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Pediatric FAST and Elevated Liver Transaminases: An Effective Screening Tool in Blunt Abdominal Trauma

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Background. **The current standard for the evaluation of children with blunt abdominal trauma (BAT) consists of physical examination, screening lab values, and computed tomography (CT) scan. We sought to determine if the focused assessment with sonography for trauma (FAST) combined with elevated liver transaminases (AST/ALT) could be used as a screening tool for intra-abdominal injury (IAI) in pediatric patients with BAT.**

Methods. **Registry data at a level 1 trauma center was retrospectively reviewed from 1991–2007. Data collected on BAT patients under the age of 16 y included demographics, injury mechanism, ISS, GCS, imaging studies, serum ALT and AST levels, and disposition. AST and ALT were considered positive if either one was >100 IU/L.**

Results. **Overall, 3171 cases were identified. A total of 1008 (31.8%) patients received CT scan, 1148 (36.2%) had FAST, and 497 (15.7%) patients received both. Of the 497 patients, 400 (87.1%) also had AST and ALT measured. FAST was 50% sensitive, 91% specific, with a positive predictive value (PPV) of 68%, negative predictive value (NPV) of 83%, and accuracy of 80%. Combining FAST with elevated AST or ALT resulted in a statistically significant increase in all measures (sensitivity 88%, specificity 98%, PPV 94%, NPV 96%, accuracy 96%).**

Conclusions. **FAST combined with AST or ALT > 100 IU/L is an effective screening tool for IAI in children following BAT. Pediatric patients with a negative FAST and liver transaminases < 100 IU/L should be observed rather than subjected to the radiation risk of CT.**

Key Words: **FAST; blunt abdominal trauma; children; screening.**

INTRODUCTION

In the United States, trauma is the leading cause of death in children less than 19 y of age [1]. Over 60% of all pediatric trauma deaths are due to motor vehicle injuries alone, resulting in a greater loss of life in children than cancer, heart disease, respiratory conditions, and infections combined. It is estimated that 10% of deaths are due to abdominal injuries [2].

The current standard for evaluation of the pediatric patient with blunt abdominal trauma (BAT) consists of physical examination, screening laboratory values, and computed tomography (CT) scan. However, obtaining a history and reliable physical examination findings can be challenging in an injured child. Furthermore, given that children, especially those younger than 10 y of age, are generally more sensitive to ionizing radiation [3], concerns relating to radiation-induced cancer limit the utility of CT as a screening tool [4–6].

Focused assessment with sonography for trauma (FAST) is an accurate, noninvasive, and rapid method of evaluating adult patients with BAT. In children, however, the optimal use of FAST is controversial and has yet to be determined. Some question the use of FAST as an appropriate screening tool due to reported low negative predictive value (NPV) in children with BAT [7–11]. We sought to determine the value of FAST as a screening tool employed at a major urban freestanding trauma center for over a decade in pediatric patients suffering abdominal trauma. We hypothesized that

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combining elevated liver transaminases with FAST would increase the utility of this imaging modality.

METHODS

Ryder Trauma Center (RTC), located at the University of Miami/Jackson Memorial Medical Center, is the only level 1 trauma center serving the 2.4 million residents of Miami-Dade County, Florida. On average, 4300 trauma patients per year are evaluated at RTC. Approximately 10% of all patients evaluated and treated at this center are injured children.

We performed a retrospective review of the trauma registry database in order to analyze all patients less than 16 y of age with BAT evaluated at RTC from 1991 to 2007. The study was approved by the Institutional Review Board at the University of Miami Miller School of Medicine. The data collected consisted of patient age, gender, race, mechanism of injury, injury severity score (ISS), Glasgow coma score (GCS), diagnostic imaging studies, serum alanine aminotransferase (ALT), aspartate aminotransferase (AST) levels, and disposition.

The standardized FAST protocol used at RTC has been previously described [12]. Briefly, FAST was performed in the resuscitation room by certified technologists and radiologists in the early part of the study, but in more recent years, almost exclusively by surgical residents, trauma fellows, and trauma surgery attendings. Patients were scanned in the supine position and views of the pericardium, bilateral subphrenic spaces (when performed by radiology), Morrison's pouch, perisplenic region, and pelvis were examined for the presence of free intraperitoneal fluid (Fig. 1). Visualized solid organ injuries were noted and recorded. The trauma surgery attending or fellow interpreted real-time US images. Radiology consultation was obtained for equivocal cases. The presence of free intraperitoneal fluid or solid organ injury was considered a positive result. FAST was considered negative if the above were absent.

