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The role of focused abdominal sonography for trauma (FAST) in pediatric trauma evaluation

Eric R. Scaife [a,*], Michael D. Rollins [a], Douglas C. Barnhart [a], Earl C. Downey [a], Richard E. Black [a], Rebecka L. Meyers [a], Mark H. Stevens [a], Sasha Gordon [b], Jeffrey S. Prince [b], Deborah Battaglia [c], Stephen J. Fenton [a], Jennifer Plumb [d], Ryan R. Metzger [a]

[a]*Division of Pediatric Surgery, University of Utah, Salt Lake City, UT, USA*
[b]*Primary Children's Medical Center, Department of Radiology, Salt Lake City, UT, USA*
[c]*Division of Emergency Medicine, University of Utah, Salt Lake City, UT, USA*
[d]*Division of Pediatric Emergency Medicine, University of Utah, Salt Lake City, UT, USA*

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Abstract
Purpose: With increasing concerns about radiation exposure, we questioned whether a structured program of FAST might decrease CT use.
Methods: All pediatric trauma surgeons in our level 1 pediatric trauma center underwent formal FAST training. Children with potential abdominal trauma and no prior imaging were prospectively evaluated from 10/2/09 to 7/31/11. After physical exam and FAST, the surgeon declared whether the CT could be eliminated.
Results: Of 536 children who arrived without imaging, 183 had potential abdominal trauma. FAST was performed in 128 cases and recorded completely in 88. In 48% (42/88) the surgeon would have elected to cancel the CT based on the FAST and physical exam. One of the 42 cases had a positive FAST and required emergent laparotomy; the others were negative. The sensitivity of FAST for injuries requiring operation or blood transfusion was 87.5%. The sensitivity, specificity, PPV, and NPV in detecting pathologic free fluid were 50%, 85%, 53.8%, and 87.9%.
Conclusions: True positive FAST exams are uncommon and would rarely direct management. While the negative FAST would have potentially reduced CT use due to practitioner reassurance, this reassurance may be unwarranted given the test's sensitivity.

The computed tomography (CT) scan was invented in the early 1970s. The first papers to discuss the use of CT in the evaluation of pediatric trauma patients were published in the 1980s [1,2]. CT scans are now a routine part of the trauma evaluation, and over 50% of children who require a formal trauma evaluation at a trauma center will have an abdominal CT scan performed [3]. In 2001, Dr. David Brenner raised the issue of the radiation associated with a CT scan [4]. He argued that the radiation dose from a single CT scan offered a small but not insignificant risk of radiation-induced cancers.

* Corresponding author. 100 N. Mario Capecchi, Suite 2600, Salt Lake City, UT 84113-1103, USA. Tel.: +1 801 662 2950; fax: +1 801 662 2980.
E-mail address: eric.scaife@hsc.utah.edu (E.R. Scaife).

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He also argued that these risks are more significant in children who have particularly radiosensitive tissues and many expected life years during which time the radiation exposure could manifest itself.

In contrast, the first papers to discuss the use of ultrasound (US) in the evaluation of injured children appeared in the early 1990s [5,6]. Focused abdominal sonography for trauma (FAST) quickly became popular at adult trauma centers, and by 1999, approximately 80% of adult trauma centers were using FAST [7]. The enthusiasm for FAST did not translate to pediatric trauma centers. In 2009, it was reported that only 15% of free-standing children's hospitals used FAST as compared to 96% of adult institutions [8]. The tepid interest in FAST at pediatric hospitals could largely be explained by two factors. At adult hospitals, the FAST exam has replaced the diagnostic peritoneal lavage (DPL). At pediatric institutions, truly hemodynamically unstable patients with an abdominal source of bleeding are rare, and therefore the need for a DPL exam is unnecessary. Secondly, several early studies demonstrated that the sensitivity of FAST in hemodynamically stable patients is limited [9–11]. The low sensitivity is explained by the fact that over one-third of children with abdominal injuries will have no free fluid in the abdomen despite evidence of a solid organ injury on CT scan [12].

