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Enhancing clinical risk assessment in pediatric blunt abdominal trauma: A novel scoring system using ultrasound and laboratory data

Mehdi Nasr Isfahani[1,2], Elahe Nasri Nasrabadi[1], Zahra Rabiei[1*], Neda Al-Sadat Fatemi[2,3] and Farhad Heydari[1]

Abstract

Background Given the importance of diagnosing intra-abdominal injury (IAI) in children with blunt abdominal trauma (BAT) and preventing radiation exposure to children by avoiding CT scans, this study aimed to evaluate a scoring criterion based on ultrasound (US) findings and laboratory data in assessing the clinical risk of IAI in children with BAT.

Materials and methods In this retrospective study, baseline and clinical information of 180 children (under 18 years of age) with BAT including physical examination, hemodynamic parameters, and laboratory data, were extracted from medical records. US findings were considered abnormal if any report of mild free fluid or solid organ injury was noted. The presence or absence of IAI was assessed through medical records or telephone interviews to inquire about the patients' outcome within the two-week period post-discharge. The primary outcome was the identification of IAI, assessed through a combination of US findings, physical examination (abdominal tenderness), and laboratory parameters (WBC count and hematuria). The measurement methods included Chi-squared tests, Fisher's exact test, independent samples t-test, logistic regression, and ROC analysis.

Results The current study showed that 153 (85%) and 27 (15%) patients were without and with IAI, respectively. The positive US finding with sensitivity and specificity of 92.59% and 44.44%, respectively, abdominal tenderness with sensitivity and specificity of 81.48% and 87.58%, respectively, hematuria with sensitivity and specificity of 62.96% and 50.33%, respectively, and high WBC level with sensitivity and specificity of 85.19% and 76.47%, had a significant diagnostic value in detecting the presence of IAI (P value < 0.001). A cutoff point ≥ 2 from the sum of the scores of these four criteria can predict the presence of IAI with a sensitivity of 81.48% and a specificity of 94.12% (AUC = 0.94; P value < 0.001).

Conclusion This study shows that a scoring system based on positive US findings, abdominal tenderness, hematuria, and high WBC levels effectively diagnoses IAI in BAT children. A score of 2 or more strongly indicates the presence of IAI, improving decision-making for further imaging and treatment. Implementing this system can reduce unnecessary CT scans and radiation exposure, enhancing pediatric trauma care.

Keywords Blunt abdominal trauma, Intra-abdominal injury, Ultrasound, CT scans

*Correspondence:
Zahra Rabiei
itr@mui.ac.ir
[1]Department of Emergency Medicine, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran
[2]Trauma Data Registration Center, Al-Zahra University Hospital, Isfahan University of Medical Sciences, Isfahan, Iran
[3]Department of Health in Disasters and Emergencies, School of Management and Medical Informatics, Isfahan University of Medical Sciences, Isfahan, Iran

Introduction

Abdominal traumas such as abdominal bruising (AB) or BAT with a prevalence of 80–90% are among the most common traumas in children [1]. In addition, abdominal trauma is the most common cause of death due to unknown injuries [2, 3]. On average, 6–12% of BAT children referred to emergency departments (EDs) had IAI, which can be one of the main causes of trauma-related childhood morbidity [4, 5]. Although some complications caused by trauma in children are irreparable by themselves, many of these complications can be minimized by timely diagnosis of the injury and appropriate treatment actions in a center equipped with a capable treatment team and specific facilities for children's treatment [6].

The first effective step in BAT is patient history, examination, and the physician's correct clinical picture [7]. However, the examination is one of the main challenges as it always leaves room for doubt and ambiguity and is unreliable [8]. More than half of the children with serious trauma and IAI do not have any bruising or ecchymosis during the examination [9]. Therefore, after the examination, it is necessary to perform timely and preferable paraclinical actions according to the type of trauma following the diagnosis to make a treatment decision. One of the most significant paraclinical actions in pediatric abdominal and pelvic trauma is urine analysis and imaging of this area [1].

The importance of urinalysis is that in case of the absence of hematuria, it is largely assumed that the kidney system and urinary tract are healthy. However, in case of the presence of hematuria, further examinations are required to find the source of blood in the urine. Therefore, this criterion alone cannot help to diagnose IAIs such as kidney damage [10, 11].

Hence, there is a need for other available diagnostic modalities such as ultrasound. Abdominal and pelvic ultrasound, especially Focused Assessment with Sonography in Trauma (FAST), due to its availability and cheapness is performed as an emergency action in all children with a history of BAT to initially check the presence or absence of free fluid in the abdomen and pelvis [2, 12]. However, the central point in this imaging method is that, unlike adults, where the report of the presence of free fluid means damage to the organs inside the abdomen, this issue has not yet been proven in children [13–16]. Therefore, if free fluid is seen in the ultrasound of the child's abdomen and pelvis, it is recommended to perform a computed tomography (CT) scan following the diagnostic process due to the concern of errors in timely diagnosis in critical situations. Meanwhile, the negative predictive value of abdominal and pelvic CT scans is 75%, which can still be challenging for the treatment team to decide whether to continue the child's hospitalization or early discharge [17–19]. Furthermore, one of the main concerns about this issue is the complications arising from multiple CT scans in children [20].

Being exposed to radiation in children is important because the organs and tissues are growing and have not yet reached the final stage of their maturity. Moreover, as a certain amount of radiation to a smaller cross-sectional area occurs in children, as compared to adults, the oncogenic effects of radiation have more time for the cells to become cancerous until decades later [21]. Besides, the noteworthy concern is about the CT scan results as the majority of them are reported as normal and were not required to be done for the child. One way to reduce children's exposure to radiation is to ensure that imaging methods are truly necessary for the child. To diagnose IAI, clinicians can use clinical evidence from the child, hemodynamic status, blood tests, and ultrasound findings.

Pediatric BAT is a significant cause of morbidity and mortality among children worldwide. Accurate and timely assessment of IAIs in pediatric patients remains a critical challenge for emergency physicians. Traditional diagnostic modalities, such as CT scans, although effective, pose potential risks due to radiation exposure, particularly in the pediatric population. Therefore, there is an urgent need for non-invasive, reliable, and easily accessible biomarkers to help in the early detection and evaluation of IAIs.

Trauma-induced leukocytosis, characterized by an elevated WBC count, is a common finding in patients with significant injuries. However, the interpretation of WBC elevation in the context of trauma is multifaceted. Elevated WBC levels can result from systemic inflammation due to trauma itself, without necessarily indicating the presence of specific organ injuries.