CT scans were performed with oral and intravenous contrast on a four-channel multi-detector scanner. Oral contrast was mixed with water and administered by mouth or nasogastric tube (Fig. 1). Non-ionic contrast was delivered through a peripheral intravenous (IV) catheter using a power injector. Three-dimensional reconstructions were obtained from axial images using a standard workstation. CT scans were interpreted by attending radiologists.

FIG. 1. FAST examination performed in trauma resuscitation area with portable ultrasound unit. Note seatbelt sign across upper abdomen and patient drinking oral contrast for CT scan. (Color version of figure is available online.)

FAST and FAST plus elevated AST or ALT levels (either >100 IU/L) were compared against the gold standard of CT scan. The sensitivity, specificity, positive predictive value (PPV), NPV, and accuracy for FAST and FAST plus elevated AST/ALT were calculated using standard formulas. Student's t-test was used to compare mean ISS scores. Z-test was used to compare sample populations. Statistics used to describe our cohort include mean, standard deviation, and range. A P value < 0.05 was considered statistically significant.

RESULTS

Overall, 3171 patients less than 16 y of age with BAT were identified in the 17-y study period. A total of 1008 (31.8%) patients had a CT scan during their trauma evaluation, while FAST was performed in 1148 (36.2%), and 497 (15.7%) patients received both. Of the 497 patients evaluated with both CT and FAST, 400 (87.1%) also had serum liver transaminases (AST/ALT) measured.

The demographics and clinical characteristics of the 400 patients who had all three diagnostic tests (CT,

TABLE 1

Demographics and Clinical Characteristics.

	Number (%)	Mean ISS (std)	*P* value
Age (y)			
0-4	90 (23)	13.4 (12.3)	0.01 *versus* 10-15
5-9	126 (32)	14.8 (12.3)	0.06 *versus* 10-15
10-15	184 (46)	17.5 (12.4)	
Sex			NS
Male	251 (63)	16.0 (13.1)	
Female	149 (37)	15.4 (11.4)	
Race/ethnic			NS
Black	211 (53)	15.9 (12.6)	
White	103 (26)	15.8 (11.5)	
Hispanic	85 (21)	15.8 (13.4)	
Mechanism			NS
BAT	396 (99)	15.8 (12.5)	
MVC	147 (37)	15.0 (13.0)	
PHBC	138 (35)	16.9 (13.1)	
Fall	35 (9)	12.3 (9.6)	
Bicycle	33 (8)	14.6 (12.2)	
ATV/MC	24 (6)	20.6 (10.8)	
Assault	8 (2)	21.3 (18.7)	
Other	11 (3)	13.8 (9.9)	
BAT+penetrating	4 (1)	9.5 (7.0)	
GSW	1		
SW	1		
Other	2		
Disposition			
ICU	235 (59)	19.7 (12.4)	<0.001 *versus* ward, home
OR	44 (11)	19.0 (12.4)	<0.001 *versus* ward, home
Ward	102 (26)	6.4 (5.6)	<0.001 *versus* home
Home	19 (5)	1.7 (1.5)	

ISS = injury severity score; std = standard deviation; y = years; NS = not significant; BAT = blunt abdominal trauma; MVC = motor vehicle crash; PHBC = pedestrian hit by car; ATV = all terrain vehicle; MC = motorcycle; GSW = gunshot wound; SW = stab wound; ICU = intensive care unit; OR = operating room

FAST, AST/ALT) are shown in Table 1. The oldest record selected dated to July 1994. The mean GCS was 12.1 ± 4.1 for the cohort. Overall, 18 patients died in the intensive care unit (ICU) and one patient died in the operating room (OR) for an in-hospital mortality of 4.8%. The average patient age was 8.6 ± 4.5 y (range infant to 15 y). Patients 10 y of age and older were more commonly injured (46%) than those 5 to 9 y of age (32%) or less than 5 y (23%). Males outnumbered females nearly two to one (63% *versus* 37%). African Americans (53%) and Hispanics (21%) accounted for the majority of our pediatric trauma patient population. Four patients sustained some form of penetrating trauma in addition to BAT. Motor vehicle crashes (MVC) were the most common mechanism (37%), followed by pedestrians hit by car (PHBC). More than half of the patients were transferred to the ICU from the trauma resuscitation area, and only 5% were discharged home.

