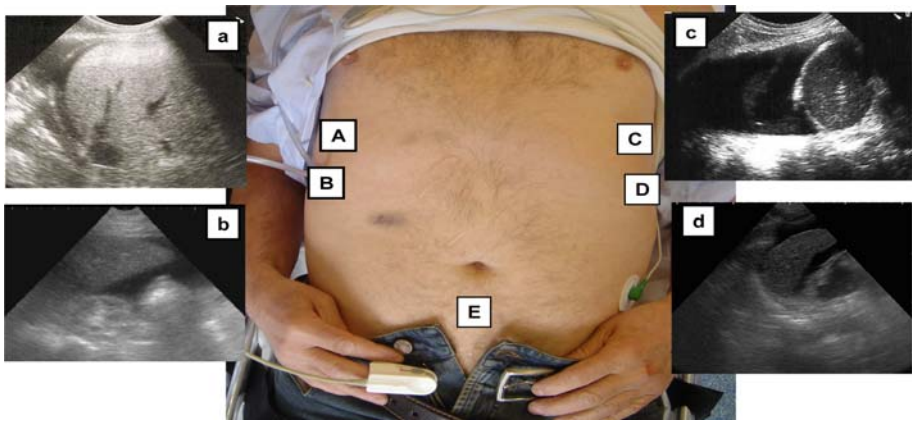
Table 1. Sensitivity, specifity and accuracy of ultrasound in blunt abdominal trauma. (FAST: focused abdominal sonography in trauma; HHFAST: hand-held FAST; p-FAST: prehospital FAST; CT: computed tomography; DPL: diagnostic peritoneal lavage; PHASE: prehospital application of sonography in emergencies).

First author and reference no.	Modality	n	Sensitivity	Specifity	Accuracy	Diagnostic reference standard
Boulanger [27]	FAST	206	81	98	96	DPL, CT
Boulanger [8]	FAST	400	81	97	94	DPL, CT
Brown [28]	FAST	2693	84	96	96	DPL, CT, laparotomy, autopsy
Rozycki [10]	FAST	1227	75.7	99.8		DPL, CT, laparotomy
Tso [29]	FAST	163	69	99	96	DPL, CT
Wherrett [9]	FAST	69	100	94	96	DPL, CT, laparotomy
Kirkpatrick [15]	HHFAST	313	68.6	96.9	91.6	CT, laparotomy
Walcher [19]	p-FAST	202	93	99	99	CT, laparatomy
Busch [30]	PHASE	38	90	96		FAST, CT



Figures 1a to 1d. The picture in the middle shows the standard projections routinely obtained in a FAST examination: a longitudinal view of the right upper quadrant, showing a thoracic view (*A*), as well as the right lobe of the liver, the right kidney and Morison's pouch (*B*) which may fill with free fluid; a longitudinal view of the left upper quadrant, showing a thoracic view (*C*) and the left kidney, the spleen and the space between them (*D*), which may also fill with free intraperitoneal fluid; and a transverse and longitudinal view of the suprapubic region to depict the urinary bladder and the retrouterine or retrovesical pouch (pouch of Douglas) (*E*). The small pictures demonstrate pathological findings: a) free fluid between diaphragm and liver; b) in Morison's pouch; c) hemothorax; d) free fluid around spleen and left kidney.

FAST

The ultrasound examination (US) offers several advantages as a diagnostic method. The first reported use of US for BAT was in assessing splenic hematomas in 1971 [6]. However, the ultrasound examination did not become the clinical standard for identifying the presence of free intraperitoneal fluid until after several studies had been performed in the mid-1990s [7]. The benefit of US lies in its high sensitivity for detecting intraperitoneal fluid which accumulates in dependent areas of patients in the supine position, indicating a BAT (Table 1). The examination provides a quick, standardized overview of the intraperitoneal cavity when searching for the typical sites of free fluid accumulation: Morison's pouch, Coller's pouch (splenorenal fossa), and the pouch of Douglas (Figure 1). The examination detects intraperitoneal fluid with a high degree of accuracy, but it can not differentiate between blood, urine, bile or ascites. The presence of free abdominal fluid in combination with hemodynamically unstable patients indicates the need for urgent laparotomy without any further diagnostics [8–11].

In order to distinguish the screening method from generic US of the entire abdomen, in 1997 an international Consensus Conference Committee defined the acronym ''FAST,'' meaning ''focused assessment with sonography for trauma,'' to describe the application of US in the initial evaluation of the trauma patient [7].