Studies have shown that leukocytosis may predict the severity of injury and the likelihood of IAIs. For instance, Ibrahim et al. (2019) demonstrated that elevated WBC count could be a predictor of occult injury in pediatric patients with blunt abdominal trauma, though it may not always correlate with injury severity [22]. Similarly, Rau et al. (2023) found that trauma could significantly increase various WBC subtypes, including monocytes, neutrophils, and lymphocytes, due to stress-induced hyperglycemia, without necessarily indicating organ damage [23].

Conversely, several studies support the utility of WBC count as a potential marker for predicting IAIs. Faridaalaee et al. (2013) observed a significant correlation between elevated WBC count and the severity of intra-abdominal injuries, suggesting the need for further diagnostic imaging, such as CT scans [24]. Ka et al. (2015) concluded that a higher WBC count was associated with the presence of intra-abdominal organ injuries, supporting the use of CT scans for further evaluation [25].

At present, although there have been many studies on the diagnostic value of each of these criteria in the age group of traumatized adults, less attention has been devoted to the diagnosis of IAI in children. Moreover, few studies have been conducted to score these criteria and achieve a scoring system in clinical risk assessment of IAIs in BAT children. Hence, the present study aimed to investigate the diagnostic value of physical examinations, laboratory data, and ultrasound findings (US) in the diagnosis of IAI in BAT children and achieving executive prioritization in the process of diagnostic action in these children.

Materials and methods

Study design and setting

The present study was conducted retrospectively, encompassing all cases involving children under 18 years of age who presented with trauma complaints. The patients were admitted to the emergency departments of Kashani and Al-Zahra hospitals in Isfahan from 2020 to 2023.

Study participants

The sample size was considered to be 180 patients at the confidence level of 95%, the test power of 80%, and taking into account the result of previous studies reporting the diagnostic sensitivity of abdominal ultrasound in the diagnosis of abdominal injury equal to 82% [26], the matching ratio of at least 0.50, and the error level of 0.08.

The inclusion criteria of the study comprised the files of BAT children under 18 years of age, whose visit to the hospital was less than six hours after the occurrence of trauma and for whom a surgical visit or a CT scan of the abdomen and pelvis, a request to repeat the ultrasound by the attending radiologist, or a serial physical examination of the abdomen were requested. In addition, if a report of unstable hemodynamics or requirement of emergency surgery was recorded in the patient's file upon entering the hospital, they were not included in the study.

Ethical considerations

After obtaining the code of ethics from the Ethical Committee of Isfahan University of Medical Sciences (Approval code: IR.MUI.MED.REC.1403.285) and written consent from the hospital officials, the hospital files were checked, and finally 180 files of children eligible to enter the study were randomly selected. During a phone call, consent was obtained from the child's parents to participate in the study.

Data collection

Patients' basic and clinical information such as age, gender, mechanism of trauma (e.g., motor vehicle crash, fall, assault, and direct trauma), abdominal tenderness, abdominal distention, systolic and diastolic blood pressure (SBP and DBP), respiratory rate (RR), heart rate (HR), and Glasgow coma scale (GCS) were obtained from patients' files and then recorded.

Moreover, the results of the patient's laboratory data such as hematuria (≥ 25 RBC/hpf significant for microscopic hematuria), hematocrit (HCT), hemoglobin (Hb), white blood cell (WBC), and red blood cell (RBC) were recorded. Furthermore, the following values were considered: WBC values $> 10 \times 10^9$/L as abnormal WBC, RBC values $< 4 \times 10^{12}$/L as abnormal RBC, Hb values < 12 g/dl as abnormal Hb, and HCT values $< 30\%$ as abnormal HCT.

The patient's US report was extracted from their file by the radiologist or emergency medicine specialist and reported as follows: the patient's US findings were considered abnormal (positive) if any report of mild free fluid or solid organ injury was noted. These findings were documented by the radiologist or emergency medicine specialist in the patient's medical file and subsequently recorded as part of the study data. Otherwise, the US was considered negative.

Finally, if a CT scan was performed for the patient and the result was recorded in their file, this report was extracted to evaluate the presence or absence of IAI. Otherwise, If the patient was discharged based on the surgeon's diagnosis, their contact number recorded in the file was called and the patient's outcome, within two weeks after discharge was inquired about. In detail, if this patient returned to the hospital again (IAI present) or had a good and favorable general condition (IAI absent), it was recorded as the definitive patient outcome.

Assessment of intra-abdominal injuries

The standard assessment for identifying IAI in this study involved a two-step process. First, evaluation via medical records included reviewing CT scan reports, surgical or clinical notes, and abnormal US findings documented by radiologists or emergency medicine specialists. Second, a follow-up telephone call was made to obtain information on the patient's general condition during two weeks post discharge. If the patient had returned to the hospital for IAI-related symptoms or required further medical intervention, it was recorded as a positive outcome for IAI. Conversely, a stable condition without the need for further medical attention was recorded as a negative outcome for IAI.

Data analysis

Finally, the collected data was entered into SPSS (ver. 26) software. Quantitative and qualitative data were shown as means ± standard deviation (SD) or n (%), respectively. At the level of inferential statistics, Chi-squared tests and Fisher's exact test were used to compare the frequency distribution of qualitative data between two

Table 1 Baseline characteristics of BAT children

Characteristics	IAI Absent (*n* = 153)	IAI Present (*n* = 27)	*P* value
Age; year	9.59 ± 4.46	11.11 ± 5.23	0.113*
Sex			
Male	106(69.3%)	16(59.3%)	0.372**
Female	47(30.7%)	11(40.7%)	
Mechanism injury			
All motor vehicle crash	107(69.9%)	14(51.8%)	0.118***
Fall	30(19.6%)	4(14.8%)	
Assault	13(8.5%)	4(14.8%)	
Direct trauma	3(2.0%)	5(18.5%)	

All motor vehicle crashes: Motor rolling, Motor to car accidents, Car to-pedestrian accidents, Motor to-pedestrian accidents, Car to car accidents, Motor to motor accident

*: Significance level obtained from independent sample t-test

**: Significance level obtained from Fisher's exact test

***: Significance level obtained from Chi-squared tests

Table 2 Determination and comparison of laboratory parameters associated with IAI in BAT children