The threat of radiation reported in the early 2000s caused us to rethink the potential use of FAST in the evaluation of pediatric trauma patients. We sought to determine whether pediatric trauma surgeons formally trained in FAST would potentially limit the number of abdominal CT scans and identify significant injuries in our pediatric trauma population.

1. Materials and methods

1.1. FAST training

Six surgeons were trained and evaluated over an average of 16 months prior to initiation of the study. Training included technical instruction on use of the US machine, and viewing of an instructional video on FAST. A didactic session was held to teach the principles and physics of US and FAST, as well as provide hands-on training in the approach to the FAST exam. Proctored exams occurred in the clinic setting, as well as during trauma resuscitations. Proctoring and further training were provided by a certified pediatric sonographer, or an adult emergency medicine physician certified in ultrasonography. Each surgeon had to perform a minimum of 30 exams, with at least five being proctored and critiqued, and at least five positive for abdominal free fluid. A final competence exam was conducted using pediatric patients with both a positive and a negative exam. Positive exam models were patients with ascites or with a ventriculoperitoneal shunt. Competence was measured using an evaluation method that assessed: detection of known intraabdominal fluid, orientation and accuracy of probe placement in all four exam fields, adequate fanning through three of the fields, acceptable efficiency/time frame to obtain images, and the ability to identify key structures.

Surgeons were trained on an Ultrasonix SP ultrasound machine (with a pediatric-specific probe for smaller children), and used this machine for the duration of the study.

1.2. Study procedures

This study was conducted in an urban pediatric level 1 trauma center that serves a large, multi-state catchment area. Institutional review board (IRB) approval was secured before enrolling patients into the study (IRB# 17320). Patients (age, 0–17 years) requiring a trauma team activation were enrolled prospectively and consecutively from 10/2/09 to 7/31/11. Patients with abdominal imaging (CT or FAST) from a referring hospital were excluded, as were patients with penetrating or open abdominal wounds. Seven surgeons participated in the study, six of which received the training described above, and an additional surgeon who had previous training as well as years of experience performing FAST in adults and adolescents.

For each patient, surgeons initially declared their intention to obtain an abdominal CT by the conclusion of the primary physical exam, and prior to conducting a FAST. Then, upon completing the FAST, the surgeon declared whether the CT could, theoretically, be eliminated. The surgeon recorded this decision on a study data form along with their findings on FAST, and other information. Surgeons had to complete the form prior to CT/surgery, except for the question that asks if the findings on head CT had further influenced decision to obtain an abdominal CT.

For evaluating the diagnostic characteristics of FAST in detecting free fluid or solid organ injury (SOI), the findings

Table 1 Patient and clinical characteristics of cases included for study (FAST performed and adequately recorded) versus eligible cases not included.

	Patients included in study (n = 88)	Eligible patients not included (n = 95)
Age (years), median (IQR)	7 (2–12)	7 (3–12)
Transferred from another hospital	31 (35%)	25 (26%)
Trauma-1 activation [a]	26 (30%)	25 (26%)
Trauma-2 activation	62 (70%)	70 (74%)
Injury severity score, median (IQR)	10 (5-21)	9 (2-18)
GCS ≤ 8 [b]	19 (22%)	15 (16%)
Abdominal AIS ≥ 2	16 (18%)	17 (18%)
Emergent laparotomy	2 (2%)	2 (2%)

[a] There are two levels of trauma activations, where trauma-1 activations are called for more critical cases.
[b] The first GCS recorded in the emergency department.

Table 2 Reasons stated for ordering abdominal CT prior to conducting FAST.

	All cases (N = 88), n (%)	CT “cancelled” (N = 42), n (%; 95% CI)	Not “cancelled” (N = 46), n (%; 95% CI)	p Value
Mechanism of injury	69 (78%)	36 (86%; 71–95)	33 (72%; 57–84)	0.112
Physical exam	19 (22%)	1 (2%; 0–13)	18 (39%; 25–55)	<0.001
Hemodynamically unstable	4 (5%)	2 (5%; 1–16)	2 (4%; 1–15)	1.000
Obtunded	14 (16%)	5 (12%; 4–26)	9 20%; 9–34)	0.326
Other:	5 (6%)	3	2	–
Hematocrit of 5	1 (1%)	1	0	–
Known pelvic injury	1 (1%)	0	1	–
Unreliable history	1 (1%)	0	1	–
Hematocrit of 33 without lacerations	1 (1%)	1	0	–
Low blood pressure	1 (1%)	1	0	–
Not recorded	7 (8%)	4	3	–

