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Role of FAST or Abdominal Ultrasound to Limit CT Imaging in Evaluation of the Pediatric Abdominal Trauma Patient

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Abstract Blunt abdominal trauma (BAT) can produce serious intra-abdominal injuries (IAI) in children. An early diagnosis is important to reduce morbidity and mortality, but pediatric patients sustaining BAT rarely require an operative intervention. Although the computed tomography (CT) scan is currently the best diagnostic tool to detect IAI, increased awareness of the risks of radiation exposure, high costs, and low utility has led to efforts to reduce the use of CT in the workup of pediatric trauma patients. Focused assessment with sonography for trauma (FAST) is an accurate, noninvasive, and rapid method of evaluating patients with BAT. Many institutions have developed criteria using physical signs and common biochemical markers of abdominal injury in combination with FAST as a screening tool to prevent the overuse of CT in children. We review the use of FAST and scoring systems as tools to limit CT imaging in the evaluation of the pediatric abdominal trauma patient.

Keywords FAST · Abdominal ultrasound · Pediatrics · Children · Trauma · CT · Abdominal trauma

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Introduction

In the USA, trauma is the leading cause of death in children [1]. It is estimated that 10 % of all pediatric deaths are due to abdominal injuries [2], with 90 % of these injuries caused by blunt trauma [3]. Mechanisms are predominantly motor vehicle accidents, falls, and intentional injuries [4•]. Blunt abdominal trauma (BAT) can produce solid organ injury to the spleen, liver, and kidneys, as well as major vascular or hollow viscus injury. An early diagnosis of the nature and extent of abdominal injuries is important to reduce morbidity and mortality.

Patients sustaining BAT that present with hemodynamic instability unresponsive to resuscitative attempts require emergent laparotomy. This is rare, however, as more than 90 % of pediatric patients with intra-abdominal injuries (IAI) caused by BAT will be treated nonoperatively [5]. The current standard for evaluation of the stable pediatric patient with BAT consists of history, physical examination, screening laboratory values, and computed tomography (CT) scan. Nevertheless, obtaining a reliable history and physical examination can be challenging in an injured child with decreased mental status, distracting injuries, and associated fear and apprehension. CT scan is currently the best diagnostic tool in terms of sensitivity and specificity to detect IAI [4•, 6]. The cons to widely using CT scanning for every trauma is the following. Children are more sensitive to radiation-induced cancer, which limits the utility of CT as a screening tool [7–9, 10•]. Also, CT is expensive and may be hampered by patient movement, requiring sedation or general anesthesia. Lastly, even though CT is considered the best imaging test for diagnosing IAI, fewer than 15 % of pediatric patients sustaining blunt trauma are found to have IAI on CT, with most of these injuries ultimately being managed nonoperatively [11]. This

Table 1 Effectiveness of screening tools for IAI in children following BAT (adapted from Sola et al. [12••])

	FAST	FAST + AST/ALT	*P* value
Sensitivity	50.4	88.1	<0.001
Specificity	91.2	98	<0.001
Positive predictive value	68	93.7	<0.001
Negative predictive value	83.1	96.1	<0.001
Accuracy	80.1	95.5	<0.001

increased awareness of the risks of radiation exposure, high costs, and low utility has led to efforts to reduce the use of CT in the workup of pediatric trauma patients.

Recently, multiple institutions have evaluated factors associated with IAI following BAT in an effort to generate screening tools that could be applied to limit the use of CT scans in the pediatric population [12••, 13, 14]. Focused assessment with sonography for trauma (FAST) is an accurate, noninvasive, and rapid method of evaluating adults with BAT. In children, however, the use of FAST as a screening tool has been controversial because of the reported low negative predictive value (NPV) in children with BAT [15,16, 17•]. Other signs of abdominal injury have been used in combination with FAST as an effective screening tool to identify those who would benefit from CT. Many institutions have developed criteria to prevent the overuse of CT in children and have reported their experiences. Herein, we review the most recent reports regarding the use of FAST and scoring systems as screening tools for IAI and thereby determine those patients who would benefit from CT scan.

Screening Tools and Scoring Systems

In 2009, Sola et al. [12••] retrospectively analyzed our institution's experience by comparing the use of FAST and FAST plus elevated aspartate aminotransferase (AST) or alanine aminotransferase (ALT) levels against the gold standard of CT scan for the detection of IAI following BAT in 400 pediatric patients. The sensitivity, specificity, positive predictive value (PPV), NPV, and accuracy of FAST and FAST plus elevated AST/ALT (either >100 IU/l) were each assessed. As depicted in Table 1, the use of FAST plus AST/ALT has been an effective screening tool at our institution with an NPV of 96.1 %.