Laboratory parameters	IAI Absent (*n* = 153)	IAI Present (*n* = 27)	OR (95% CI)	*P* value*
Hematuria	77(50.3%)	14(51.8%)	8.435(1.141–62.370)	0.037
WBC; ×10^9/L	9.47 ± 3.59	13.30 ± 2.65		
Normal	117(76.5%)	4(14.8%)	Ref.	< 0.001
Abnormal	36(23.5%)	23(85.2%)	20.221(4.659–87.766)	
RBC; 10^{12}/L	4.67 ± 0.44	4.62 ± 0.36		
Normal	141(92.2%)	26(96.3%)	Ref.	0.695
Abnormal	12(7.8%)	1(3.7%)	0.189(0.007–5.131)	
Hb; g/dl	13.05 ± 2.77	12.56 ± 1.39		
Normal	141(92.2%)	25(92.6%)	Ref.	0.649
Abnormal	12(7.8%)	2(7.4%)	0.082(0.020–1.241)	
HCT; %	37.74 ± 3.57	37.19 ± 3.21		
Normal	145(94.8%)	25(92.6%)	Ref.	0.647
Abnormal	8(5.2%)	2(7.4%)	2.590(0.613–15.357)	

*: Significance level obtained from logistic regression

groups with and without IAI. Moreover, based on the results of the Kolmogorov-Smirnov test indicating the normal distribution of quantitative data, an independent samples *t*-test was used to compare the mean of quantitative variables between two groups (with and without IAI). In addition, logistic regression was used to evaluate the factors related to IAI, and the OR index (95% confidence interval (CI)) was reported. Then, ROC analysis was performed for the significant indices obtained from the regression analysis, and their diagnostic value in the diagnosis of IAI was evaluated. The sensitivity, specificity, positive and negative predictive values, and area under the curve (AUC) were also reported. A significance level of less than 0.05 was considered in all analyses.

Table 3 Determination and comparison of clinical examinations and hemodynamic parameters related to IAI in BAT children

Variables	IAI Absent (*n* = 153)	IAI Present (*n* = 27)	OR (95% CI)	*P* value*
Physical examinations				
Abdominal tenderness	19(12.4%)	22(81.5%)	27.590(7.008-108.618)	< 0.001
Abdominal distension	1(0.7%)	0(0%)	-	0.674
GCS	15.00	15.00	-	-
Hemodynamic Parameters				
SBP; mmHg	112.81 ± 9.94	112.22 ± 10.05	0.339(0.045–2.551)	0.778
DBP; mmHg	73.93 ± 7.79	73.22 ± 7.19	0.219(0.036–1.335)	0.658
HR; bpm	94.88 ± 15.26	99.11 ± 12.44	1.289(0.222–7.472)	0.174
RR; bpm	17.65 ± 2.65	17.11 ± 2.68	2.926(0.610-14.029)	0.328
Ultrasound finding*				
Negative	68(44.4%)	2(7.4%)	Ref.	< 0.001
Positive	85(55.6%)	25(92.6%)	31.961(3.458-295.395)	

Results

In this study, out of 180 BAT children with a mean age of 4.85 ± 10.09 years, 122 (67.8%) and 58 (32.2%) were male and female, respectively. Moreover, 153 (85%) and 27 (15%) patients were without and with IAI, respectively. More than 60% of the traumas were caused by motor vehicle crashes. There was no significant difference in age, gender, and mechanism of injury between children with and without IAI (P value > 0.05) (Table 1).

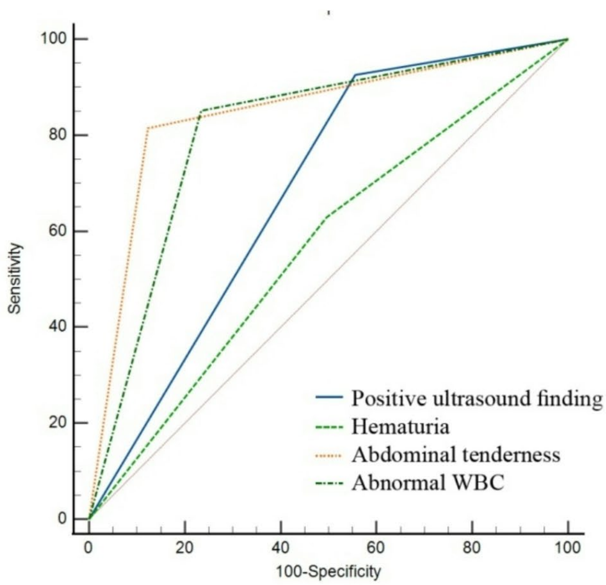
Furthermore, hematuria (OR (95% CI): 8.435(1.141–62.370)) and abnormal WBC (OR (95% CI): 20.221(4.659–87.766)) had a direct and significant relationship with IAI (P value < 0.05), while RBC, Hb, and HCT had no significant relationship with these children's IAI (P value > 0.05) (Table 2).

Moreover, all children's consciousness was equal to 15 based on the GCS criterion. One person had abdominal distension without IAI. Notably, abdominal tenderness had the most relationship with the existence of IAI (OR (95% CI): 27.590(7.008-108.618); P value < 0.001). Besides, hemodynamic parameters such as SBP, DBP, HR, and RR were not significantly different in children with and without IAI (P value > 0.05). The US findings were positive in 110 cases such that positive US findings in children with IAI with 92.6% was significantly more than the children without IAI with 55.6%. This finding statistically shows that a positive US finding can make the chance of IAI 31.961 times more likely (P value < 0.001) (Table 3).

Table 4 Determination of the diagnostic value of factors related to IAI in BAT children

Factors	Sensitivity (95% CI)	Specificity (95% CI)	PPV	NPV	AUC (95% CI)	*P* value*
Positive ultrasound finding	92.59(75.7–99.1)	44.44(36.4–52.7)	22.7	97.1	0.68(0.61–0.75)	< 0.001
Abdominal tenderness	85.19(66.3–95.8)	76.47(68.9–82.9)	39.0	96.7	0.81(0.74–0.86)	< 0.001
Hematuria	62.96(42.4–80.6)	50.33(42.1–58.5)	18.3	88.5	0.57(0.49–0.64)	< 0.001
WBC > 10 × 10^9/L	81.48(61.9–93.7)	87.58(81.3–92.4)	53.7	96.4	0.84(0.78–0.89)	< 0.001
Sum score Cut off point ≥ 2						
	81.48(61.9–93.6)	94.12(89.1–97.3)	71.0	96.6	0.94(0.89–0.97)	< 0.001