Comparison of cases in which surgeon subsequently wanted to cancel CT versus cases in which surgeon did not want to cancel. Note: More than one reason could be stated for each case, and this occurred for 25 cases.

on FAST as reported by the surgeon were compared to findings on CT as noted on the radiologist’s report of the CT conducted at the time of initial evaluation. Radiologists were unaware that their reports were being utilized for the study. Note, however, that it is not uncommon for radiologists to exclude mention of insignificant fluid in their reports. This did not pose a problem for estimating sensitivity and negative predictive value (NPV) of FAST because for these parameters, we were most interested in FAST’s ability to detect clinically significant fluid. However, because FAST could potentially detect fluid that is not mentioned on a typical radiologist’s report, this could skew the estimates for specificity and positive predictive value (PPV) in a way that is not clinically meaningful. Hence, for these two parameters, we chose to compare FAST findings to those reported by a second radiologist who independently reviewed the CT images for the study in a blinded fashion, noting any fluid, significant or not.

At the completion of the study, the surgeons and pediatric emergency medicine physicians (attendings and fellows) were surveyed about the utility of FAST in the setting of pediatric trauma, using an anonymous online survey tool.

1.3. Data analysis

Data were analyzed using Stata 12.1 (StataCorp, College Station, TX). Summary statistics were presented as proportions with 95% confidence intervals (CI), medians with interquartile range (IQR), or as means with 95% CI. Tests for differences in medians were conducted using the Wilcoxen test (or Kruskal–Wallis for multiple comparisons). Tests for differences in means were conducted using t-test (or ANOVA for multiple comparisons), after transformation of data values if distributions were considered non-normal. Post hoc comparisons were conducted using Tukey–Kramer method. Tests for association were conducted using Pearson ^{2} or Fisher exact method. Statistical differences were considered significant if $p < 0.05$.

2. Results

During the study period, 676 children required activation of the trauma team for evaluation of traumatic injury. Of these, 140 presented with prior abdominal imaging at an outside facility, and were excluded for analysis. Of the remaining 536 cases, 183 had potential abdominal trauma, as indicated by planned use of abdominal CT during initial evaluation, and not having open or penetrating abdominal wound. Out of these 183 cases considered eligible for enrollment into the study, ultrasound was utilized in 128, with FAST conducted and documented adequately in 88, therefore meeting the inclusion criteria for study. Reasons for exclusion could also include: assistance provided to surgeon as a part of ongoing training opportunities, non-surgeon use of ultrasound machine, and equipment malfunction. No differences in patient and clinical characteristics were observed between these 88 cases and the remaining 95 eligible cases not included (see Table 1). However, there was an association between the specific surgeon attending the trauma activation and whether a FAST was adequately performed and recorded ($p < 0.001$), with the proportion of eligible cases meeting inclusion criteria ranging from 11% of cases attended to 83% of cases attended.

For the 88 cases included for study, Table 2 shows the reasons chosen by the surgeon for ordering an abdominal CT, as recorded just prior to performing the FAST exam. The most common reason was mechanism of injury (78% of cases), followed by findings on physical exam (22%), then patient’s mental status (obtunded; 16%). Hemodynamic instability was an uncommon reason likely due to the paucity of such cases. More than one reason was stated for 28% of cases.

The sensitivity, specificity, PPV, and NPV of FAST for detecting free fluid were assessed by comparing to CT scan. Table 3A lists these values for each of the four anatomic fields interrogated by the FAST exam, as well as combined for overall values. Values for sensitivity and PPV were

Table 3 Diagnostic characteristics of FAST for free fluid as compared to CT (n = 75).

