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ORIGINAL ARTICLE

Management of pediatric blunt abdominal trauma with split liver or spleen injuries: a retrospective study

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Abstract

Background Blunt abdominal trauma is a prevailing cause of pediatric morbidity and mortality. It constitutes the most frequent type of pediatric injuries. Contrast-enhanced sonography (CEUS) and contrast-enhanced computed tomography (CECT) are considered pivotal diagnostic modalities in hemodynamically stable patients.

Aim To report the experience in management of pediatric split liver and spleen injuries using CEUS and CECT.

Patients and methods This study included 246 children who sustained blunt abdominal trauma, and admitted and treated at three tertiary hospitals in the period of 5 years. Primary resuscitation was offered to all children based on the advanced trauma and life support (ATLS) protocol. A special algorithm for decision-making was followed. It incorporated the FAST, baseline ultrasound (US), CEUS, and CECT. Patients were treated according to the imaging findings and hemodynamic stability.

Results All 246 children who sustained a blunt abdominal were studied. Patients' age was 10.5 ± 2.1. Road traffic accidents were the most common cause of trauma; 155 patients (63%). CECT showed the extent of injury in 153 patients' spleen (62%) and 78 patients' liver (32%), while the remaining 15 (6%) patients had both injuries. CEUS detected 142 (57.7%) spleen injury, and 67 (27.2%) liver injury.

Conclusions CEUS may be a useful diagnostic tool among hemodynamically stable children who sustained low-to-moderate energy isolated blunt abdominal trauma. It may be also helpful for further evaluation of uncertain CECT findings and follow-up of conservatively managed traumatic injuries.

Keywords Pediatric · Blunt abdominal trauma · CECT · CEUS · Spleen · Liver

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Introduction

Children's abdominal trauma poses a challenging dilemma to emergency physicians, pediatricians, and pediatric surgeons [1, 2]. Blunt force trauma constitutes the most common type of pediatric injuries (90%) [3–6]. The frequently injured organs are the spleen and liver, followed by the kidneys, small bowel, and pancreas [7–9]. Non-operative management (NOM) of blunt trauma although started for more than 40 years back is still slowly adopted by many health facilities [10]. Solid organ injuries account for 70–90% in cases of hepatic injury and about 60% of patients with injured spleen. Such injuries necessitated the use of different imaging modalities for diagnosis after the primary resuscitation [11, 12]. These imaging modalities include Focused Assessment with Sonography for Trauma (FAST) which is the initial tool to determine the treatment cascade. Contrast-enhanced sonography (CEUS) and contrast-enhanced computed tomography (CECT) are used as diagnostic modalities in hemodynamically stable patients [13]. They may also be used to observe the progress in healing of traumatized organ [12]. Currently, CEUS is used to follow-up blunt abdominal trauma, since it entails low radiological hazards as well as its availability and feasibility [14].

Moreover, most centers are moving away from using the CECT alone to grade abdominal injury to dictate non-operative management protocols. CEUS may be an aid for further evaluation of uncertain CECT findings and follow-up of conservatively managed traumatic injuries [15].

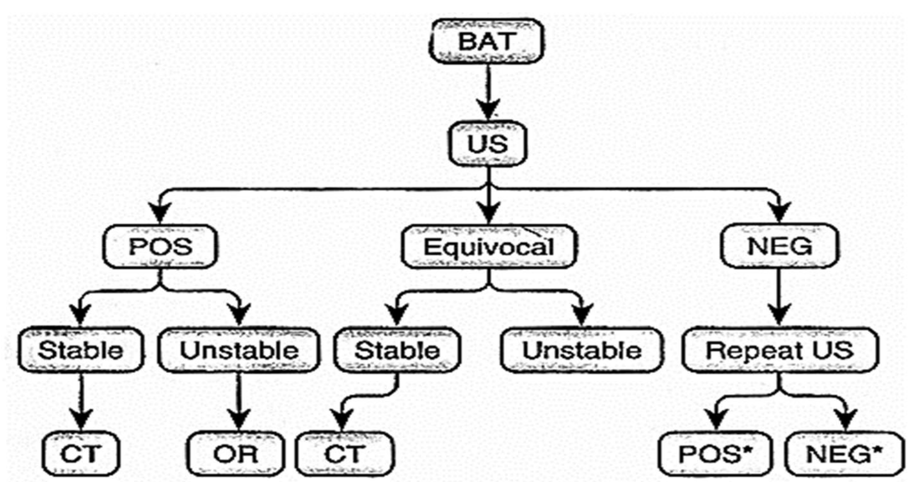
The current study was conducted to retrospectively report a local experience in management of pediatric split liver and spleen injuries. It also aimed to highlight the role of CEUS and CECT in management of blunt pediatric trauma investigating the CEUS role in verification of uncertain CECT findings during the follow-up of conservatively managed patient.