The mean ISS for the entire cohort was 15.8 ± 12.4. There was no significant difference in mean ISS between sex, race, or mechanism. However, patients age 10–15 had higher mean ISS compared with ages 0–4 and 5–9 ($P = 0.01$ and 0.06, respectively). Patients requiring ICU or OR had higher ISS compared with patients transferred to the ward or discharged ($P < 0.001$). Similarly, ISS of patients admitted to ward was significantly higher than those discharged (6.4 *versus* 1.7, $P < 0.001$). Patients sustaining injuries due to assault or motorcycle crashes had the highest average ISS (21.3 and 20.6, respectively).

Of the 400 patients analyzed, 135 had positive CT scans identifying 166 injuries (Table 2). The most commonly injured solid organs were liver (n = 59, 35.5%) and spleen ($n = 53$, 31.9%). FAST was negative in 67 patients with 70 injuries. FAST examination was negative in patients with 25 liver and 18 splenic injuries. With few exceptions, most of these patients had grades I and II injuries and, in many cases, 1 cm or less in size and not associated with free fluid. FAST was negative in adrenal, renal, and pancreatic injuries that consisted of small retroperitoneal hematomas or intraparenchymal hemorrhages. Similarly, FAST was negative in patients with pelvic fractures that were not associated with intraperitoneal fluid.

TABLE 2

Positive Computed Tomography Injuries.

	FAST +	FAST–	Total
Liver	34	25	59
Spleen	35	18	53
Kidney	10	8	18
Adrenal	1	6	7
GI	5	4	9
Pancreas	2	2	4
Pelvic fracture	4	5	9
Free fluid	5	2	7
Total	96	70	166

GI = gastrointestinal

TABLE 3

Statistics of FAST and FAST + Elevated AST/ALT.

	FAST	FAST + AST/ALT	*P* value
True positives	68	89	
True negatives	330	293	
False positives	32	6	
False negatives	67	12	
Sensitivity	50.4	88.1	<0.001
Specificity	91.2	98.0	<0.001
Positive predictive value	68.0	93.7	<0.001
Negative predictive value	83.1	96.1	<0.001
Accuracy	80.1	95.5	<0.001

In our pediatric trauma patients, FAST had an accuracy of 80.1% (Table 3). FAST was positive in 68 of the 135 patients with positive CT scans for a sensitivity of 50.4%. FAST was negative in 330 of the 362 patients with negative CT scans for a specificity of 91.2%. The PPV and NPV of FAST examination were 68% and 83.1%, respectively.

Combining FAST with elevated AST or ALT resulted in a statistically significant increase in all measures ($P < 0.001$). FAST plus elevated AST/ALT significantly increased accuracy to 95.5%. If FAST was positive, or if either AST or ALT were greater than 100, sensitivity increased to 88% with 89 true positives of 101 patients with positive CT scans. Similarly, specificity increased to 98% with only six false positives. Furthermore, PPV and NPV significantly increased to 93.7% and 96.1%, respectively.

DISCUSSION

From 2000 to 2006, 12,175 children died per year in the U.S. due to unintentional injuries [13]. Transportation related accidents were the leading cause of death, but injuries due to falls were the leading cause of the 9.2 million annual nonfatal injuries in American children. Blunt trauma accounts for 90% of pediatric injuries [14]. Although not as common as isolated traumatic brain injury, abdominal trauma is a leading cause of mortality and morbidity in children [15].

Diagnosis of intra-abdominal injury (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 due to preventable morbidity and mortality. The tools at the surgeon's disposal for making the correct diagnosis are knowledge of the mechanism of injury, physical examination, and diagnostic imaging modalities.

Mechanisms of injury well known to be associated with IAI include MVC with unrestrained, lap belted, or ejected occupants, PHBC, and falls > 10 feet [16–18]. Lap-belt or seatbelt syndrome involves rapid deceleration and compression of the intestine against the spine, resulting in transverse abdominal ecchymoses (Fig. 1), intestinal perforation, and lumbar spine (Chance) fracture. Patients with abdominal pain or tenderness and a seatbelt sign following MVC are associated with a 3- and 13-fold increase in IAI and gastrointestinal injury, respectively [19]. Similarly, bicycle handlebar injuries to the abdomen are associated with small bowel and pancreatic trauma [20].