Region	Sensitivity	Specificity	PPV	NPV	Inconclusive FAST exam [a]
A. Comparing to free fluid on CT					
Overall	8/22 (36%)	40/48 (83%)	7/13 (54%)	45/58 (78%)	4
Right upper quadrant	4/11 (36%)	56/61 (92%)	5/6 (83%)	58/65 (89%)	4
Pericardial	NA (0 cases)	66/75 (88%)	0/1 (0%)	66/66 (100%)	8
Left upper quadrant	4/10 (40%)	58/62 (94%)	4/5 (80%)	61/67 (91%)	3
Pelvis	5/18 (28%)	44/51 (86%)	4/9 (44%)	50/62 (81%)	4
Ignoring minimal pelvic fluid on CT					
Overall	7/14 (50%)	51/60 (85%)	7/13 (54%)	51/58 (88%)	4
Pelvis	5/10 (50%)	56/63 (89%)	4/9 (44%)	57/62 (92%)	4
B. Comparing to free fluid or SOI on CT					
Overall	7/16 (44%)	49/58 (85%)	7/13 (54%)	49/58 (84%)	4

[a] Inconclusive FAST exams were not counted toward positive nor negative FAST exam findings.

generally lower than those for specificity and NPV; though it should be noted that due to the paucity of positive cases in the study (as determined by CT), estimates for sensitivity and PPV are more affected by cases with inaccurate FAST findings. When minimal fluid in the pelvis (a region known to frequently collect clinically-insignificant fluid) was not counted toward positive CT cases, the overall sensitivity of FAST improved from 36% to 50%, as well as the sensitivity of the pelvic field (28% to 50%). In general, the overall accuracy of FAST appears better for the right and left upper quadrants than for the pericardial and pelvic fields. For each of the four fields, we queried the surgeons about their confidence in the result of the exam. For each field, the surgeon could indicate positive, negative, or inconclusive findings. If positive or negative, the surgeon then recorded his/her confidence of their finding on a 1–5 scale, with 5 representing the highest level of confidence. As shown in Table 4, there was a significant effect of field of view on the surgeon's confidence level (p = 0.025). The pericardial view had the lowest mean confidence score, though only statistically different from the RUQ according to post hoc analysis. This view also had the most cases with inconclusive findings. Surgeons appeared most comfortable with the right and left upper quadrant views.

Free fluid detection on FAST was also assessed in relation to the presence of either free fluid or solid organ injury (SOI) on CT (Table 3B). There were only two cases in this study that were positive for SOI on CT without mention of free fluid. For all 16 cases with a SOI or free fluid detected on CT (excluding minimal pelvic fluid), 7 were positive for fluid on FAST, suggesting a sensitivity of 44%. Of the 58 cases without SOI or significant free fluid on CT, FAST was negative for fluid in 49, suggesting a specificity of 85%.

After conducting the FAST exam, the surgeon would have elected to cancel the abdominal CT) in 42 (48%) of cases (Table 5). Of these 42 cases, the FAST exam was negative in 40 (95%), inconclusive in 1 (2%), and positive for 1 (2%) case. The reason stated for wanting to cancel the CT in the positive case was to transport the patient directly to the operating room (OR) from the emergency department (ED). This patient was hypotensive in the ED and had a large amount of free fluid on FAST. The child was resuscitated and then taken to CT. Her injuries included a severe TBI, a liver laceration, and mesenteric tears. She was taken to the OR for control of the bleeding from her mesentery and eventually died of her head injury.

In 40 cases the FAST was negative and the surgeon indicated they would have cancelled the CT. On 13 occasions the surgeon actually cancelled the CT based upon the FAST, physical exam, and history. Of the remaining 27 cases where the CT would have been cancelled, the FAST exam had a false-negative rate of 15%.

When we compared the cases where the CT would have been cancelled to the cases where it was not cancelled, three characteristics separate the groups. In the cases where the CT would have been cancelled the patients were younger, the ISS was lower, and the abdominal injury severity scores were lower. Interestingly, patients with an isolated head injury were evenly represented in both groups (Table 5).

Another aim of the study was to determine if FAST helped to identify abdominal injuries of significance, which we defined as injuries requiring laparotomy or a blood transfusion. In our study cohort of 88 patients, 8 (9%) had significant abdominal injury—all 8 received blood

Table 4 Surgeon's level of confidence for FAST exam findings.