Methodology

This 5-year-retrospective study took place within the general trauma divisions of three local tertiary hospitals in the period from January 2015 to December 2020. It included children sustaining blunt abdominal trauma who were admitted and treated during this period. Excluded were those who suffered from blunt trauma with extra-abdominal major injuries. Patients who were hemodynamically unstable after adequate resuscitation as well as children with early or subsequent generalized peritonitis were also excluded.

Initial resuscitation was carried out hand in hand with history and examination according to the ATLS protocol [1]. After resuscitation, a special algorithm for decision-making was followed (Fig. 1).

Attending staff at emergency room including emergency physicians and attending pediatricians initially performed FAST to the hemodynamically stable traumatized patient. The three hospitals have the same type and techniques for imaging using similar ultrasonography machines as well as CT machines settings for all patients. CEUS was done using the harmonic, low mechanical index, contrast-specific software, contrast tuned imaging (CnTI), and pulse inversion. It was done after an initial based line ultrasound. Linear and curved transducers were used with sonographic frequencies ranged from 2.5 to 7.5 MHz, using (Siemens Sonoline



BAT= Blunt abdominal trauma. US= Ultrasound

POS= Positive NEG= Negative

CT= Computed tomography OR= Operative room

Fig. 1 Adopted algorithm after Staren [16] for management of children with blunt abdominal trauma in our study

Elegra, Germany) ultrasound system. An intravenous injection of Lumason contrast agent was introduced by the dosage of 0.03 mL/kg based on pediatrics body weight [15]. The maximum dosage per every bolus injection was 2.4 mL. CECT scans were blindly reported by another expert radiology consultant. All scans took place using a 256-multislice CT scanner Somatom Sensation (Siemens Medical Systems, Erlangen, Germany) with a slice width of 10 mm, a 2.5 mm collimation, a 0.75 s rotation time, a table feed of 15 mm, and a 3 mm reconstruction interval. Pre- and post-contrast scans were routinely performed. Patients received 1–2 mL/kg of intravenous contrast medium (Iohexol, 300 mg/mL). Serial scans were acquired routinely during the portal venous phase approximately 80 s after the contrast injection, and arterial phase 20 s in case of hemodynamic instability (5 patients). Reformatted sagittal and coronal images were obtained using the maximum intensity projection (MIP) and multiplanar reformation (MPR) techniques. Lower thoracic CECT scans were included as routine [15]. Critical patients were not assessed with CEUS. Yet, immediately after a positive FAST finding, they were transferred to CT room or to operative theater depending on their hemodynamic stability. Spleen and liver injuries were graded according to the American Association for the Surgery of Trauma (AAST) scale [16]. The scale graded from I to V. Conservative management was aborted in case of hemodynamic instability at any stage of the examination. Surgery in such conditions became an obligation.

Collected data were statistically analyzed using χ^2 analysis. P values less than 0.05 were considered statistically significant. Sensitivity and specificity were calculated. All calculations were performed using Statistical Package for Software Sciences (SPSS) version 26.0, Armonk, New York, IBM Corporation. In every center, the CEUS was performed by two expert radiologists independently. Interrater reliability was calculated using the Cohen's kappa statistics to determine the agreement between the radiologist in diagnosing liver and spleen trauma [17].

Results

The study included 246 children who sustained a blunt abdominal injury based on the previously mentioned inclusion criteria. The number of male patients were 150 (61%), while females were 96 (39%) with a ratio 1.6:1. Their age varied between 1 and 16 years with the mean of 10.5 ± 2.1 (mean ± SD). Spleen was the most frequent injured organ in 153 patients (62%), while 78 patients (32%) suffered from liver injury. The remaining 15 patients suffered from both liver and spleen injuries. Road traffic accidents (RTA) were the most common cause of trauma in 155 patients (63%). Falling from heights in 61 patients (25%) was the second cause followed by direct trauma in 27 patients (11%). Other uncommon causes like building break down triggered trauma in three patients (1%) (Table 1).

Most frequent types of splenic and liver injuries were type II (spleen = 60 patients, liver = 36 patients) according to AAST classification (Table 2).

The results of Cohen Kappa statics to determine inter-rater agreement about CEUS findings for each hospital were as follows:

1. Hospital one: There was perfect agreement between the radiologist's judgments, $\kappa = 0.88$ (95% CI 0.82–0.94), $P < 0.001$ for the liver, and $\kappa = 0.95$ (95% CI 0.91–0.99), $P < 0.001$ for the spleen.
2. Hospital two: there was substantial to perfect agreements $\kappa = 0.72$ (95% CI 0.64–0.80), $P < 0.001$ for the liver, and $\kappa = 0.81$ (95% CI 0.71–0.91), $P < 0.001$ for the spleen.
3. Hospital three: there was perfect agreements among raters $\kappa = 0.84$ (95% CI 0.76–0.92), $P < 0.001$ for the liver, and $\kappa = 0.89$ (95% CI 0.81–0.97), $P < 0.001$ for the spleen.