The FAST examination has advantages over both DPL and CT in terms of performance speed. Fur-

thermore, US is portable, readily available and thus can easily be integrated into the resuscitation of patients with trauma without delaying therapeutic measures. It is thus of great value for patients who are hemodynamically unstable and cannot be sent to the CT scan room. However, some limitations should be considered. Visibility is shortened by gross obesity and skin emphysema due to a lack of penetration of sonographic waves or reverberation artefacts. A major limitation in comparison to the CT scan is its dependence on operator skill.

FAST is the gold standard early screening method for BAT in the ED, and is also part of the Advanced Trauma Life Support® algorithm [12].

At the trauma scene, however, clinical parameters and physical examination are the only prehospital measures used to detect intra-abdominal bleeding, in spite of the low accuracy and reliability of this approach. BAT remains a challenging aspect of trauma management during the prehospital period, as crucial time may be lost for patients with undiagnosed intra-abdominal bleeding.

Time plays a major role in trauma management. Clarke et al. [13] demonstrated for hypotensive patients with BAT that the probability of death increases in the ED by about 1% for every 3 min that elapses before intervention. It is assumed that these results can also be applied to prehospital management. The determination of a source of hemorrhage at the trauma scene may expedite transport and disposition, and may result in more timely and effective definite therapy.

Figures 2a and 2b. The use of p-FAST at the trauma scene. a) 7-year-old boy with BAT after he fell from monkey bars. b) 59-year-old male with BAT from a tram accident.

p-FAST

The first portable hand-held ultrasonography units were developed in a joint civilian–military initiative in order to provide ultrasound capabilities that are suitable for the battlefield or a mass casualty situation. Brooks et al. [14] were able to demonstrate that handheld ultrasound is a valuable tool for the assessment of the trauma patient within a field hospital. Kirkpatrick et al. [15] confirmed that hand-held FAST is a valuable test that affords high sensitivity, specificy and accuracy (Table 1).

These hand-held devices add another dimension to FAST, as their lightweight nature, small size, and relative simplicity of use (Figure 2) facilitate the application of prehospital FAST (p-FAST) to detect life-threatening injuries including hemoperitoneum, hemothorax, and pneumothorax [16, 17] within the ''golden hour'' and allow appropriate triage of the patients.

A German pilot study in 2001 [18] and a consecutive prospective multicenter study [19] investigated the feasibility of p-FAST in prehospital trauma care. It was demonstrated that p-FAST is a useful and reliable diagnostic tool at the trauma scene. p-FAST could be performed with levels of sensitivity, specificity and accuracy that were comparable to those of FAST performed under in-hospital conditions (Table 1). In 95% of the patients (219/230) there was enough time to perform p-FAST during prehospital care. p-FAST was not completed at the scene due to unfavorable circumstances – e.g., technical failure (bright sunlight), artefacts due to thoracic skin emphysema in patients with severe thoracic trauma or gross obesity – on only 16 occasions.

The mean investigation time was 2.4 ± 0.8 min when the results were negative, whereas positive findings were detected within seconds. These results are

Table 2. Consequences of p-FAST results.

Modification of therapy (21%) and management on scene (30%)
Appropriate/different choice of trauma center (22%)
Transfer of prehospital findings to trauma team (52%)
Changes in trauma team management (92%)
Ultrasound at the scene 35 min prior to FAST in the emergency department

comparable to those of FAST in the ED, where mean investigation times of around 2.3 to 2.6 (±13 s to 1.2 min) were described for negative results [8, 9], as well as 19 s for the scanning and interpretation of positive sonograms [9].

The study results demonstrated that p-FAST could be performed on average 35 ± 13 min prior to in-hospital FAST or CT scan. In 52% of the cases, the report passed from the scene to trauma center was supplemented with the findings from p-FAST. Based on this information, all receiving trauma teams modified their preparations by expanding their team to include a surgeon, and prepared the theater for urgent laparotomy.

The study demonstrated not only changes in information transfer and trauma team management, but also changes in prehospital care at the trauma scene in 21% of the cases, as well as changes in prehospital management aimed at shortening the time to surgical therapy in 30% of cases, thus avoiding the need for any therapy beyond advanced life support. Furthermore, in 22% of the cases the choice of receiving hospital was changed to the closest appropriate trauma center because of the p-FAST results. Twenty-two percent of the cases may seem to be a minor fraction, but this result is biased by the design of the study, as it took place in urban settings. In rural settings, where both mean response times and mean transport times [20] are higher, the choice of receiving hospital may be more important. However, there is no evidence as yet that the integration of this investigation with prehospital trauma care leads to a better outcome.

