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Evaluation of an evidence-based guideline to reduce CT use in the assessment of blunt pediatric abdominal trauma☆,☆☆,★,★★

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ABSTRACT

Purpose: About half of pediatric blunt trauma patients undergo an abdominopelvic computed tomographic (CT) scan, while few of these require intervention for an intraabdominal injury. We evaluated the effectiveness of an evidence-based guideline for blunt abdominal trauma at a Level I pediatric trauma center.
Methods: Pediatric blunt trauma patients ($n = 998$) age 0–15 years who presented from the injury scene were evaluated over a 10 year period. After five years, we implemented our guideline in which the decision for CT was standardized based on mental status, abdominal examination, and laboratory results (alanine aminotransferase, aspartate aminotransferase, hemoglobin, urinalysis).
Results: There were no differences in age, GCS, SIPA or ISS scores between the patients before or after guideline implementation. Nearly half of the patients (48.3%) underwent CT scan before guideline implementation compared to 36.7% after ($p < 0.0002$). There was no difference in ISS ($p = 0.44$) between CT scanned patients in either group. No statistical differences were found in rate of intervention ($p = 0.20$), length of stay ($p = 0.65$), or readmission rate (0.2%) before versus after guideline implementation. There were no missed injuries.
Conclusion: Implementation of an evidence-based clinical guideline for pediatric patients with blunt abdominal trauma decreases the rate of CT utilization while accurately identifying significant injuries.
Level of evidence: III.

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Trauma is the leading cause of death in children [1,2] and the use of computed tomography (CT) scans in the evaluation of the pediatric patient has become increasingly prevalent [3,4]. It is estimated that more than half of pediatric blunt abdominal trauma patients undergo a CT scan and only a small percentage of these patients require intervention for intraabdominal injury [5–7]. In the emergency department (ED), CT scan use has increased despite controlling for pediatric patient volume [3,4]. Pediatric trauma patients presenting to adult or mixed – adult and pediatric – trauma centers undergo more CT scans than those presenting to pediatric trauma centers [8]. One multicenter trial across Level I pediatric trauma centers looked at a prediction model in blunt abdominal trauma to avoid CT scans and found that the range of imaging frequency across centers was between 3% and 96% [9].

When compared to adults, children are at higher risk for the harms of radiation exposure from CT because of their increased proportion of dividing cells and a longer lifespan over which to develop adverse sequelae [10,11]. Similarly, risk of cancer is also increased in children owing to the relatively smaller body size over which the ionizing radiation is absorbed [8,10,12]. Despite broad changes to the dosing and protocols for radiation delivery to pediatric patients the number of patients that undergo imaging remains high [10,12,13]. Thus, there is a continued need to identify patients who could be safely observed or discharged without the harms of ionizing radiation.

The use of a clinical algorithm to decrease the use of CT imaging in pediatric trauma patients has been externally validated utilizing a public dataset [5]. We sought to determine the effect of an evidence-based guideline for blunt abdominal trauma evaluation on CT utilization. The possible benefits of decreased CT utilization would be a decreased proportion of patients undergoing radiation exposure and decreased healthcare cost. We hypothesized that such a guideline would decrease our use of abdominopelvic CT imaging in our pediatric blunt abdominal trauma population while still identifying important injuries.

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1. Methods

Institutional IRB approval was obtained. In 2013 our level I pediatric trauma center implemented an evidence-based guideline that was based on prior work by the guidelines committees of the Eastern Association for the Surgery of Trauma (EAST) and Pediatric Trauma Society (PTS) [14–19]. This guideline was modified slightly for our institution such that the decision for CT was driven by nonnormal findings in at least one assessment area including mental status, abdominal examination, focused assessment with sonography for trauma (FAST) exam, and laboratory results (aspartate aminotransferase (AST), alanine aminotransferase (ALT), hemoglobin (hgb), urinalysis) (Fig. 1). Patients with unremarkable initial findings were to be observed with serial abdominal exams and follow-up complete blood count (CBC). Delayed decisions for imaging or intervention were based on changes during this course of observation. Patient data were recorded retrospectively in the trauma registry. Patients age 0–15 years with blunt abdominal trauma who presented from the injury scene were identified using the institution's pediatric trauma registry over a 10 year period in order to compare patients from the five years prior to the guideline implementation to patients from the first five years of guideline use.