*: Significance level obtained from ROC analysis



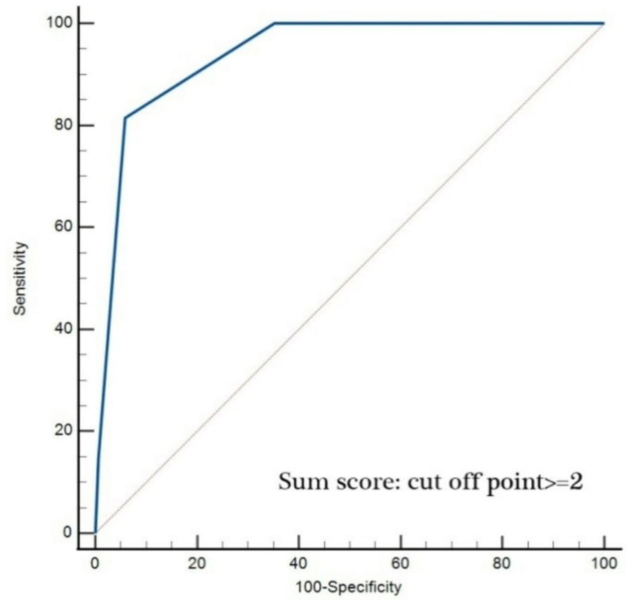


Fig. 1 ROC curve illustrating the diagnostic value of each criterion, including ultrasound US, hematuria, abdominal tenderness, and elevated WBC levels, as well as their combined scores in diagnosing IAI in children with BAT

If there is any report of free fluid or solid organ damage in the US, it is considered a positive US finding.

*: Significance level obtained from logistic regression.

Considering the significance of the relationship between positive US results, the presence of abdominal tenderness, hematuria, and a high WBC level with the presence of IAI, the results of the ROC diagnostic value of these criteria in the diagnosis of IAI were examined and indicated that the positive US finding with a sensitivity and specificity of 92.59% and 44.44%, respectively, abdominal tenderness with sensitivity and specificity of 81.48% and 87.58%, respectively, hematuria with sensitivity and specificity of 62.96% and 50.33%, respectively, and high WBC level with sensitivity and specificity of 85.19% and 76.47%, had a significant diagnostic value in detecting the presence of IAI (P value < 0.001). In addition, the sum of the scores of these four criteria revealed that if more than two of these four criteria are positive, the presence of IAI can be predicted with sensitivity of 81.48% and specificity of 94.12% (AUC = 0.94; P value < 0.001). (Table 4; Fig. 1).

Considering the higher OR value in the logistic regression analysis and the higher sensitivity values in the ROC analysis for each of the above-mentioned criteria, the diagnostic flowchart of IAI is presented in Fig. 2. According to this flowchart, it is evident that out of 27 BAT children with a definite diagnosis of IAI, 25 had positive US findings. Moreover, 21, 17, and only 4 of them had abdominal tenderness, high WBC levels, and hematuria, respectively. Therefore, examining the presence of IAI in BAT children indicated that following the order of prioritization and the priority of evaluation for scoring of these patients according to this flowchart can be the best diagnostic selection algorithm with the highest accuracy.

Development of the STAR scoring system

In this study, we developed the STAR scoring system to evaluate the clinical risk of IAI in children with BAT. During the analysis of our study data, we identified four key criteria that were significantly associated with IAI. These criteria were:

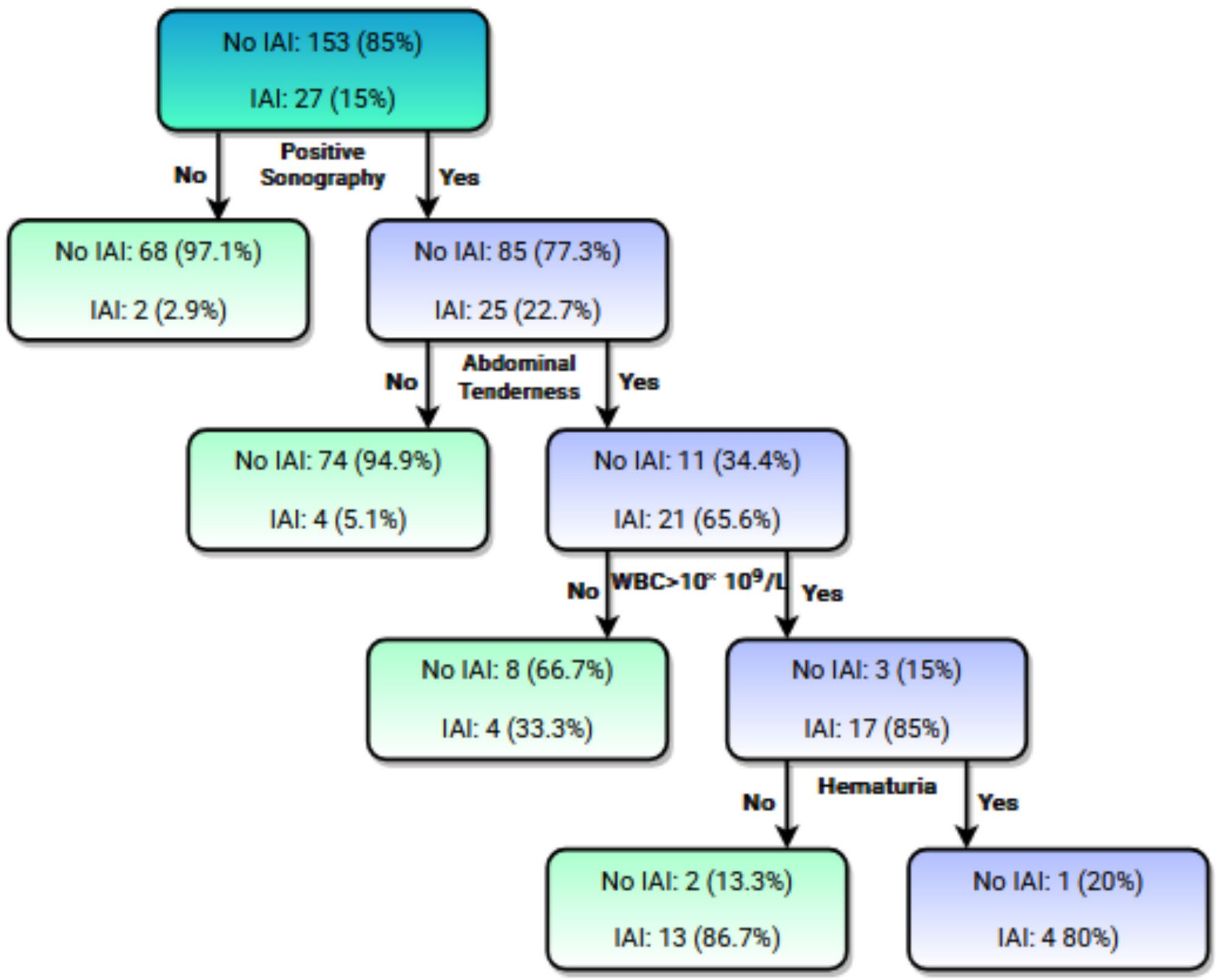


Fig. 2 Algorithm for prioritizing criteria related to the diagnosis of IAI in BAT children

- **S**onography (positive US findings).
- **T**enderness (abdominal tenderness).
- **A**bnormal WBC levels (high WBC levels).
- **R**ed urine (hematuria).