Also in 2009, Karam et al. [13] reported their experience using the Blunt Abdominal Trauma in Children (BATiC) score to predict the need for CT scan. The BATiC was developed from a retrospective analysis of 147 pediatric trauma patients assessing factors associated with IAI and ultimately assigning items a value based on the relative

Table 2 Blunt abdominal trauma in children score (Adapted from Karam et al. [13])

	BATiC value for item
Abnormal abdominal Doppler US	4
Abdominal pain	2
Signs of peritoneal irritation	2
Hemodynamic instability	2
AST >60 IU/l	2
ALT >25 IU/l	2
WBC count >9.5 g/l	1
LDH >330 IU/l	1
Lipase >30 IU/l	1
Creatinine >50 μg/l	1

The Blunt Abdominal Trauma in Children (BATiC) score is calculated by summing the points for each item. The score range is 0–18

Table 3 High-risk clinical variables for intra-abdominal injury used in the clinical prediction rule (adapted from Streck et al. [14])

Hypotension (for age)
Abnormal abdominal exam (distention, tenderness, peritonitis, or contusion)
AST >200 U/l
Microhematuria (>5 RBCs per high power field)
Hematocrit <30 %
Amylase >100 U/l

adjusted odds ratio after statistical analysis. As shown in Table 2, factors include abnormal FAST exam, abdominal pain, peritonitis, hemodynamic instability, and elevated laboratory values including white blood cell (WBC) count, AST, ALT, lactate dehydrogenase (LDH), lipase, and creatinine. In hemodynamically stable children with a negative FAST and a BATiC score ≤7, IAIs are very unlikely, and a CT scan could be avoided. Using this scoring system, the BATiC negative likelihood ratio was 0.10, considered a conclusive decrease in the likelihood of IAI. The initial laboratory workup had a negative likelihood ratio of 0.53, with FAST alone having a slightly better negative likelihood ratio of 0.28. BATiC, a score that combined physical examination findings, selected laboratory tests, and FAST, was much more effective in predicting significant IAI than each item alone.

In 2012, based on their review of the literature, Streck et al. [14] also created a clinical prediction rule to identify BAT patients at low risk for IAI. From their review, the presence of any one of six variables (Table 3) was considered predictive of IAI [3, 18]. IAIs were considered present if a spleen, liver, pancreas, diaphragm, kidney/urinary tract, or gastrointestinal tract injury was identified

Fig. 1 FAST examination performed in the trauma resuscitation area with a portable ultrasound unit. Reprinted from Sola et al. [12••], copyright 2009, with permission from Elsevier

by CT or at the time of operative exploration. Based on 97 pediatric trauma patients who had abdominal CT, their clinical prediction rule would have identified patients with IAI correctly with a sensitivity of 94.1 % and an NPV of 98.8 %.

Conclusions

Blunt trauma accounts for 90 % of pediatric injuries [4•]. Although not as common as isolated traumatic brain injury, abdominal trauma is a leading cause of mortality and morbidity in children [19]. Diagnosis of IAI can be challenging in pediatric patients. This is compounded by the need to make an accurate and timely diagnosis since missed and delayed injuries have severe consequences. The tools at the surgeon's disposal for making the diagnosis are knowledge of the mechanism of injury, physical examination, and several imaging modalities. Few consensus guidelines exist for evaluation of BAT in children, and there is great disparity across the US. In recent years however, similar protocols have been developed at multiple institutions for identifying those patients at high risk of IAI who would benefit for CT.

Altered mental status, distracting injuries, as well as nonverbal and uncooperative children may limit the evaluation of pediatric patients with BAT. The presence of hypotension, abdominal tenderness, or femur fracture in pediatric BAT patients has been prospectively shown to be predictive of IAI [3]. Hemodynamically unstable children with a positive FAST require emergent laparotomy without further imaging or diagnostic workup [20]. Yet, whether further imaging is warranted remains controversial in hemodynamically stable pediatric patients without significant mechanism or physical exam findings following BAT.