Patients were excluded from the study if they had a GCS <13, sustained a penetrating injury, isolated orthopedic, burn, self-harm, inhalation, or asphyxiation injuries; if they were intubated upon arrival; or if they presented from a referring institution. Variables of interest included mechanism of injury, injuries sustained, Glasgow Coma Score (GCS), heart rate and systolic BP on arrival, Injury Severity Score (ISS), length of stay, and discharge disposition. Registry data were verified by review of the electronic medical record when needed. We defined intervention as procedures performed in interventional radiology or the operating room for management of abdominal injuries. Readmission was defined as admission to the hospital within 30 days of discharge from the initial injury admission.

Descriptive statistics were computed by guideline period. Univariable comparisons were made using chi-square tests for categorical variables, and t-tests, median tests, or ANOVA for continuous variables. Multivariable logistic regression analysis was performed to identify predictors of outcomes. A p-value of less than 0.05 was considered statistically significant. Statistical analyses were performed using JMP Pro 13.0 (SAS Institute, Cary, NC).

2. Results

A total of 6377 patients were identified in the trauma registry database from June 1, 2008 through July 30, 2018. All patients evaluated before June 23, 2013 were included in the preguideline comparison group. After exclusion, 998 patients were eligible for study, including 460 patients in the preguideline implementation group and 538 in the postguideline implementation group (Fig. 2). Comparisons of baseline characteristics yielded no statistically significant differences in age, GCS, elevated shock index pediatric-adjusted (SIPA) or Injury Severity Score (ISS) scores between the patients pre- or postguideline implementation (Table 1). There was a statistically significant difference in sex (33% females pre vs. 40.5% post; $p = 0.02$). Nearly half of patients (48.3%) underwent a CT scan before guideline implementation compared to 36.8% after implementation ($p < 0.0003$) (Table 2). More