These criteria were chosen based on an extensive literature review, validation by clinical experts, and preliminary data analysis. To evaluate the diagnostic value of these criteria, we employed statistical methods such as univariate analysis, logistic regression, and receiver operating characteristic (ROC) analysis. Our findings indicated that each of these variables independently increased the risk of IAI, leading to the development of the STAR (Sonography, Tenderness, Abnormal WBC, Red urine) scoring system.

Designed to maximize both sensitivity and specificity, the STAR scoring system utilizes a cutoff point of ≥ 2 to indicate a higher risk of IAI. The performance metrics of the STAR scoring system, including sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), are detailed in Table 4.

Discussion

In the present study, 15% of BAT children were identified with a definite diagnosis of IAI. There was no significant difference in age, gender, and mechanism of injury between children with and without IAI. The hemodynamic parameters of these patients were stable, and all of them had a full level of consciousness (GCS = 15). In the US, more than 90% of these individuals reported mild free fluid, which was considered positive. Therefore, the positivity of the US finding had a direct and significant relationship with the presence of IAI in these children so this criterion alone with sensitivity and specificity of 92.59% and 44.44%, respectively, had a significant value in diagnosing the existence of IAI.

Consistent with the mentioned finding, many studies have reported the diagnostic value of ultrasound with a sensitivity of 20–80% and specificity of 77–100% in predicting IAI in children with trauma [27–33].

A review study reported that in children with hemodynamically stable BAT and a GCS of 14 to 15, a positive FAST or point-of-care ultrasound (POCUS) examination result means that IAI is likely; however, a negative examination result alone cannot prevent further diagnostic actions for IAI. The results of the diagnostic value of the CT scan had a sensitivity of 97.7% and specificity of 84.7% with oral contrast and a sensitivity of 98% and specificity of 81% without the use of oral contrast. Therefore, they stated that there was no need for a CT scan in low-risk BAT children with a GCS of 14 to 15, a normal abdominal examination, and a negative US finding [34]. In this regard, Ellison et al. reported the prevalence of IAI to be 14% in 4897 children with blunt torso trauma following an abdominal CT scan with and without oral contrast [35]. Given that the risk associated with a CT scan diagnostic test is evaluated at 0.00023, and the risk of cancer caused by radiation from an abdominal CT scan is reported to be 20 per 100,000 in male children and 26 per 100,000 in female children [36], performing more detailed assessments may enable accurate diagnosis of IAI in many of these children.

In addition, abdominal tenderness was one of the most common symptoms in the physical examination of these patients and had a direct and significant relationship with the presence of IAI. The sensitivity and specificity of this criterion in detecting the presence of IAI was equal to 81.48% and 87.58%, respectively. In this respect, physical examination can be treated as a crucial step while evaluating abdominal trauma. A review of the literature indicated that the initial sign is abdominal tenderness with a prevalence of 67–75%, followed by the defense with a prevalence of 24–39% and contracture with a prevalence of 16–21%. Clinical judgment as well as physical examination has a specific significance regarding intestinal injury [3, 37].

In line with this study, another study investigating IAI following blunt torso trauma introduced abnormal abdominal examination including distension, tenderness, peritonitis, or contusion, and showed that 76.5% of patients with IAI and only 11.1% of patients without IAI had an abnormal abdominal examination. They reported the sensitivity and specificity of this criterion in detecting the presence of IAI as 76% and 89%, respectively [38].

Holmes et al. also reported abdominal tenderness in 59% of children with IAI and 29% of children without IAI. They figured out a direct and significant relationship between this criterion and IAI (adjusted OR: 5.8; 95% CI: 3.2 to 10.4) [39].

Hematuria and a high level of WBC are among the laboratory findings that had a direct relationship with the presence of IAI and had a significant value in detecting the presence of IAI with a sensitivity of 62.96% and 85.19% and specificity of 50.33% and 76.47%, respectively.

The potential role of artificial intelligence (AI) in assessing pediatric trauma is an emerging and promising field. AI applications can significantly enhance diagnostic accuracy, predict patient outcomes, and optimize clinical workflows. For example, Di Sarno et al. (2024) highlighted that AI could provide decision support systems, image analysis, and risk stratification tools that improve the assessment and management of pediatric traumas [40]. AI algorithms can analyze medical images to detect subtle signs of injuries that might be missed by human observers, as demonstrated in the study by Lampros et al. (2024) on pediatric traumatic brain injury [41]. Furthermore, AI-driven predictive models can assist clinicians in determining the likelihood of intra-abdominal injuries based on clinical and laboratory data, reducing the reliance on CT scans and minimizing radiation exposure to children. Additionally, Maleeha et al. (2022) discussed how AI systems can provide real-time decision support, ensuring timely and effective care [42]. Integrating AI into pediatric trauma assessment holds great promise for improving patient management and outcomes [40–42].

In a study on adult patients with blunt intra-abdominal injury, Nishijima et al. reported that hematuria with a sensitivity of 41% and specificity of 90% along with abnormal WBC (WBC > 10,000 cell/μL) with a sensitivity of 81% and specificity of 54% were valuable in diagnosing IAI. They also examined some other laboratory parameters such as liver factors, hematocrit, and serum lactate, and evaluated their sensitivity and specificity in diagnosing the presence of IAI [26].

Hematuria was associated with IAI in some previous studies on children with blunt trauma [39, 43]. However, the use of microscopic hematuria in evaluating children with blunt trauma is controversial [43]. Previous studies have suggested microscopic hematuria cut-off points of more than 5 RBC/hpf, more than 20 RBC/hpf, and more than 50 RBC/hpf for predicting IAI [44–46]. The current study's researchers considered a threshold of over 25 RBC/hpf as a conservative value and identified it as an independent predictor of IAI, despite having a lower diagnostic value compared to the other three criteria. Consequently, this evaluation can be summarized as follows: each of the four criteria (positive ultrasound findings, presence of abdominal tenderness, hematuria, and elevated WBC levels) significantly contributed to diagnosing IAI in children. The study's objective was to develop a scoring system based on specific criteria to achieve a more accurate diagnosis of IAI in children who have experienced BAT. It is worth mentioning that, according to the current researchers, this system necessitates high specificity (high negative predictive value) in addition to high sensitivity, ensuring that no positive cases are overlooked.

