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ORIGINAL ARTICLE

Variability in the evalution of pediatric blunt abdominal trauma

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Abstract

Purpose To describe the practice pattern for routine laboratory and imaging assessment of children following blunt abdominal trauma (BAT).

Methods Children (age < 16 years) presenting to 14 pediatric trauma centers following BAT over a 1-year period were prospectively identified. Injury, demographic, routine laboratory and imaging utilization data were collected. Descriptive, comparative, and correlation analysis was performed.

Results 2188 children with a median age of 8 (4,12) years were included and the median injury severity score was 5 (1,10). There were significant differences in activation status, injury severity, and mechanism across centers; however, there was no correlation of level of activation, injury severity, or severe mechanism with test utilization. Routine laboratory and imaging utilization for hematocrit, hepatic enzymes, pancreatic enzymes, base deficit urine microscopy, chest and pelvis X-ray, and abdominal computed tomography (CT) varied significantly among centers. Only obtaining a hematocrit had a moderate correlation with CT use. There was no correlation between centers that were high or low frequency laboratory utilizers with CT use.

Conclusions Wide variability exists in the routine initial laboratory and imaging assessment in children following BAT. This represents an opportunity for quality improvement in pediatric trauma.

Level of evidence Level II.

Keywords Pediatric · Blunt abdominal trauma · Variability

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Introduction

The evaluation of children sustaining blunt abdominal trauma is challenging due to multiple factors including age related physiologic and developmental considerations, alterations in mental status, and the lower comfort level of adult providers in taking care of children. The current standard for the diagnosis of intra-abdominal injury (IAI) in adults and children is cross-sectional imaging with computed tomography (CT) [1, 2]. Given the costs and associated long-term radiation risks of CT, screening laboratory and imaging tests, in addition to other clinical variables, may be used to identify patients who might benefit from a CT as part of their initial trauma evaluation [3, 4]. Indication for CT is a subject of debate within the pediatric trauma community.

Several studies have concluded that the routine use of common laboratory panels in pediatric blunt abdominal trauma does not provide meaningful clinical benefit [5, 6]. These studies, and others evaluating individual laboratory and imaging tests including hematocrit [7–9], hepatic enzymes [10, 11], pancreatic enzymes [12–15], urine analysis [16–19], and chest radiographs [20, 21] have shown conflicting results regarding their utility to predict IAI. Laboratory and imaging findings used in collaboration with history and clinical evaluation have been used to generate predictive models to either predict IAI or identify children with a very low risk of IAI [3, 4, 7, 22–24].

Variability in practice patterns contributes to increased costs and acute treatment cost of trauma has been shown to be higher than other disease groups [25–27]. This study was conducted to evaluate the degree of practice variability in the management of children following blunt abdominal trauma (BAT).

Methods

This was a planned secondary analysis of a multicenter, prospective, observational study by 14 centers of the Pediatric Surgery Research Collaborative (PedSRC) [4]. Institutional review board approval was obtained at each center. Each center is an American College of Surgeons Pediatric Level I trauma center. The details of the study methods have been previously published [4]. Briefly, the overarching goal of the primary study was to identify a clinical prediction model to determine which patients were at very low risk for IAI following BAT and could safely avoid abdominal computed tomography (CT) as a part of their initial evaluation. Patients less than 16 years of age were enrolled over a 1-year period that concluded in July 2015. Exclusion criteria included presentation greater than 6 h after injury, abdominal CT imaging prior to arrival to the pediatric trauma center, isolated head or extremity mechanism of injury, same level fall and penetrating/burn/hanging mechanism.

The purpose of this secondary analysis was to describe the practice pattern for routine laboratory and imaging assessment. For this analysis, evaluated data elements included demographics (age, race, mechanism of injury), level of trauma activation, injury severity score (ISS), laboratory tests [hematocrit (HCT), hepatic enzymes (AST), pancreatic enzymes (amylase or lipase), base deficit, urine analysis (UA)], and imaging [chest radiography (CXR), pelvis Xray, and abdominal computed tomography (CT)]. Serious mechanism of injury was defined as: all-terrain vehicle crashes, motor vehicle crashes with ejection, rollover, unrestrained passenger or death in the same crash, falls > 10 feet in height, pedestrian or bicyclist struck by an automobile, motorcycle or dirt bike crashes, and bicycle collision with handlebar striking the abdomen [28]. Utilization was defined as percent of patients receiving the test by center. For each test, centers were classified as high or low users based on their position above or below the mean for each test.