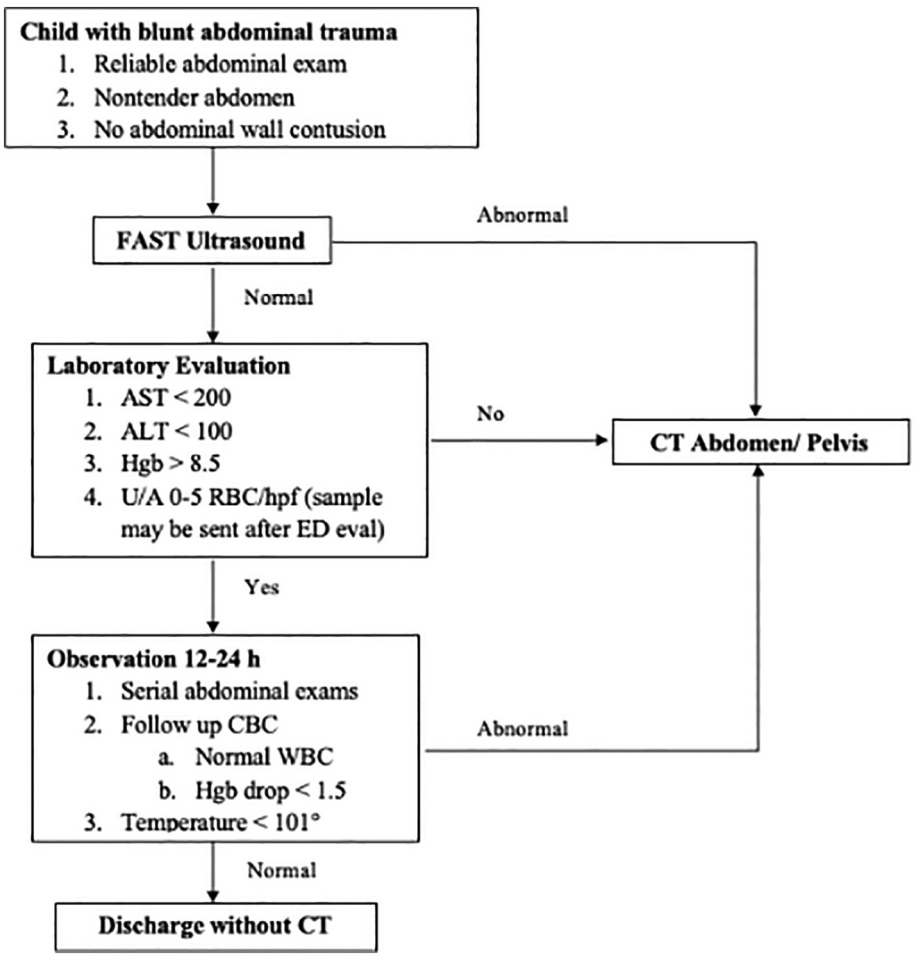

Fig. 1. Blunt abdominal trauma guideline. CT imaging could be obtained at the treating trauma surgeon's discretion. The anemia level was considered in context of additional injuries.

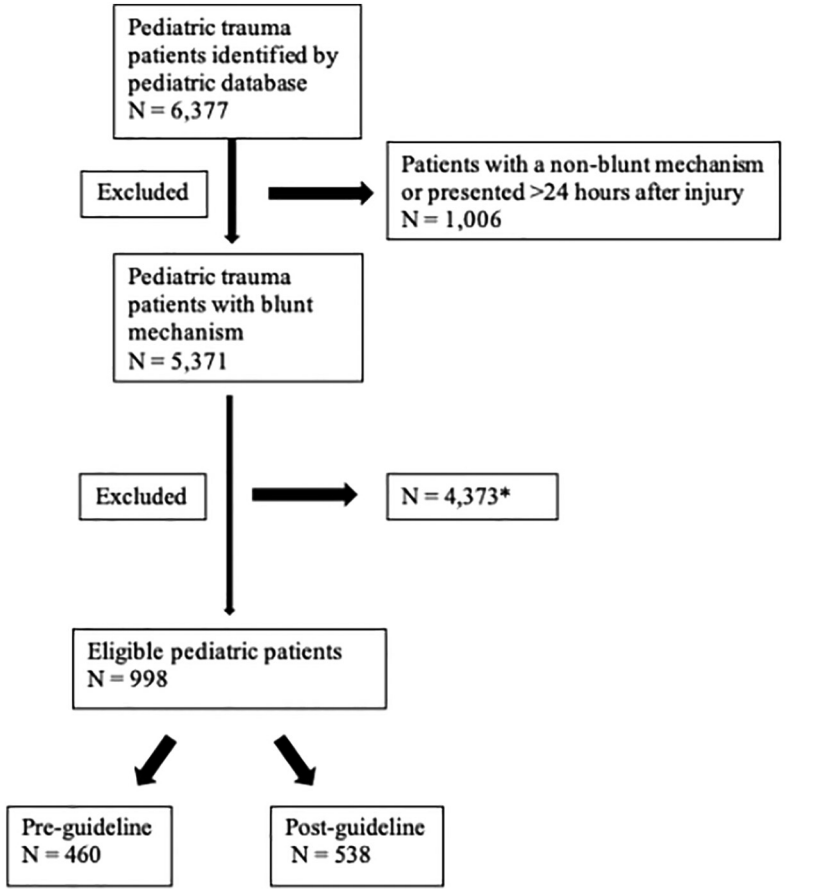

Fig. 2. Inclusion/exclusion criteria.

solid organ injuries (45 vs. 52) were identified with fewer CT scans (222 vs. 198) in the postguideline group compared to the preguideline group.