Decreased mental status, distracting injuries, as well as nonverbal and uncooperative children due to fear and apprehension may limit the physical examination in pediatric patients with BAT. However, the presence of hypotension, abdominal tenderness, or femur fracture in pediatric BAT patients has been prospectively shown to be predictive of IAI [16]. In addition, hemodynamically unstable children with a positive FAST require emergent laparotomy without further imaging or diagnostic workup [21]. However, in hemodynamically stable pediatric patients with significant mechanism or physical exam findings following BAT, further imaging is warranted to localize and determine the extent of IAI.

From its first use in the 1980s until today, CT remains the definitive imaging modality for pediatric BAT patients in the U.S. [22–25]. CT is highly sensitive and specific for solid organ injuries in children [24]. Since most of these injuries are managed nonoperatively, CT is credited with safely diminishing the intensity of care by reducing the number of nontherapeutic laparotomies. In addition to being noninvasive, CT is presently widely available in most centers, and provides full-body imaging in minutes.

However, CT is not without limitations, and can be unreliable with blunt bowel and mesenteric injuries in children [26–28]. Furthermore, there is growing concern of the overuse of CT in BAT and its implication for pediatric patients. A recent study found that although abdominal CT was positive in 310 of 897 pediatric BAT patients, only 18 (2%) required surgical exploration [29]. This relative low yield, which is even lower in young children with mild to moderate injuries [6], must be weighed against the lifetime risk of cancer from CT radiation. It is estimated that the risk of a fatal cancer from radiation is 1 per 1000 pediatric CT scans [5, 30] or 0.18% lifetime for abdominal CT in a 1-y old child [4]. However, it is possible to limit radiation exposure from multislice CT by controlling parameters such as scan passes, X-ray tube current, peak voltage, pitch factor, and gantry rotation time [30], and all facilities must implement the as low as reasonably achievable (ALARA) concept for CT in children [31]. Lastly, CT requires the administration of IV contrast with the potential risk of contrast-induced nephropathy, and can sometimes require sedation of uncooperative patients.

FAST has many characteristics that make it appealing as a screening test for BAT in children. It is rapid, easy to perform, and portable, without requiring patient transport to a radiology suite. At RTC, exams are obtained in the resuscitation area shortly after the primary survey. In addition, FAST provides imaging without subjecting the patient to sedation, injection of IV contrast, or exposure to ionizing radiation. FAST is especially useful and highly accurate with 100% sensitivity and specificity in hypotensive pediatric patients with BAT [21]. However, the utility of FAST in hemodynamically stable children with BAT is not clear, given the conflicting results of multiple published studies [2, 7–10, 21, 32–42]. Analysis of the studies in which all patients evaluated by FAST were compared with CT criterion standard [7, 8, 10, 33, 36, 38, 40, 41] revealed a wide range for sensitivity (30%–90%), specificity (77%–100%), PPV (59%–100%), and NPV (50%–96%).

Our study is the largest single institution study comparing FAST *versus* CT in pediatric patients with BAT at a level 1 trauma center. Our patient population consisted of mostly minority (74%) males (63%) sustaining transportation related trauma (86%). These patients were moderately injured children, given the mean ISS of 15.8 and high proportion (70%) transferred to the ICU or OR, but had excellent survival (95%). At our center, FAST was 50% sensitive, 91% specific, with a PPV of 68%, NPV of 83%, and accuracy of 80%. These results are within the ranges previously mentioned, and confirm that FAST will miss patients with small parenchymal or retroperitoneal injuries, and especially those without free fluid.

Liver transaminases are elevated in pediatric BAT patients with IAI even in the absence of hepatic injury [43]. Furthermore, elevated transaminases have been prospectively shown to be an important predictor of IAI in pediatric blunt trauma patients [16]. The hypothesis that combining FAST with elevated liver transaminases would improve the utility of this imaging modality was proven with statistically significant increases in all measures. Sensitivity and specificity increased to 88% and 98%, respectively. Most importantly, NPV significantly increased to 96% lending further utility of a combined negative study to rule out IAI.

We conclude that although FAST can be negative in patients with small parenchymal or retroperitoneal injuries without free fluid, FAST combined with elevated AST or ALT is an effective screening tool for IAI in children following BAT. We recommend that pediatric patients with a negative FAST and liver transaminases < 100 IU/L should be observed rather than subjected to the radiation risk of CT scan.

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