Field	Inconclusive cases	Confidence level, mean (95% CI)
Left upper quadrant (n = 83)	5	4.75 (4.62–4.88)
Pelvis (n = 84)	4	4.64 (4.51–4.77)
Pericardial (n = 80)	8	4.55 (4.42–4.68)
Right upper quadrant (n = 84)	4	4.85 (4.71–4.98)

Surgeons scored their confidence on a scale of 1 to 5, with 5 representing highest level of confidence.

Table 5 Characteristics of cases with abdominal CT cancelled (theoretically) versus cases with CT not cancelled.

	CT "cancelled" (n = 42)	Not "cancelled" (n = 46)	p Value
Age (years), median (IQR)	4 (1–11)	8.5 (3–14)	0.019 *
GCS ≤ 8 (%, 95% CI) [a]	21% (10–37)	22% (11–36)	0.972
Injury severity score, median (IQR)	10 (5–14)	12 (6–25)	0.044 *
Head AIS ≥ 3 (%, 95% CI)	43% (28–59)	33% (20–48)	0.321
Isolated head injury (%, 95% CI) [b]	14% (5–29)	17% (8–31)	0.691
Abdominal AIS ≥ 3 (%, 95% CI)	5% (1–16)	24% (13–39)	0.015 *
Emergent laparotomy	2% (0–13)	2% (0–12)	1.000
iSTAT hematocrit, median (IQR) [a]	36 (33–38)	36 (34–40)	0.453
Receiving blood in the ED (%, 95% CI)	5% (1–16)	9% (24–21)	0.678

* Indicates statistical significance ($p < .05$).
[a] Recorded in the emergency department.
[b] Having a head AIS ≥ 3 and no other region AIS > 1.

transfusion, and 3 had abdominal surgery. Of the three surgical cases, all had a positive FAST exam. Of the other five significant cases (which required blood transfusion only), four had a negative FAST exam, and for one of these, the surgeon would have elected to cancel CT. Hence, this was considered a missed case (i.e., would have been missed if the surgeon could have actually cancelled CT). The other cases included a grade 5 liver laceration, two grade 3 liver lacerations, and a grade 3 splenic laceration.

The last question to the surgeon on our data sheet for the study was whether the FAST had any other benefit to the examiner. On nine occasions an answer was given for this question. The most common phrasing used to answer this question was characterized as "reassurance." The surgeon either felt that the physical exam was negative and was "reassured" by a negative FAST, or on one occasion the abdomen was tender and the decision to get a CT was reinforced by a positive FAST.

Results from the survey (Table 6) conducted at the conclusion of the study suggest a more favorable view by pediatric emergency medicine physicians than surgeons for the implementation and routine use of FAST for pediatric trauma. After the study was closed, we followed the surgeon's ongoing use of US. The use rate decreased from 70% of potential abdominal trauma cases to 30% in the 6 months after the conclusion of the study.

Table 6 FAST exam survey responses (% of responders with positive response).

Question	Surgeon (n = 7)	Pediatric emergency medicine physician (n = 15)
Should FAST be routinely utilized for pediatric trauma?	43%	80%
Is FAST useful for a select subset of patients?	100%	80%
Compared to how you felt prior to the study, are you more impressed with the utility of FAST?	43%	47%
Do you recommend that pediatric level I centers have an ultrasound machine in the trauma bay?	72%	93%

3. Discussion

The interest in emergency US in pediatric EDs has increased dramatically in recent history. A survey of children's hospitals and pediatric emergency medicine training programs revealed that 96% of responders reported having a dedicated US machine in the ED but only 27% reported having a program for the clinical use of US. It is concerning that of those who use US only 52% of the institutions had established credentialing criteria to grant US privileges [13]. The American College of Surgeons Committee on Trauma recognizes the FAST exam as an adjunct to the evaluation of the pediatric patient, but despite its increased popularity, the use of FAST in children is not ubiquitously employed at all pediatric trauma centers nor is its role in the evaluation of an injured child clearly understood [14].