We evaluated those patients who had normal abdominal examinations and laboratory findings and still underwent a CT scan. Preimplementation there were 337 of 460 (73.2%) with no positive variables and 129 (38.2%) of these underwent a CT scan. In the postguideline group 376 of 538 patients (69.8%) had no positive variables and 79 (21.0%) underwent a CT scan. Of the 208 patients who underwent a CT scan and had normal findings, 26 had a rib fracture, pneumothorax or pulmonary contusion (12.5%), 38 had a femur, or tibia/fibula fracture (38.3%), and 19 had loss of consciousness or concussion (9.1%). In addition, 20 had a face/skull fracture (9.6%). 10 had intracranial hemorrhage (4.8%), 10 had pelvis fractures (4.8%) and 43 had other soft tissue injuries (20.7%). The median ISS of CT scanned patients did not change over time. Median was 8 (IQR 4–13) preguideline and 9 (IQR 4–13) postguideline ($p = 0.54$). Evaluation of ED length of stay (LOS) between the pre and postguideline implementation time periods showed an increase in overall ED LOS from a median of 3.42 h (IQR 2.40–4.68) preguideline to 4.05 h (IQR 2.8–5.48) postguideline ($p < 0.001$).

There was improvement of total obtained lab values with AST and ALT values recorded for 504 compared to 386 patients in the post versus preguideline groups (93.7% compared to 83.9%). For hemoglobin, 96.7% compared to 90.4% of participants' values were obtained ($n = 416$ and

Table 1
Demographics of patients pre- versus postprotocol implementation.

	Preprotocol	Postprotocol	*p* Value
	N = 460	*N* = 538	
Age, years			
Median (IQR)	10 (5–14)	9 (4–13)	0.27
Sex			
Female (%)	153 (33)	218 (40.5)	0.02*
GCS	*N* = 457	*N* = 530	
Median = IQR	15	15	0.52
ISS			
Median (IQR)	5 (2–9)	5 (2–9)	0.83
SIPA elevation,	*N* = 449	*N* = 520	
n (%)	155 (34.5)	187 (35.9)	0.6

* Statistically significant $p < 0.05$.

Table 2
Outcomes pre- versus postprotocol implementation.

	Preprotocol	Postprotocol	*p* Value
	N = 460	*N* = 538	
CT scan rate, *n* (%)	222 (48.3)	198 (36.8)	0.0003*
LOS	*N* = 458	*N* = 538	
Mean (IQR)	2 (1–3)	2 (1–3)	0.65
Rate of intervention, *n* (%)	6 (1.3)	13 (2.4)	0.2
Discharge to home, *n* (%)	453 (98.5)	528 (98.1)	0.72

LOS = length of stay.
* Statistically significant $p < 0.05$.

520 respectively). The number of urinalysis samples increased from 303 (65.9%) to 366 (68%) pre- versus postguideline. The total utilization of FAST was 16.4% across the study periods with an increase in documentation of 1.5% (7 patients) preguideline implementation to 29.2% (157 patients) post.

Length of stay ($p = 0.65$) and rate of readmission (0.2%) did not differ between the two groups. No missed abdominal injuries were identified in either group. The need for intervention was low and did not differ between the two groups ($p = 0.203$). The odds of CT scan were 6.1 times more likely with presence of abdominal contusion (95% CI 3.6–10.2, $p < 0.0001$). Odds of CT scan were 11.6 and 4.4 times more likely with AST >200 and ALT >100 respectively (95% CI 1.3–103.3, $p < 0.05$; 103–14.8, $p < 0.02$). Odds of CT scan were 4.4 times more likely with acute hemoglobin drop to less than 8.5 (95% CI 0.4–26.7, $p = 0.2$) and finding of hematuria resulted in 2.8 times more likely to have a CT scan (95% CI 1.5–5.1, $p = <0.001$). We evaluated the odds of a procedural intervention based on the guideline variables including presence of abdominal contusion, elevated transaminases, low hemoglobin and hematuria. The odds of procedural intervention were increased by presence of abdominal contusion, elevated ALT and acute anemia (Table 3).

