Original article

Prehospital ultrasound imaging improves management of abdominal trauma

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Background: **Blunt abdominal trauma with intra-abdominal bleeding is often underdiagnosed or even overlooked at trauma scenes. The purpose of this prospective, multicentre study was to compare the accuracy of physical examination and prehospital focused abdominal sonography for trauma (PFAST) to detect abdominal bleeding.**

Methods: **Six rescue centres took part in the study from December 2002 to December 2003, including 230 patients with suspected abdominal injury. The accuracy of physical examination at the scene and PFAST were compared. Later examinations in the emergency department (ultrasonography and/or computed tomography) were used as the reference standard.**

Results: **The complete protocol and follow-up was obtained in 202 patients. The sensitivity, specificity and accuracy of PFAST were 93 per cent, 99 per cent and 99 per cent, respectively, compared with 93 per cent, 52 per cent and 57 per cent for physical examination at the scene. Scanning with PFAST occurred a mean(s.d.) 35(13) min earlier than ultrasound in the emergency department. Abdominal bleeding was detected in 14 per cent of patients. Using PFAST led to a change in either prehospital therapy or management in 30 per cent of patients, and a change to admitting hospital in 22 per cent.**

Conclusion: **In this study, PFAST was a useful and reliable diagnostic tool when used as part of surgical triage at the trauma scene.**

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Introduction

Over the last few decades, mortality rates and the incidence of multiple organ failure among multiply injured patients have decreased owing to improvements in rescue systems, trauma management and intensive care. However, the outcome in severely injured patients remains heavily influenced by initial life support and early surgical care. Within these factors, time plays a major role, especially with respect to early management of major blunt abdominal trauma and perforating truncal injuries[1,2].

Abdominal and pelvic injuries are major causes of early death after severe trauma, hence it is important to focus on their initial assessment and management. In the case of uncontrolled haemorrhage, immediate diagnosis and urgent laparotomy offers the only chance of survival. This raises the question of how to obtain the diagnosis as early as possible in order to make a decision regarding surgical treatment. In the case of blunt abdominal trauma, no relevant physical signs can be trusted to provide adequate information regarding the need for surgery. Even patients with completely normal clinical examination and vital signs may have abdominal pathology[3]. It has been shown that the assessment of response to resuscitation by sequential physiology scores could help to determine the need for urgent laparotomy in an abdominal emergency[4].

Until recently, focused abdominal sonography for trauma (FAST) performed immediately after admission to the receiving trauma centre has been the standard procedure for diagnosing bleeding due to abdominal

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injury[5,6]. For more than a decade, it has been known that the presence of free abdominal fluid detected by FAST, in combination with haemodynamic instability, requires urgent laparotomy[7–11].

Before the use of FAST, management of blunt abdominal trauma was very challenging during the prehospital interval, and crucial time may have been lost in patients with undiagnosed intra-abdominal bleeding[1].

Recently, it has been demonstrated that the detection of abdominal bleeding can be achieved before hospital admission using prehospital focused abdominal sonography for trauma (PFAST)[12,13]. That study was conducted among the ground ambulance service in Frankfurt, Germany, where PFAST was shown to improve overall trauma management. Ultrasound evaluation was exclusively performed by a single investigator.

The purpose of the present multicentre study was to evaluate the feasibility of PFAST performed routinely by different emergency doctors and paramedics at the trauma scene. Additionally, the study aimed to compare the accuracy of PFAST with physical examination, using ultrasonography and computed tomography (CT) in the emergency department as the 'gold standard'.

Materials and methods

Between December 2002 and December 2003, a prospective, multicentre study was performed involving five air rescue centres in South West Germany (Frankfurt/Main, Freiburg, Leonberg, Mannheim, Ochsenfurt) and one ground ambulance team in Frankfurt/Main. The research protocol was approved by the ethics committee of the university hospital.