Univariate descriptive analysis (means, medians, proportions, and p values) was performed for demographic clinical and laboratory variables. Comparative tests, utilizing Chi square for categorical data, Student's *t* test for parametric data, and or Wilcoxon–Mann–Whiney *U* test for non-parametric data were performed. SAS, version 9.3 (SAS Institute) and IBM SPSS for Windows, version 24 (IBM Corp., Aromonk, NY, USA) were used for statistical analysis; $p < 0.05$ was considered significant. Correlations of diagnostic tests with CT use were assessed with Pearson and Spearman correlation coefficients; as appropriate. Coefficients were defined as: $r < 0.3$, weak; $0.7 < r > 0.3$, moderate; and $r > 0.7$, strong. Data are presented as median [first quartile, third quartile] or mean ± standard deviation.

Results

Overall, 2188 patients were included. The median number of patients per center was 120 (101, 200). The median age was 8 [4, 12]. The racial distribution was as follows: Caucasian (48.9%), Black (36%), and other/not reported (15.1%). The most common mechanism of injury at all centers was motor vehicle collision (46.4%), followed by: pedestrians hit by automobiles (15.8%), and other (37.8%). The incidence of a serious mechanism was 60.4%. The highest level of trauma activation was initiated for 17.5% of patients. Tachycardia and hypotension for age were present in 29.8 and 2.8% of patients, respectively. The incidence of an abnormal physical exam was 39.8%. The median ISS was 5 [1, 11] and the

Table 1 Demographic and injury characteristics

Center	*N*	Age (years)	Race			Mechanism			Severe mechanism (%)	Highest activation status (%)
			Caucation (%)	Black (%)	Other (%)	MVC (%)	Peds by Auto (%)	Other (%)		
1	105	8 (3.75,12)	61.9	31.4	6.7	31.4	17.1	51.5	58.1	13.3
2	125	7.5 (4,11)	41.6	37.6	20.8	56.8	14.4	28.8	72.8	7.2
3	84	9.5 (6,13)	45.2	15.5	39.3	16.7	28.6	54.7	60.7	3.6
4	292	8 (3.75,11)	38	56.8	5.5	51.4	16.8	31.8	65.4	16.6
5	200	7 (4,12)	35	20.5	44.5	54.5	16.5	29	56	31.8
6	159	8 (3.75,13)	61.6	34.6	3.7	54.1	11.9	34	70.4	10.7
7	176	9 (5,12)	73.3	22.7	33.3	42.6	15.3	42.1	44.3	9.1
8	95	8 (4,12)	63.2	29.5	7.3	36.8	15.8	47.4	65.3	43.2
9	237	8 (4,12)	49.4	43.9	6.7	42.2	16.5	41.3	62.9	13.1
10	304	8 (5,13)	38.8	49.7	11.5	49.7	18.4	31.9	56.3	12.5
11	112	9 (5,13)	59.8	34.8	5.4	57.1	9.8	33.1	48.2	18.8
12	115	11 (5,14)	75.7	12.2	12.1	68.3	11.3	50.4	48.7	20
13	101	7 (3,12)	48.5	45.5	6	67.3	10.9	21.8	69.3	10.9
14	83	7 (3,11)	13	13.3	73.7	19.3	15.7	65	24.1	56.8
Comparison (*p*)		< 0.001		< 0.001			< 0.001		< 0.001	< 0.001

MVC motor vehicle collision

Table 2 Physical exam and physiology

Center	Abnormal physical exam (%)	Tachycardia (%)	Hypotension (%)	ISS	GCS
1	26.7	22.9	1.9	1 (1, 9)	15 (15, 15)
2	26.4	31.2	8	2 (1, 6)	15 (15, 15)
3	41.7	21.4	2.4	5 (2, 10)	15 (15, 15)
4	51	30.8	4.8	8 (4, 13)	15 (15, 15)
5	36	33.5	2.5	10 (6, 5, 19.75)	15 (13, 15)
6	33.3	23.3	2.5	5 (1, 10)	15 (15, 15)
7	65.3	36.8	0.3	5 (1, 10)	15 (15, 15)
8	60	26.2	8.4	13 (6, 19)	15 (5, 15)
9	34.6	31.9	0.8	1 (1, 9)	15 (15, 15)
10	35.2	30.4	1.3	5 (1, 14)	15 (15, 15)
11	36.6	33	1.8	5 (2, 10.5)	15 (14, 15)
12	40.9	24.8	3.5	11.5 (5.75, 24.5)	15 (13, 15)
13	22.8	30.1	2	1.5 (1, 5.75)	15 (15, 15)
14	33.7		2.4	5 (1, 5, 10)	15 (15, 15)
Comparison (p)	< 0.001	0.112	< 0.001	< 0.001	< 0.001