To achieve this, the STAR scoring system was developed, incorporating four criteria: **S**onography (positive ultrasound findings), **T**enderness (abdominal tenderness), **A**bnormal WBC levels (elevated WBC levels), and **R**ed urine (hematuria). This scoring system ranges from 0 to 4. According to ROC analysis, if more than two of these four criteria are positive, the presence of IAI can be detected with a sensitivity of 81.48% and a specificity of 94.12% (AUC = 0.94; P value < 0.001). This rating brings us very close to our goal, as it not only offers high sensitivity but also a specificity exceeding 90%.

A score from 0 to 4 is obtained by combining these four criteria. A score of 1 indicates a positive result from one of these criteria, with each criterion's diagnostic value mentioned above. According to ROC analysis, if more than two of these four criteria are positive, the presence of IAI can be detected with a sensitivity of 81.48% and a specificity of 94.12% (AUC = 0.94; P value < 0.001). This rating brings us very close to our goal, as it offers both high sensitivity and specificity exceeding 90%.

A clinical decision rule to identify low-risk patients in pediatric blunt abdominal trauma was developed by Holmes et al. and had seven criteria including abdominal tenderness, abdominal pain, GCS, physical evidence of thoracic trauma, vomiting, physical evidence of abdominal wall trauma, and abnormal breath sounds on auscultation. A 0.3% pretest probability of an IAI requiring intervention was specified for children with blunt torso trauma without abdominal tenderness on examination, with GCS of 14 to 15, and without evidence of abdominal wall trauma or seatbelt sign [47]. Therefore, they stated that a BAT child without physical evidence of trauma, normal GCS, no abdominal tenderness, and a negative POCUS FAST result may not need further investigation for IAI because the risk of test-induced harm in this patient outweighs the likelihood of detection [47].

Streck et al.'s study defined a prediction model based on six high-risk clinical variables for blunt IAI including elevated aspartate aminotransferase, abnormal abdominal examination, hypotension, heme-positive urinalysis, elevated amylase, and low hematocrit. The mentioned study showed that the use of this prediction model can reduce the cost and radiation exposure by reducing the number of abdominal CT scans in children evaluated for BAT [5].

In another study, a proposed algorithm for evaluating IAI in children with intra-abdominal injuries has been presented. According to their study, laboratory testing could remarkably contribute to identifying children with intra-abdominal injuries after adjustment of physical examination findings. Some of the significant predictors of intra-abdominal injuries in children sustaining blunt torso trauma comprised femur fracture, abdominal tenderness, an initial hematocrit of less than 30%, AST of more than 200 U/L or ALT of more than 125 U/L, hematuria of more than 5 RBCs/hpf, and low systolic blood pressure. A significant risk for intra-abdominal injury should be considered for pediatric blunt trauma patients having any one of the mentioned findings, while the lack of these factors introduces low-risk patients for intra-abdominal injury [39].

The current study tried to find an algorithm for prioritizing the role of these criteria in diagnosing the presence of IAI. Based on the final results of this study, it is recommended that physicians prioritize the positive ultrasound findings in the diagnostic algorithm for identifying IAI in children with BAT. Subsequently, abdominal tenderness is an important and useful clinical sign that is the second priority. The high level of WBC and hematuria are the next priorities effective in the diagnosis of IAI. Therefore, in examining the existence of IAI in BAT children, it seems that following the order of prioritization and the priority of evaluation for scoring these patients according to this flowchart can be the best diagnostic selection algorithm with the highest accuracy. Previous evaluations have indicated that a positive FAST examination can eliminate the need for a CT scan in hemodynamically unstable patients. In contrast, a negative FAST examination cannot rule out IAI due to BAT alone [48]. It is important to clarify that our study was not designed to exclude IAI but rather aimed to establish an accurate and reliable diagnostic criterion that reduces the reliance on CT scans. Therefore, this study may be valuable in minimizing the use of high-risk diagnostic tools like CT scans.

Due to the retrospective nature of this study, some patients were excluded because of incomplete information in their records, resulting in a small sample size. Hence, in order to overcome these limitations, the researchers aim at conducting a prospective study using this diagnostic tool on a population of BAT children and evaluating the claims on its accuracy in practice, so that possible deficiencies can be discovered and resolved.

Limitations

This study has several limitations. The retrospective design restricts control over confounding variables and causality. Issues with impaired and incomplete data in the hospital's database may have affected the accuracy of the findings. The relatively small sample size of 180 patients limits the generalizability of the results to a broader population. Additionally, the study was conducted at only two hospitals in Isfahan, which may affect the applicability of the findings to other regions or healthcare settings. The short follow-up period of two weeks may not capture all instances of IAI, and the reliance on parental recall for telephone follow-ups introduces potential recall bias.

While our method of identifying IAI through medical records and follow-up telephone calls provides valuable insights, it may not cover all cases with or without IAI. Some cases may be missed due to limitations in the completeness of medical records, potential discrepancies in follow-up information, and the inherent challenges of remote assessments. Additionally, not all patients may have undergone a CT scan or returned for follow-up care, which could lead to underreporting of IAI cases. These limitations highlight the need for further studies with comprehensive and standardized follow-up protocols to ensure more accurate identification of IAIs.

Conclusion

The findings of this study demonstrate that the STAR scoring system based on positive US findings, abdominal tenderness, hematuria, and high WBC levels can effectively diagnose IAI in children with BAT. By assigning scores to these criteria, we found that a combined score of 2 or more indicates a high probability of IAI with maximum sensitivity and specificity. This scoring system provides a practical tool for clinicians, allowing them to make more accurate and timely decisions regarding the need for further diagnostic imaging and treatment interventions.

In clinical practice, implementing this scoring system can significantly reduce the reliance on CT scans, thereby minimizing children's exposure to harmful radiation. Moreover, this tool can help streamline the diagnostic process in emergency settings, ensuring that children with a high risk of IAI receive prompt and appropriate care. Future prospective studies are recommended to validate this scoring system and further refine its accuracy and utility in different clinical settings.