All patients with suspected abdominal trauma were eligible for inclusion in the study. Prehospital focused abdominal sonography for trauma was performed prospectively at the scene using standard techniques, as described elsewhere[3,6,7,9,11]. The main focus was on the detection of haemoperitoneum; no specific attempt was made to evaluate individual parenchymal organ pathologies[14,15], bowel or mesenteric injury[16]. The participating emergency doctors from the rescue centres included surgeons, internists and anaesthetists. Doctors and paramedics who were not familiar with ultrasound imaging received training in the use of PFAST in a 1-day course[17,18]. The hand-held ultrasound device used in all cases was the PRIMEDIC™ HandyScan (Metrax GmbH, Rottweil, Germany). This device with a 3·5 MHz curved array transducer was designed specifically for prehospital care.

At the trauma scene a primary survey with stabilization was performed, according to the principles of advanced life support. Following physical examination, preliminary diagnosis made by the emergency doctor with respect to abdominal trauma and the blood pressure and pulse rate were recorded. The duration and findings of PFAST were also recorded. Changes in prehospital therapy and patient management resulting from the findings of PFAST were documented on structured questionnaires, including free form answers. The study endpoint was the diagnosis or exclusion of a haemoperitoneum by ultrasound or CT[10,11,17,19], performed once the patient arrived in the emergency department. In addition, the trauma leaders at the receiving hospital were interviewed by structured questionnaire retrospectively to find out whether they had modified their preparation for the patient as a result of the PFAST findings, which were communicated to them from the scene.

All investigators, including the emergency doctors who performed PFAST and the radiologists who interpreted the CTs, were independent and blinded to the results of the other tests. Statistical analyses were performed using BiAS for Windows (Epsilon, Frankfort).

Results

A total of 230 patients were included in the study with suspected abdominal trauma; the trial profile is given in *Fig. 1*. The causes of injury were as follows: motor vehicle accidents 37 per cent, pedestrians struck by a vehicle 17 per cent, motorcycle accidents 16 per cent, fall from a height 10 per cent, cycling 4 per cent, gunshot or stab wounds 2 per cent and others 14 per cent. The demographic data are listed in *Table 1*.

On 219 occasions (95 per cent) the rescue team stated that there was enough time for PFAST to be performed without exceeding the intervals of prehospital care. In the remaining 11 patients (5 per cent), the prehospital time at the scene was prolonged by up to 4 min, in order to complete the protocol. Some 214 (93 per cent) of the investigations performed on the scene provided good or acceptable images for establishing a definitive diagnosis. In the remaining 16 (7 per cent), PFAST investigation was incomplete owing to unfavourable circumstances for conducting ultrasound. These included failure to obtain a clear image or technical failure, because of bright sunlight in one case, artifacts due to air emphysema in two patients with severe thoracic trauma, or gross obesity of four patients. The entire protocol and follow-up was obtained in 202 patients.

The mean(s.d.) investigation time was 2·4(0·8) min. All scans were performed either at the scene, in the ground ambulance or in the helicopter before transport of the