In addition, we evaluated if the odds of a CT scan differed by verbal ability and divided the pre- and postguideline groups into preverbal (<3 years; $N = 201$) and verbal (>4 years; $N = 797$). There was no statistical difference in the odds of CT scanning comparing between the groups based on age ($p = 0.78$). The odds ratio (OR) of having a CT scan postguideline was less likely than having one in the preguideline group whether patients were preverbal or verbal (younger OR = 0.58, 95% CI 0.29–1.15; older OR = 0.64, 95% CI = 0.48–0.85).

3. Discussion

We found that an evidence-based blunt abdominal trauma evaluation guideline at a level I pediatric trauma center decreased the use of abdominopelvic CT in our patient population while identifying important injuries. We decreased the radiation exposure by 25% between the pre- and postguideline implementation groups. Patients had similar injury severity scores between the guideline groups and ISS scores were no different between those who underwent CT scans across the guideline groups. In addition, there were no missed injuries. Predictors of procedural intervention were abdominal contusion presence, elevated ALT, and acute anemia. Our decreased CT utilization did not increase our length of stay and no missed injuries were identified.

Our study adds to the growing body of literature that the use of CT can be safely decreased with the combined interpretation of physical and laboratory assessments [9,16]. Holmes et al. have demonstrated that laboratory studies can be used to identify those with intraabdominal injury [14] and those who are at very low risk of abdominal injury on history and physical examination alone [20]. Other authors have likewise shown that a scoring system can identify those patients with intraabdominal injury and also decrease the amount of radiation exposure safely in pediatric patients with blunt abdominal trauma [7,9,14,21]. The Pediatric Emergency Care Applied Research Network (PECARN) network prospectively evaluated 12,044 patients utilizing a prediction rule of 7 physical examination and history variables – no evidence of abdominal wall trauma or seat belt sign, GCS > 13, no abdominal tenderness or thoracic wall trauma, no complaints of abdominal pain, no decreased breath sounds, and no vomiting – and showed a 97% sensitivity of identifying intraabdominal injuries that would require intervention [20]. Despite mounting evidence, the use of CT in workup of blunt abdominal trauma is highly variable across trauma centers [22]. Our study supports the conclusion that odds of obtaining a CT scan were significantly increased by presence of abdominal contusion, elevated AST and ALT levels, and hematuria. While it is interesting to analyze the components of a guideline to decrease CT use, perhaps it is the presence of a useful guideline itself that contributes to the decrease in CT use rather than the performance of any particular component. It is possible that this Hawthorne effect created a culture change in CT decision-making in the ED. Our current study is limited by the use of a historical comparison group to reveal the improvement in outcome by using the guideline. Our use of the 5 year preguideline population presumes homogeneity in patients presenting to our institution. It is possible, however, that we have a population bias given that our analyzed dataset did not account for patients who initially presented from referring institutions with imaging or those who chose referring institutions for follow-up or concerns; thus, we have no missed injuries, but it is possible we are not aware of them. It is also important to note that transferred patients can undergo a "double work-up" if images are not available or able to be loaded into the accepting institution's electronic medical record and could lead to further radiation exposure and cost [23,24].

Our experience highlights that an evidence-based guideline decreases CT utilization and that there is real-world "drift" toward a user-friendly version of the guideline. Notably, at the time of our guideline implementation, the use of evidence-based guidelines to reduce the number of CT scans was relatively new in pediatric trauma evaluation. As such, our guideline was used as a tool to lead change in radiation exposure for pediatric blunt abdominal trauma patients. In addition, varying trauma presentations result in different clinical management pathways. For example, the total utilization of bedside ultrasound – FAST – was documented in 164 patients (16.4%) of the study population. We saw an increase over time with a FAST examination being documented in the postguideline group at 19 times the rate of the preguideline group. This yield was not enough to analyze these data to make further inferences and it led us to infer a guideline without the use of FAST. This represents the real-world use of a modality (i.e. FAST) that is user dependent and low yield; FAST examinations are not better suited to detect an occult bowel injury [25]. Therefore, we theorize that the addition of FAST examinations would not have altered the outcomes of our study. Likewise, hematuria was not universally assessed likely because not all patients void in the ED and patients, families, and ward nurses may not be aware of its completion along the admission stay. Regarding the observation period, there was no uniform way of assessing strict adherence. While this represents an opportunity for improvement and standardization, we argue that this may not be clinically important. Each patient and their presentation are unique and their assessment requires knowledge of associated injuries and their current signs and symptoms. A patient who appears well, reports decreased abdominal pain and appears to be progressing over hours of observation, likely would not undergo repeat labs (i.e. CBC) for further assessment. In addition, maturation bias could be inherent in our study as our institution has a robust quality improvement program. It is possible that the small increase in ED LOS in the postguideline group was related to the time waiting for laboratory data before deciding to perform a CT, but our data cannot isolate this as the primary factor among many other factors that contribute to ED LOS. We did not stratify CT utilization by attending physicians present in the ED bay, both trauma surgeons and ED physicians, which could also lend insight into the etiology of our decreased CT use.