Implications for practice

The STAR scoring system offers several key benefits for clinical practice:

1. **Enhanced Diagnostic Accuracy**: Allows for more precise diagnosis of IAI in children with BAT, improving patient outcomes.
2. **Reduced Radiation Exposure**: Minimizes reliance on CT scans, reducing harmful radiation exposure for children.
3. **Streamlined Emergency Care**: Provides a clear framework for quicker decision-making in emergency settings.
4. **Resource Optimization**: Reduces unnecessary imaging, optimizing medical resource allocation and cost savings.
5. **Educational Tool**: Serves as a training aid for medical professionals, improving diagnostic skills.
6. **Future Research**: Emphasizes the need for further validation and refinement to enhance accuracy and utility across diverse clinical settings.

This scoring system can significantly improve diagnostic processes, optimize resource use, and ensure prompt care for children at high risk of IAI.

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Author contributions
M.N.I., E.N.N., and F.H. contributed to the conception and design of the work. M.N.I., Z.R., and E.N.N. contributed to data interpretation, drafting, and critical revision of the paper. Z.R. and N.S.F. helped with data collection. N.S.F. contributed significantly to the design and drawing of the informative and impactful algorithm, providing invaluable support throughout the project. All authors read and approved the final version of the article.

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Data availability
Data are available upon reasonable request from the corresponding author.

Declarations

Competing interests
The authors declare no competing interests.

Conflict of interest
The authors declare that they have no conflicts of interest.

Ethics approval and consent to participate
The study was conducted in accordance with the Declaration of Helsinki in its current version (World Medical Association [WMA], 2013). The ethics committee of Isfahan University of Medical Sciences approved this study (approval number: IR.MUI.MED.REC.1403.285). Through the informed oral consent of patients or their first-degree relatives, data were collected and presented anonymously in this project.

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References

1. Mele V, Piccolo CL, Trinci M, Galluzzo M, Ianniello S, Brunese L. Diagnostic imaging of blunt abdominal trauma in pediatric patients. Radiol Med. 2016;121(5):409–30. https://doi.org/10.1007/s11547-016-0637-2.
2. Drexel S, Azarow K, Jafri MA. Abdominal trauma evaluation for the pediatric surgeon. Surg Clin North Am. 2017;97(1):59–74. https://doi.org/10.1016/j.suc.2016.08.004.
3. Chaudhari PP, Rodean J, Spurrier RG, Hall M, Marin JR, Ramgopal S, Alpern ER, Shah SS, Freedman SB, Cohen E, Morse RB, Neuman MI. Epidemiology and management of abdominal injuries in children. Acad Emerg Med. 2022;29(8):944–53. https://doi.org/10.1111/acem.14497.
4. Sabounji SM, Gueye D, Ngom G. Blunt abdominal trauma in children: A review of 105 cases. J Indian Assoc Pediatr Surg. 2023 Jan-Feb;28(1):48–53. https://doi.org/10.4103/jiaps.jiaps_171_21.