ISS injury severity score, *GCS* Glasgow coma score

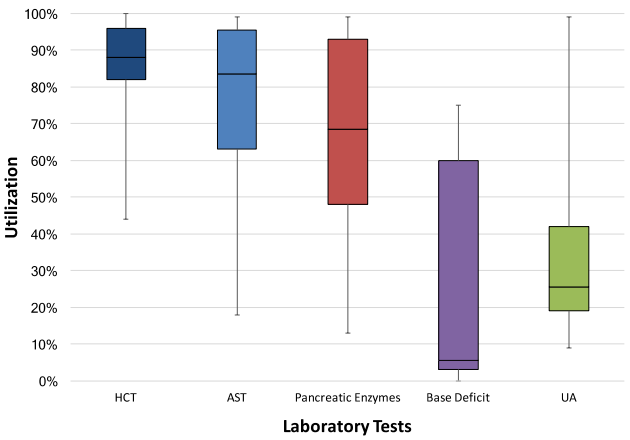

Fig. 1 Laboratory test utilization. Box and whiskers plot depicting the variability of laboratory tests in the evaluation of blunt abdominal trauma by center. *HCT* hematocrit, *AST* aspartate aminotransferase, *UA* urine analysis

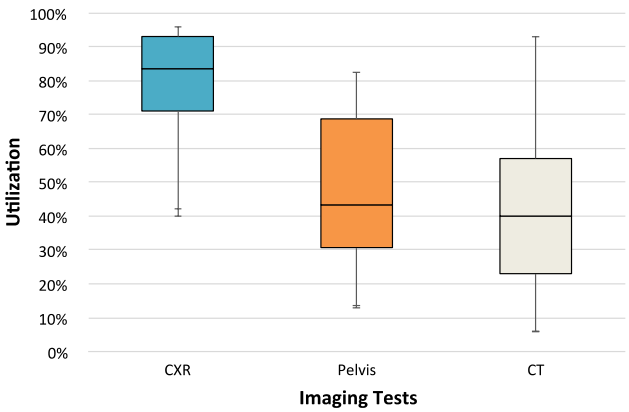

Fig. 2 Imaging Test Utilization. Box and whiskers plot depicting the variability of imaging tests in the evaluation of blunt abdominal trauma by center. *CXR* chest radiograph, *CT* abdominal computed tomography

median GCS was 15 [15]. Demographic and injury characteristics described by center can be found in Table 1. Table 2 displays the initial physical exam findings and trauma bay physiology data by center. There were significant differences in each of the categories across centers.

The box and whisker plots displayed in Figs. 1 and 2 depict the variability of use of the individual laboratory tests (HCT, AST, pancreatic enzymes, base deficit and UA) and imaging studies (CXR, pelvis Xray, and CT) by center. At the patient level, there was no correlation between the highest level of trauma activation, severe trauma (ISS > 15), or serious mechanism with ordering a HCT, AST, pancreatic enzymes, base deficit, CXR, or pelvis X-ray. However, correlations were observed at the institutional level between level of trauma activation, injury severity, and mechanism with diagnostic test utilization. There were significant, but weak correlations between highest-level trauma activation and obtaining a HCT ($r = 0.15$; $p < 0.001$), AST ($r = 0.06$; $p = 0.004$), UA ($r = -0.06$; $p = 0.004$), base deficit ($r = 0.29$; $p < 0.001$), and CXR ($r = 0.17$; $p < 0.001$). Severe trauma was also weakly correlated with test utilization-HCT ($r = 0.13$; $p < 0.001$), AST ($r = 0.07$; $p = 0.002$), base deficit ($r = 0.21$; $p < 0.001$), and CXR ($r = 0.14$; $p < 0.001$). Serious mechanism also weakly correlated with HCT (0.05;

$p = 0.02$), AST ($r = 0.06$; $p = 0.004$), base deficit ($r = 0.07$; $p < 0.001$), and CXR ($r = 0.07$; $p = 0.002$).