Based on the results summarized in Table 2, it is comprehensible that p-FAST became a widely used diagnostic tool in both German ground and air rescue systems [19], in Europe [21], and worldwide for civilian and military environment [14].

p-FAST should be performed on all traumatized patients with suspected BAT. As intra-abdominal bleeding is a dynamic situation, p-FAST should be repeated every 15 min during the prehospital period as well as in the emergency department if suspicious physical findings with negative or slightly positive initial p-FAST results occur, as hemorrhage may not yet be apparent [10].

There are several aspects that should be considered when using FAST and p-FAST. Both should be used as screening methods to identify patients at risk. They are not indicated for a definitive diagnosis. Time should not be wasted in trying to identify organ lesions; instead, the patient should be moved to CT or the operating room as quickly as possible. The FAST and (in particular) p-FAST investigations must not constrain the trauma management algorithm. Thus, US should not be performed if there is no time slot for it in trauma care. p-FAST must not be performed if its results do not have any influence on further prehospital therapy, management or the choice of hospital, or if the hand-held device does not offer the required quality. Adequate training and experience is crucial for accurate US evaluation, as the quality of the examination is highly dependent on the user, and the US examination must not delay patient management.

FAST and p-FAST training

In the 1990s several studies investigated how changing the training program (in terms of training time and supervised examinations) impacted on user competence at performing FAST [22–25]. The length of the training ranged from 2 to 30 h. In all studies, a steep learning curve was demonstrated. Furthermore, it was found that the time needed for each examination plateaued at approximately 2 min after 50–75 scans [8]. The use of patient volunteers with positive findings was found to significantly impact on the learning curve and competence [26]. A contingent where 20% of the patient volunteers have positive findings can enhance the learning curve such that ~30 FAST investigations are needed for appropriate competence [23].

Both in-hospital and prehospital trauma algorithms are strictly time-restricted, as a loss of time has a major impact on patient outcome. Therefore, the course needs to include aspects of the atmosphere at the scene, such as stress and noise. The course must also contain training on the different and sometimes difficult circumstances that may occur at the scene, such as the patient being trapped in wreckage in a sitting position, in order to prevent questionable and potentially dangerous therapeutic and logistic consequences at the scene. Training for p-FAST should be supplemented with daily practice in order to maintain the competence achieved during the one-day training.

When preparing the German multicenter study, one day of training was introduced in order to train the participating emergency physicians. This consists of

both theoretical and hands-on training. In short lectures, participants are introduced to the physical basis for ultrasound, the causes and relevance of artefacts, current studies regarding FAST and p-FAST, the rationale for performing an ultrasound examination at the scene, and how to integrate p-FAST into prehospital trauma care.

During hands-on training, participants perform p-FAST on healthy volunteers as well as on patient volunteers with positive findings due to ascites or peritoneal dialyses. The ratio of students to instructors is 2:1. During the course each trainee performs ~40 ultrasound investigations under supervision. The hands-on training consists of three parts. During the first part, participants gain experience in performing FAST investigations under optimal conditions. In the second part, participants are confronted with difficult circumstances, such as uncommon positions and different kinds of lighting. The main goal of the p-FAST training is to prepare participants for uncommon situations in trauma scenarios where they are under time pressure and where several challenges may have to addressed at the scene. Thus, the third part of the hands-on training comprises real-time scenarios, such as a vehicle accident with the patient trapped in the wreckage, and surgical triage of three or more injured patients. Here, participants learn how to integrate p-FAST into their algorithm of trauma care.

Since its introduction in 2003, more than 550 physicians and paramedics have undergone the training. In 2006 the course was certified by the German Society for Ultrasound in Medicine (DEGUM).

Conclusion

Taken together, in contrast to the low accuracy of clinical BAT findings, FAST offers a reliable tool for detecting hemoperitoneum with high accuracy, not only in the emergency department but also during prehospital trauma management. With the development of hand-held ultrasound devices, prehospital diagnostic tools can be supplemented by an easily learned investigation. Several studies have demonstrated that p-FAST can significantly improve prehospital care and management of injured patients with BAT. With the detection of hemoperitoneum at the trauma scene, the receiving hospital can be notified of the US results prior to patient admission and can therefore prepare for emergency operative hemorrhage control in advance.

Both FAST and p-FAST are of high importance in the early management of multiply injured patients, and should be mastered by every physician involved in trauma care.

Conflict of interest statement

The authors declare that there is no actual or potential conflict of interest in relation to this article.

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