5. Streck CJ, Vogel AM, Zhang J, et al. Identifying children at very low risk for blunt intra-abdominal injury in whom CT of the abdomen can be avoided safely. J Am Coll Surg. 2017;224(4):449–e4583.
6. Bixby SD, Callahan MJ, Taylor GA. Imaging in pediatric blunt abdominal trauma. Semin Roentgenol. 2008;43(1):72–82.
7. Holmes JF, Lillis K, Monroe D, Borgialli D, Kerrey BT, Mahajan P, et al. Identifying children at very low risk of clinically important blunt abdominal injuries. Ann Emerg Med [Internet]. 2013;62(2):107–e1162. https://doi.org/10.1016/j.annemergmed.2012.11.009.
8. STRECK OCHOAB. Christian. Pediatric blunt abdominal trauma evaluation and management pathways. Curr Trauma Rep. Jg., Nr. 2023;4:9.
9. Arbogast KB, Kent RW, Menon RA, Ghati Y, Durbin DR, Rouhana SW. Mechanisms of abdominal organ injury in seat belt-restrained children. J Trauma. 2007;62(6):1473–80. https://doi.org/10.1097/01.ta.0000231965.20704.16.
10. Fortin K, Wood JN. Utility of screening Urinalysis to detect abdominal injuries in suspected victims of child physical abuse. Child Abus Negl. 2020;109.
11. Afzalimoghaddam M, Fattahi M, Pourghorban R, Eftekhari M, Abdollahi A. The accuracy of various types of Urinalysis in terms of predicting intra-abdominal injury in emergency trauma patients: A diagnostic accuracy study. Arch Trauma Res. 2021;10(1):13.
12. Heydari F, Ashrafi A, Kolahdouzan M. Diagnostic accuracy of focused assessment with sonography for blunt abdominal trauma in pediatric patients performed by emergency medicine residents versus radiology residents. Front Emerg Med. 2018;2(3):e31.
13. Holmes JF, Mao A, Awasthi S, McKenzie R, Wisner DH, Kuppermann N. Validation of a prediction rule for the identification of children with intra-abdominal injuries after blunt torso trauma. Ann Emerg Med. 2009;54(4):528–e5331.
14. Bašković M, Keretić D, Lacković M, Borić Krakar M, Pogorelić Z. The diagnosis and management of pediatric blunt abdominal Trauma—A. Compr Rev Diagnostics (Basel). 2024;14(20):2257. https://doi.org/10.3390/diagnostics14202257.
15. Scaife ER, Rollins MD, Barnhart DC, Downey EC, Black RE, Meyers RL, et al. The role of focused abdominal sonography for trauma (FAST) in pediatric blunt abdominal trauma. J Pediatr Surg. 2013;48(6):1377–83.
16. Notrica DM. Pediatric blunt abdominal trauma: current management. Curr Opin Pediatr. 2015;27(3):323–9.
17. Hom J. The risk of Intra-abdominal injuries in pediatric patients with stable blunt abdominal trauma and negative abdominal computed tomography. Acad Emerg Med. 2010;17(5):469–75.
18. Fox JC, Boysen M, Gharahbaghian L, Cusick S, Ahmed SS, Anderson CL, Lekawa M, Langdorf MI. Test characteristics of focused assessment of sonography for trauma for clinically significant abdominal free fluid in pediatric blunt abdominal trauma. Acad Emerg Med. 2011;18(5):477–82.
19. Retzlaff T, Hirsch W, Till H, Rolle U. Is sonography reliable for the diagnosis of pediatric blunt abdominal trauma? J Pediatr Surg [Internet]. 2010;45(5):912–5. https://doi.org/10.1016/j.jpedsurg.2010.02.020.
20. Chatoorgoon K, Brown RL, Garcia VF, Falcone RA. Role of computed tomography and clinical findings in pediatric blunt intestinal injury: A multicenter study. Pediatr Emerg Care. 2012;28(12):1338–42.
21. Rice HE, Frush DP, Farmer D, Waldhausen JH. Review of radiation risks from computed tomography: essentials for the pediatric surgeon. J Pediatr Surg. 2007;42(4):603–7.
22. Ibrahim AA, Ismail AM, Ahmed Ali M, Ismail FH. Leukocyte count as a predictor of severity of injury in pediatric blunt abdominal trauma. World J Surg Surg Res. 2019;2:1107.
23. Rau CS, Kuo CH, Tsai CH, Chou SE, Su WT, Hsu SY, et al. Elevation of white blood cell subtypes in adult trauma patients with Stress-Induced hyperglycemia. Diagnostics. 2023;13(22):3451.
24. Faridaalaee G, et al. Correlation of white blood cell count and severity of injury in abdominal trauma; a cross-sectional study. World J Emerg Med. 2013;4(3):214–8.
25. Ka O, et al. Value of white blood cell count as a predictor of organ injury in adults with abdominal trauma. J Trauma Acute Care Surg. 2015;78(4):752–8.
26. Hershkovitz Y, et al. Elevated white blood cell count, decreased hematocrit, and presence of macrohematuria correlate with abdominal organ injury in pediatric blunt trauma patients: a retrospective study. J Pediatr Surg. 2020;55(1):49–54.
27. Nishijima DK, Simel DL, Wisner DH, Holmes JF. Does this adult patient have a blunt intra-abdominal injury? JAMA. 2012;307(14):1517–27.
28. Holmes JF, Harris D, Battistella FD. Performance of abdominal ultrasonography in pediatric blunt trauma patients: A meta-analysis. J Trauma Acute Care Surg. 2020;89(4):723–31. https://doi.org/10.1097/TA.0000000000002834.
29. Corbett SW, Andrews HG, Baker EM, et al. ED evaluation of the pediatric trauma patient by ultrasonography. Am J Emerg Med. 2000;18:244–9.
30. Suthers SE, Albrecht R, Foley D, et al. Surgeon-directed ultrasound for trauma is a predictor of intra-abdominal injury in children. Am Surg. 2004;70:164–7. discussion 167–8.
31. Fox JC, Boysen M, Gharahbaghian L, et al. Test characteristics of focused assessment of sonography for trauma for clinically significant abdominal free fluid in pediatric blunt abdominal trauma. Acad Emerg Med. 2011;18:476–82.
32. Tummers W, van Schuppen J, Langeveld H, et al. Role of focused assessment with sonography for trauma as a screening tool for blunt abdominal trauma in young children after high energy trauma. S Afr J Surg. 2016;54:28–34.
33. Calder BW, Vogel AM, Zhang JW, et al. Focused assessment with sonography for trauma in children after blunt abdominal trauma: a multi-institutional analysis. J Trauma Acute Care Surg. 2017;83:218–24.
34. Holmes JF, Kelley KM, Wootton-Gorges SL, et al. Effect of abdominal ultrasound on clinical care, outcomes, and resource use among children with blunt torso trauma: a randomized clinical trial. JAMA. 2017;317:2290–6.
35. Liang T, Roseman E, Gao M, Sinert R. The utility of the focused assessment with sonography in trauma examination in pediatric blunt abdominal trauma: a systematic review and meta-analysis. Pediatr Emerg Care. 2021;37(2):108–18.
36. Ellison AM, Quayle KS, Bonsu B, et al. Use of oral contrast for abdominal computed tomography in children with blunt torso trauma. Ann Emerg Med. 2015;66:107–e144.
37. Krahn MJ, UngarWJ M, et al. Acute appendicitis in young children: cost-effectiveness of US versus CT in diagnosis—a Markov decision analytic model. Radiology. 2009;250:378–86.
38. Karamercan A, Yilmaz TU, Karamercan MA, Aytaç B. Blunt abdominal trauma: evaluation of diagnostic options and surgical outcomes. Ulus Travma Acil Cerrahi Derg. 2008;14:205–10.
39. Holmes JF, Sokolove PE, Brant WE, Palchak MJ, Vance CW, Owings JT, Kuppermann N. Identification of children with intra-abdominal injuries after blunt trauma. Ann Emerg Med. 2002;39(5):500-9. https://doi.org/10.1067/mem.2002.122900. PMID: 11973557.
40. Di Sarno L, Caroselli A, Tonin G, Graglia B, Pansini V, Causio FA, Gatto A, Chiaretti A. Artificial intelligence in pediatric emergency medicine: applications, challenges, and future perspectives. Biomedicines. 2024;12(6):1220. https://doi.org/10.3390/biomedicines12061220. PMID: 38927427; PMCID: PMC11200597.
41. Lampros M, Symeou S, Vlachos N, Gkampenis A, Zigouris A, Voulgaris S, Alexiou GA. Applications of machine learning in pediatric traumatic brain injury (pTBI): a systematic review of the literature. Neurosurg Rev. 2024;47:737. https://doi.org/10.1007/s10143-024-02955-3.
42. Maleeha Naseem H, Arshad S, Ashraf. The role of artificial intelligence in pediatric injuries-a scoping review. Injury Prevention. 2022;28(Suppl 2):A85.1. https://doi.org/10.1136/injuryprev-2022-safety2022.252
43. Soon BK, Weizhong H. Kapur, Jeevesh. Imaging modalities in renal trauma. Atlas of radiology in pediatric kidney disorders. Singapore: Springer Nature Singapore; 2025. pp. 243–9.
44. Holmes JF et al. Clinical prediction rules for identifying adults at very low risk for intra-abdominal injuries after blunt trauma. Ann Emerg Med, 2009, 54. Jg., Nr. 4, S. 575–584.
45. Capraro AJ, Mooney D, Waltzman ML. The use of routine laboratory studies as screening tools in pediatric abdominal trauma. Pediatr Emerg Care. Jg., Nr. 2006;7:480–4. 22.
46. Seyedhosseini-Davarani S, et al. The value of Urinalysis in detection of abdominal organ injuries in children with hematuria following blunt abdominal trauma; a diagnostic study. Int J Pediatr. Jg., Nr. 2017;11:6103–10. 5.
47. Holmes JF, Lillis K. Identifying children at very Lowrisk of clinically important blunt abdominal injuries. Ann Emerg Med. 2013;62:107–e1162.
48. Fornari MJ, Lawson SL. Pediatric blunt abdominal trauma and point-of-care ultrasound. Pediatr Emerg Care. 2021;37(12):624–9.

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