A notable strength of our study is the length of time over which our practices were assessed. We demonstrated an ability to change

Table 3
Odds ratio that positive guideline parameters would result in intervention (operative room (OR): $N = 15$, interventional radiology (IR): $N = 2$, both OR and IR $N = 1$).

Variable	Odds Ratio	95% CI	*p* Value
Intervention			
Abdominal contusion present	13.7	4.5–41.9	<0.0001*
AST > 200	0.2	0.03–1.6	0.1332
ALT >100	17.6	3.7–84.6	0.0003*
Hgb < 8.5	13.7	2.1–88.6	0.0060*
Hematuria	Too few values positive to calculate		

* Statistically significant $p < 0.05$.

management practices over time at a level I academic trauma center with various learners present at different times of a trauma presentation. We surmise that with a reduction in CT use, a concomitant decrease in cost was possibly achieved which has been found in previous studies [26,27] . This is a single-institution study which limits its generalizability; however, the size of our sample lends strength to our conclusion. Our guideline can be applied to blunt abdominal pediatric trauma patients presenting from the scene across institutions. The ability to evaluate a suspected blunt abdominal trauma patient's physical examination and laboratory markers is standard in the workup across institutions and can assist in protecting patients from unnecessary ionizing radiation and the adverse sequelae thereof. While we are encouraged by the decrease in CT utilization, there is definite room for change and improvement of our guideline. In a future version, we would eliminate the need for the FAST examination as it is not carried out in real day-to-day practice based on our findings. An additional pathway for discharge to home directly from ED versus extended duration of observation in ED prior to discharge home – instead of admission for observation – should be included if the workup for intraabdominal injury is negative. In the former two categories, the ability to discharge to home without a CT scan should be studied in greater depth.

The goal of our blunt abdominal trauma guideline is to safely avoid radiation exposure in those who have a low risk of injury but still present concern for intraabdominal injury. We assume that those who require immediate intervention or will progress to require intervention quickly will not have a delay in treatment. Patients in whom possible injury is equivocal and therefore undergo a CT scan are those in whom we hope to avoid CT scans. It is possible that in a future version of our guideline we could include those who have higher risk of blunt abdominal injury in addition to those with lower risk. In addition, we could consider formally incorporating chest x-ray and amylase as Streck et al. did [9].

Our guideline demonstrates a decrease in CT utilization and consistent identification of injuries utilizing evidence-based criteria for assessment of pediatric patients who have suffered blunt abdominal trauma. We recommend continued use of this evidence-based guideline across centers to assist in decreasing unnecessary exposure to ionizing radiation in pediatric blunt abdominal trauma group. Future study needs include the evaluation of referred patients who form a significant percentage of those seen at many tertiary care centers including ours and deserve attention in further work.

4. Conclusion

We found that the implementation of an evidence-based blunt abdominal trauma guideline at our level I pediatric trauma institution decreased the rate of CT scanning and subsequent ionizing radiation exposure of our patient population. The use of physical examination findings combined with laboratory data can aid in identifying those at highest risk for abdominal injury and spare radiation exposure safely to those at much lower risk. Further work is needed to categorize the patients transferred to tertiary care centers and the potential cost savings.

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