On one hand, since most injuries following BAT are managed nonoperatively [11], CT can safely reduce the number of nontherapeutic laparotomies. However, CT can be unreliable with blunt bowel and mesenteric injuries in children [21–23]. Furthermore, there is growing concern about the overuse of CT in BAT and its implication for pediatric patients. A recent study found that only 5.8 % of all patients with a positive abdominal CT for IAI ultimately underwent an operative exploration [24]. This relatively low yield must be weighed against the lifetime risk of radiation-induced cancer. It is estimated that the risk of a fatal cancer from radiation is 1 per 1,000 pediatric CT scans [8, 10•] or 0.18 % lifetime for abdominal CT in a 1-year-old child [8]. This risk may be potentially small for an individual child, but given the popularity of CT scans over a lifetime, the risk is cumulative and certainly bears an epidemiologic significance. Children are thought to be at greatest risk for radiation-induced malignancy because of their relatively small size per radiation dose and increased life expectancy relative to adults [25]. Lastly, CT requires the administration of intravenous (IV) contrast with the potential risk of contrast-induced nephropathy and can also require sedation of uncooperative patients.

FAST has many characteristics that make it appealing as a screening test for IAI following BAT in children. It is rapid, easy to perform, and portable. FAST can be obtained in the resuscitation area shortly after the primary survey as surgical residents, trauma fellows, and trauma surgery attendings can readily perform them. Patients are scanned in the supine position, and views of Morrison's pouch, the perisplenic region, pelvis, and pericardium are evaluated for the presence of free intraperitoneal fluid (Fig. 1). In addition, FAST provides imaging without subjecting the patient to sedation, IV contrast, or ionizing radiation.

A recent survey regarding the use of FAST at adult and pediatric trauma centers showed that 96 % of adults-only institutions use FAST, while only 15 % of children's hospitals utilize it [26]. Also, in most centers that use FAST, the trauma surgeons perform the examination [26]. It is clear that the use of FAST is common practice in modern trauma centers, and it is unlikely to go away. It has been regarded as the future stethoscope and is becoming a modality that is taught in both surgical and emergency residency programs. Nevertheless, although FAST is a regular part of the adult trauma experience, its use remains a rarity at pediatric trauma centers.

Liver transaminases are elevated in pediatric BAT patients with IAI even in the absence of hepatic injury [27].

Furthermore, elevated transaminases have been prospectively shown to be an important predictor of IAI in pediatric blunt trauma patients [3]. Combining FAST with liver transaminases significantly improves the utility of this modality (Table 1) [12••].

Another consideration is that injuries missed by abdominal FAST are perhaps inconsequential. Soundappan et al. [28••] reported a study of trauma patients evaluated with FAST. Of all missed injuries, all were minor and managed nonoperatively. Coley et al. [15] similarly showed that of their pediatric trauma injuries that were missed by FAST, all were minor and could have been managed with simple observation. Certainly, a CT scan will detect minor splenic, liver, and renal lacerations where FAST will not, but in the low-risk patient, it may not be mandatory to define these injuries.

FAST is especially useful and highly accurate with 100 % sensitivity and specificity in hypotensive pediatric patients with BAT [20]. The utility of FAST alone in hemodynamically stable children with BAT has shown conflicting results [2, 15, 16, 20, 28••, 29•]. However, its use in combination with other established signs of IAI could be a very effective screening tool for those who would benefit from CT imaging [12••, 13, 14]. As evidenced from our review, multiple institutions have developed a specific system incorporating laboratory values, physical exam findings, and FAST specifically for this purpose, and these systems have been validated as being highly effective in screening pediatric BAT patients at risk for IAI [12••, 13, 14].

It is essential that modern surgeons define guidelines for evaluating and managing the pediatric trauma patient. The question is whether alternative measures can be used to safely limit the number of CT scans performed. Selective imaging is an important consideration to minimize radiation to children, and for time and resource management as well as cost containment. If this is to happen, the modality utilized must prove safe and efficacious. Knowledge of the risk factors that are associated with IAI helps to guide the selective use of CT scanning for detection of IAI. From our review, we conclude that the use of FAST combined with other established signs of IAI is an effective screening tool for those who would require a CT in the hemodynamically stable child following BAT. We recommend that each institution develop a protocol to identify pediatric patients at risk for IAI following BAT, either through analysis of their own experience or by adopting one of the several systems that have been reported. Those patients that do not meet the criteria should be observed. And, as always, the result of a simple score or screening criteria can never replace the clinical judgment of an experienced physician.

Compliance with Ethics Guidelines

Conflict of Interest Casey J. Allen, Jun Tashiro, and Juan E. Sola declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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