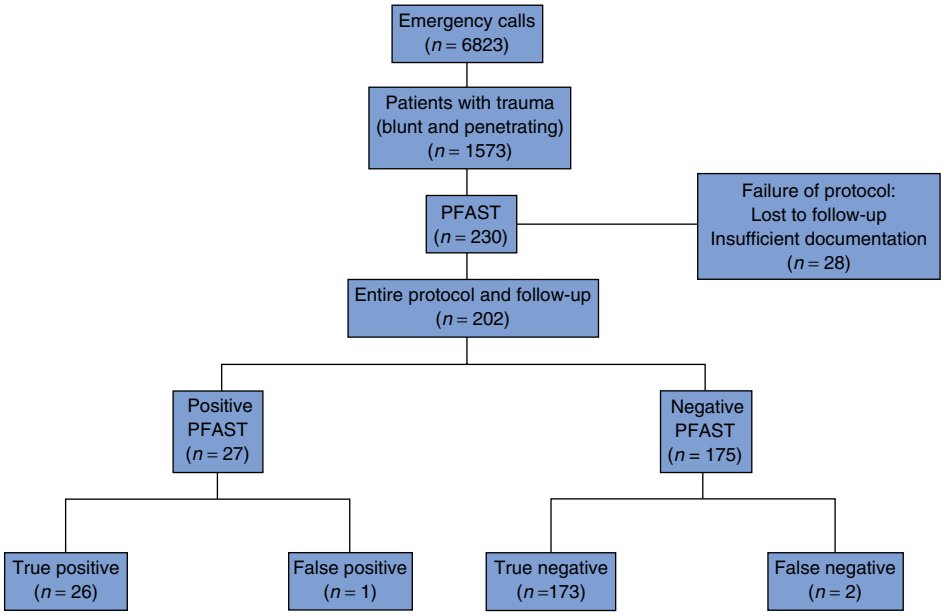

Fig. 1 Trial profile of the multicentre study

Table 1 Demographic data and the severity of trauma according to the injury severity score[20] of all 230 patients

Age (years)*	35·5(17·9) 3–70
Sex ratio: M : F (%)	152 : 78 (66 : 33)
ISS of all patients†	16·2(16·3)
ISS of patients with negative FAST†	14·0(13·9)
ISS of patients with positive FAST†	30·6(22·8)

*Values are mean(s.d.) range; †values are mean(s.d.). ISS, injury severity score; FAST, focused abdominal ultrasonography for trauma.

patient. On average, PFAST was performed 35(13) min earlier than ultrasound or CT in the receiving hospital.

As a result of the physical examination at the trauma scene, the emergency doctors suspected that 110 patients had abdominal trauma with bleeding. In only 26 patients was this bleeding confirmed and validated by ultrasound or CT in the admitting hospital. Thus in 84 patients, the suspicion of abdominal bleeding based on clinical signs, haemodynamic parameters and the mechanism of injury was not confirmed. Therefore, the sensitivity of physical examination alone for intra-abdominal bleeding was 93 (95 per cent confidence interval (c.i.) 76 to 99) per cent, the specificity 52 (95 per cent c.i. 44 to 59) per cent and the accuracy 57 (95 per cent c.i. 50 to 64) per cent.

Using PFAST at the trauma scene

Some 6823 emergency calls were recorded; 1573 patients had blunt or penetrating trauma (*Fig. 1*). A total of 230 patients were managed by emergency physicians and paramedics trained in the use of PFAST, and were included in the study. Primary survey was performed before PFAST. Twenty-eight patients were excluded because they were lost to follow-up.

Overall, the incidence of free abdominal blood on ultrasound was 28 of 202 (14 per cent) including 26 true positives and two false negatives. Therefore PFAST had a sensitivity, specificity and accuracy of 93 (95 per cent c.i. 76 to 99) per cent, 99 (95 per cent c.i. 97 to 100) per cent and 99 (95 per cent c.i. 96 to 100) per cent, respectively.

In 17 patients, positive findings were found on PFAST in only one of three probe locations (right upper quadrant, left upper quadrant, retrovesical space); nine patients had free abdominal fluid in two or three anatomical sites. Free abdominal fluid was found mainly in the pouch of Douglas (18 patients), followed by the right upper quadrant (12 patients) and the left upper quadrant (eight patients). There was no correlation between the location of free fluid detected by PFAST and the need for subsequent laparotomy.

In 42 patients (21 per cent), prehospital care at the trauma scene was changed because of the findings of PFAST. Mostly fluid resuscitation was modified by reducing volume replacement in order to reduce blood loss by permissive hypotension, once significant head injury was excluded. In 61 patients (30 per cent), prehospital management was also changed. When intra-abdominal bleeding was found on PFAST, the overall management at

the scene was influenced to avoid any therapy beyond advanced life support. Additional therapy was either omitted or performed more quickly in order to shorten the time to surgery. If PFAST was negative, deliberated rescue of patients who were trapped could go ahead.