The only diagnostic test that had a significant correlation with CT use was HCT (Spearman 0.63, $p = 0.01$). The relationship was with HCT obtained, not the resulting value. With respect to abnormal laboratory and diagnostic test results, only an abnormal CXR ($r = 0.22$; $p < 0.001$), low HCT ($r = 0.13$; $p < 0.001$), and elevated AST ($r = 0.34$; $p < 0.001$) were weakly correlated with CT utilization. Additionally, the highest level of trauma activation ($r = 0.25$; $p < 0.001$ and an ISS > 15 ($r = 0.3$; $p < 0.001$) was weakly correlated with CT utilization. There was no correlation between a serious mechanism of injury and CT use. High utilization centers for each test were as follows: HCT − 57.1% (8/14), AST − 64.2% (9/14), pancreatic enzymes − 50% (7/14), base deficit − 42.8% (6/14), UA − 8.6% (4/14), CXR − 42.8% (6/14), and pelvis X-ray − 50% (7/14). There was no relationship between centers that were high frequency laboratory utilizers with CT utilization. Of note, there was no difference in CT utilization by time of arrival. 7am–7 pm and 7 pm–7am), and overall, there was no difference in the frequency of CT utilization; 42.9% of CT scans were obtained during the day (07:00–19:00) and 46.1% were obtained at night (19:00–07:00) ($p = 0.137$).

Discussion

In medicine, variability impacts effectiveness, efficiency, and quality of health care services [29–32]. Variability is multifactorial in origin and is a product of individual practitioner as well as systemic factors. At the provider level, clinical uncertainty, lack of familiarity with evidence, lack of knowledge, bias, the practice of defensive medicine, and other factors may lead to variability. At the system level, social, economic, environmental, and organizational conditions may constrain clinical practice and introduce variability. Variability may lead to inappropriate, ineffective, and overall poor quality of care. In general, "bad" variability reflecting limits in professional knowledge and the failure of its implementation is minimized while "good" variability that makes care patient-centered is maintained.

Our study demonstrates the immense variability in the evaluation of children that sustain blunt abdominal trauma. Variability is approached systematically starting with the thoughtful collection and publication of high quality data. Clinical outcomes that will have the most impact on equity, effectiveness, efficacy, and healthcare outcomes are prioritized. Finally, actionable implementation is planned, often incorporating best practices and evidence-based guidelines, to design and assess quality interventions. This paradigm leads to decreased uncertainty that may reduce variability and improve outcomes.

The frequency of blunt pediatric trauma, combined with the high resource utilization associated with traumatic injury care makes it an optimal target for quality improvement—particularly with respect to the diagnosis of injuries [25–27, 33, 34]. Several single center retrospective studies have called into question the utility of routine trauma panels for blunt abdominal trauma for identifying injuries. A review of 285 pediatric blunt abdominal trauma patients showed that in patients with a normal physical examination of the abdomen and a normal UA, there is low prevalence of laboratory abnormalities (5.6%) and additional laboratory testing seldom identified unsuspected injury [22]. A review of 240 pediatric blunt trauma patients from 1999 to 2000 concluded that routine trauma laboratory panels, by themselves, were of little value [6]. Finally, a study of 382 pediatric blunt trauma patients from 1996 to 1999 showed that no individual routine laboratory test had adequate test characteristics to properly screen for IAI [5].

In contrast, several studies have concluded that laboratory tests, in conjunction with additional clinical data, can be used to screen for or predict IAI. A single center, retrospective review of 1040 moderate risk pediatric blunt trauma patients from 1991 to 1995 that showed that findings of abdominal abrasions, an abnormal chest examination, and microscopic hematuria as well as elevated levels of AST and ALT, and elevated WBC count are associated with IAI [35]. Another single-center, retrospective review of 351 pediatric blunt trauma patients from 1997 to 2001 using logistic regression and recursive partitioning showed that physical examination findings such as abdominal tenderness, abrasion, and ecchymosis combined with laboratory testing could predict the risk of IAI [7]. Finally, an evaluation of 1095 pediatric blunt abdominal trauma patients from 1996 to 1998 showed that, when controlling for physical examination findings, laboratory tests contribute significantly to the identification of IAI [36].

At the core of this discussion is the ability of clinicians to perform risk assessment for IAI in a potentially highly diverse patient population and whether risk stratification can be achieved using with laboratory and imaging information. In patients with a high risk of IAI laboratory tests are not useful for screening as they will undergo CT regardless of the results. Similarly, very low risk children are unlikely to benefit from CT. Towards this end, a multicenter, prospective observational study conducted by the Pediatric Emergency Care Applied Research Network (PECARN), which included 12,044 pediatric blunt abdominal trauma patients, showed that a prediction rule consisting of 7 patient history and physical examination findings, without laboratory or imaging data, identified children with blunt torso trauma who are at very low risk for IAI receiving acute intervention [28]. The rule had a negative predictive value 99.9%, a sensitivity of 97%, and

a specificity of 42.5%. Unfortunately, the rule failed to identify several clinically important IAIs.