Despite the common use of FAST at adult and pediatric trauma centers it is not clear that rigorous standards exist for either verification of skills or maintenance of proficiency. Most FAST exams in the United States are performed by surgeons or surgical residents [8]. Interestingly, the Accreditation Council for Graduate Medical Education (ACGME) requires competency with bedside ultrasound of emergency medicine trainees but not of general surgery residents [15]. A 2010 survey of Canadian general surgery residents indicated that only 39% of them felt comfortable making treatment decisions based on their FAST exams and 12% were very uncomfortable with the exam [16]. A 2006 American survey declared that 68% of general surgery residents received didactic training while 79% had hands-on training [17]. The difference suggests that some programs teach FAST with an "on-the-job" training approach. While one can confidently state that the presence of FAST training programs is not consistent or universal, it is distinctly unclear whether American trauma centers have systems that routinely review the quality of the exams performed as part of their continuous quality improvement process.

With our study we committed to a formal training program and regular review of the exams. The individual who performs the FAST could be a radiologist, an ultrasound technician, an emergency room physician, or a trauma surgeon. All of these models have been employed, and at our institution we elected to train the pediatric trauma surgeon in this role. The training program involved a didactic session, a minimum of 30 practice exams, and a final competence exam performed with model patients and an experienced ultrasonographer as the proctor. With this standard, it took us over a year to train all of our surgeons.

After the training was completed we routinely coached the surgeons on their skills and performed quality assessment of the exams at our monthly trauma performance improvement meeting. Even with this degree of commitment, the surgeons never felt they became expert level ultrasonographers. Between 4% and 10% of the time the exams were judged to be inconclusive and the surgeon's especially struggled with the pericardial and pelvic views. Perhaps most telling is that even though the majority of our surgeons felt that a pediatric level 1 trauma center should have a US machine their use of the machine dropped from 70% of the potential activations to 30% within 6 months after the conclusion of the study.

Our primary goal was to determine if we could use US as a screening test to improve the selectivity of our CT use. The ideal screening test would have a high sensitivity, and therefore a limited number of false-negative tests. Sensitivity rates for pediatric FAST exams have historically been between 30% and 50% [9–11]. A more recent series of 431 patients found a sensitivity of 52% and that a negative FAST exam did little to aide in decision making [18]. In a 2007 meta-analysis of pediatric blunt trauma patients the authors concluded that abdominal ultrasound only has a modest sensitivity for the prediction of hemoperitoneum, and again that a negative ultrasound examination has questionable utility [18]. In our experience the sensitivity of the FAST exam for significant amounts of fluid was 50% and the specificity was 85% (Table 3).

Our hypothesis was that FAST could theoretically decrease the number of CT's performed. Indeed the surgeons indicated that nearly one-half of the time the US would have influenced them to eliminate the CT. The patients who did not have the CT cancelled were more likely to be older, have a higher ISS, and have a higher abdominal injury score (AIS). For those who would have had the CT cancelled the limited sensitivity of US would have missed two significant intraabdominal injuries (Table 5). When queried as to why the surgeon would eliminate the scan, the most typical response was that the exam provided reassurance and the surgeon felt that there was a low probability of an abdominal injury based upon the physical exam. Considering the low sensitivity, the poor utility of a negative exam, and the threat of a missed injury it seems that this reassurance might be misleading.

In conclusion, if a pediatric trauma center is to consider the use of FAST as part of their trauma evaluation, they must appropriately train the individual performing the exam and develop a method for maintaining high quality and reliable exams. In our study, the sensitivity of FAST was limited and consistent with other reports in the literature. A negative exam offered reassurance to the surgeon; however, this reassurance may be characterized as suspect, since the test offered several false-negative examinations. Thirdly, the true-positive exam in a hemodynamically unstable patient is a rare occurrence in pediatric trauma surgery and may not justify the cost and educational investment in pursuing an ultrasound program. These patients may be better served with intraoperative resuscitation or volume resuscitation followed by a CT scan in those patients who have been stabilized. Lastly, the enthusiasm for the FAST exam in our pediatric institution waned after the conclusion of our study. Without the regular supervision of the study the surgeons reverted to a practice that did not routinely include FAST.

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