The report from the scene to the receiving trauma centre was supplemented by the findings of PFAST in 105 patients (52 per cent), and in 44 patients (22 per cent) the choice of receiving hospital was changed. As a result of additional information, all trauma teams modified their preparations by including an abdominal surgeon and preparing theatre for urgent laparotomy.

Early follow-up of the 28 patients who had intra-abdominal bleeding showed that laparotomy was needed in 12 patients, including seven who had splenectomy. Fourteen patients had no surgical intervention and two died before surgical control of the haemorrhage. One of the two with a false negative PFAST required laparotomy; the other was managed conservatively.

Discussion

In contrast to the low accuracy of physical examination and haemodynamic measurement, PFAST was highly reliable in the detection of a haemoperitoneum. In this study, only two false negative findings and one false positive finding were noted. Intra-abdominal bleeding is a dynamic situation and therefore one explanation for the false negative findings might be that the ultrasound examination was performed so soon after the trauma that haemorrhage due to splenic laceration was not yet apparent enough to give a positive result[11]. Therefore, it is suggested that PFAST should be repeated every 15 min during the prehospital period interval if the initial PFAST findings are negative but physical examination is suspicious.

The location of free abdominal fluid detected during PFAST in this study differed from the data of Rozycki[21] and Hahn[22], who showed a correlation between parenchymal organ injury and the appearance of free blood, primarily located in Morison's pouch. In this study, most pathological findings were found in the pelvis, as also described by Nance in children[23]. The results may differ because PFAST was performed on patients found in different positions at the scene of the trauma.

The accuracy of PFAST was high; the data correlated favourably with studies concerning the accuracy of ultrasound imaging under optimal conditions in the emergency department[11,18,19]. Even teams who received 1-day training in PFAST reported accurate results. Data from the literature suggest that training programmes provide competence in FAST and are associated with a steep learning curve[17,18,24].

In 95 per cent of the patients, there was enough time to complete the PFAST investigation within the prehospital phase; the procedure itself took on average less than 2·5 min. Other studies have reported that the mean(s.d.) time taken to perform FAST in the emergency department was 154(13) s[10] and 2·6(1·2) min[7].

In only 7 per cent of patients was PFAST not completed owing to suboptimal conditions for imaging. However, in these rare cases it is recommended that the patients are treated as if they had a positive PFAST, because physical examination alone would have resulted in a correct diagnosis in only half of the patients. The major prerequisites for success with PFAST are an intensive training programme and good equipment. Several hand-held ultrasound units have been designed for mobile use[25,26].

In approximately one third of the patients in this study, the findings of PFAST had an influence on trauma management at the scene. In the event of intra-abdominal bleeding, the prehospital phase was minimized to allow immediate transport of the patient to hospital; helicopter transport was considered[27]. In contrast, if the PFAST was negative, the routine algorithm for trauma care at the scene was followed, including primary and secondary survey in accordance with advanced life support.

In the event of a positive PFAST, patients should ideally go to an appropriate trauma centre. Clarke *et al.* showed that, for patients with abdominal bleeding, the probability of death increased by approximately 1 per cent for every 3 min delay in the emergency department[1]. Therefore, the closest appropriate hospital should be chosen and the trauma team should be informed. A change in the choice of admitting hospital was made in approximately 20 per cent of patients in this study. This may be only a minor advantage in an urban setting, but in rural hospitals with less experience in treating life-threatening injuries, PFAST gives the surgeons more information and more time to prepare[28]. Helicopter transport may be required to bring a patient to an appropriate trauma centre if the regional hospital is unable to arrange immediate laparotomy.

The air rescue centres that took part in this multicentre study now include the information from PFAST in their standard reports from a trauma scene. Following the results of this study, one major air rescue provider in Germany (24 helicopters and four fixed wing aircrafts) has incorporated and established PFAST into its algorithm for trauma management.

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