Building on the observations and limitations of the PECARN study, this prospective observational study was initiated with the goal to improve our ability to identify clinically important IAI. The primary analysis of this investigative effort generated a prediction rule consisting of 5 variables, including the complaint of abdominal pain, abnormal abdominal physical exam, abnormal CXR, elevated AST, and abnormal pancreatic enzymes that, when absent, identified an extremely low risk population in which CT could be safely avoided (very low risk: 34% of population; 0.6% risk of IAI; 0.0% risk of IAI requiring intervention) [4].

In this secondary analysis, we have shown that wide variability exists in the routine initial laboratory and imaging assessment in pediatric patients following blunt abdominal trauma. Although there were differences in demographics, activation status, injury severity, and mechanism across centers in this study, there was no correlation of these factors with diagnostic test use. There were significant, but weak correlations between injury severity and laboratory test utilization that may be a reflection of the traditional evaluation employed in pediatric trauma. Hematocrit was the only screening test obtained that had a relationship with CT use. Although the etiology of this relationship is unclear, it may result from the high relative frequency in which this test was obtained. We were also unable to identify a correlation between centers that were high or low laboratory utilizers with frequency of CT use. At the patient level, we did not observe any relationship between trauma activation level, severe trauma, or serious mechanism with diagnostic test utilization. However, when looking at institutions, there were significant, although very weak relationships between these parameters. This suggests a potential for institutional bias as the etiology of the observed variability and warrants additional investigation.

There are several limitations associated with this analysis. Unfortunately, we did not collect data that would provide information with respect to the practice of individual providers. Similarly, we did not collect data that would inform institutional bias such as trauma protocols that would affect the evaluation of pediatric blunt abdominal trauma patients. There may be additional confounding variables that could provide insight into the observed variability that were not collected. Finally, the nature of the data collection did not permit more advanced statistical descriptions that could provide additional adjustments within center populations. With only 14 centers, it was not feasible to perform statistical analysis controlling for the differences in patient characteristics between centers. Despite these limitations, this analysis provides a snapshot of the current clinical evaluation at level one pediatric trauma centers across the United States.

The results of this study present an opportunity to improve the quality of our care by optimizing resource utilization within the pediatric trauma community. The dissemination and implementation of evidence-based risk assessment and prediction rules should allow centers to limit their diagnostic approach without compromising care for these complex patients.

Author contributions Study conception and design: CJS, AMV, JZ, EYH, MSD, RTR, MLB. Acquisition of data: AMV, RFW, EYH, MTS, KT, RAF, MSD, JHH, MLB, RTR, BJN-M, SDSP, DM, JSU, CJS. Analysis and interpretation of data: CJS, AMV, JZ, PDM. Drafting of manuscript: CJS, AMV. Critical revision of the Manuscript: AMV, RFW, EYH, MTS, KT, RAF, MSD, JHH, MLB, RTR, BJN-M, SDSP, DM, JSU, CJS.

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Compliance with ethical standards

Conflict of interest Adam M. Vogel, MD declares that he has no conflict of interest. Jingwen Zhang, MS declares that he has no conflict of interest. Patrick D. Mauldin, PhD declares that he has no conflict of interest. Regan F. Williams, MD declares that she has no conflict of interest. Eunice Y. Huang, MD, MS declares that she has no conflict of interest. Matthew T. Santore, MD declares that he has no conflict of interest. Kuojen Tsao, MD declares that he has no conflict of interest. Richard A. Falcone, MD, MPH declares that he has no conflict of interest. M Sidney Dassinger, MD declares that he has no conflict of interest. Jeffrey H. Haynes, MD declares that he has no conflict of interest. Martin L. Blakely, MD, MS declares that he has no conflict of interest. Robert T. Russell, MD, MPH declares that he has no conflict of interest. Bindi J. Naik-Mathuria, MD, MPH declares that she has no conflict of interest. Shawn D. St Peter, MD declares that he has no conflict of interest. David Mooney, MD, MPH declares that he has no conflict of interest. Jeffrey S. Upperman, MD declares that he has no conflict of interest. Christian J. Streck, MD declares that he has no conflict of interest.

Ethical approval This article does not contain any studies with animals performed by any of the authors. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. IRB approval was obtained at each participating institution.

Informed consent As a prospective, observational study, the study was deemed minimal risk and the need for informed consent was waived by participating center IRBs.

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