From the aforementioned results, we concluded that inter-rater reliability is ranging from substantial to perfect for liver's CEUS assessment. On the other hand, it was almost perfect for spleen's CEUS examination.

Table 1 Relation between cause and type of injury

Sex	Causes of trauma				Type of injury			Total
	RTA	Fall from heights	Direct trauma	Building collapse	Splenic	Liver	Both liver and spleen	
Male	93	40	15	2	88	54	8	150
Female	62	21	12	1	65	24	7	96
Total	155	61	27	3	153	78	15	246

Table 2 Distribution of patients according to the AAST classification ($n = 246$)

AAST grades	0	< I	I	II	III	IV
Liver	155	5	33	36	12	5
Spleen	73	20	31	60	57	5

Fig. 2 Focused ultrasound for a blunt abdominal trauma (FAST) showing Morrison pouch anechoic collection

Fig. 3 FAST—free fluid in right paracolic gutter extending to Morrison pouch

Among children included in this study, the decision to abort conservative treatment had to be taken in nine patients (3.7%). All children underwent FAST assessment (Figs. 2, 3). CECT showed splenic lacerations (Figs. 4, 5) While, Figs. 6, 7, 8 showed different grades of liver injuries. The notion that patients with negative FAST might have positive CT findings was not investigated, as negative FAST patients who were hemodynamically stable undergone no further radiological studies.

CEUS detected 142 (57.7%) spleen injury and 67 (27.2%) liver injury. It enabled identification of intraabdominal injuries (Figs. 8, 9). Its sensitivity, specificity, and overall accuracy in detecting spleen injury were 89.5%, 94.6%, and 91.4%, respectively. While its capability to detect liver injury was 75.6% sensitivity, 95.2% specificity, with an overall

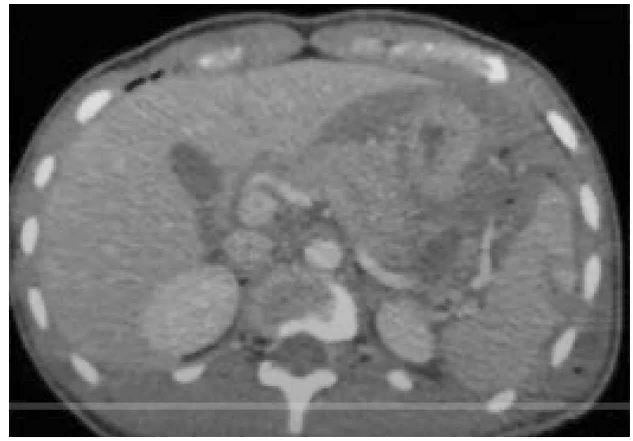


Fig. 4 Splenic lacerations

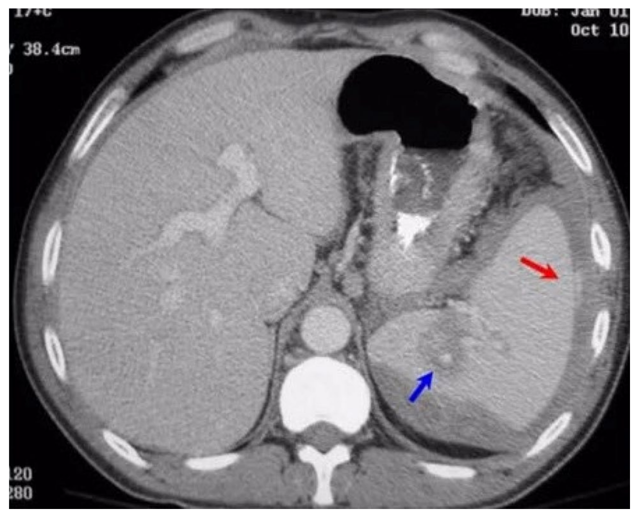


Fig. 5 Splenic lacerations

Fig. 6 Grade II, liver lacerations

Fig. 7 Compressed liver parenchyma due to subcapsular hematoma (grade II)

Fig. 8 CEUS splenic laceration

accuracy rate of 89%. However, specificity of CECT was higher than CEUS.

In addition, the positive predictive value for CEUS in splenic injury was (96.5%). This was significantly higher than that for liver (88.1%) (Fig. 10).

Discussion

Blunt abdominal trauma accounts for the vast majority of pediatric injuries [18, 19]. Most of these injuries are due to automobile crashes. Yet, little percentage of children sustains abdominal trauma due to falling from heights. In preschool population, direct injuries constitute a significant cause of abdominal trauma. On the other hand, school children suffer from abdominal trauma due to bicycles-ridings injuries.

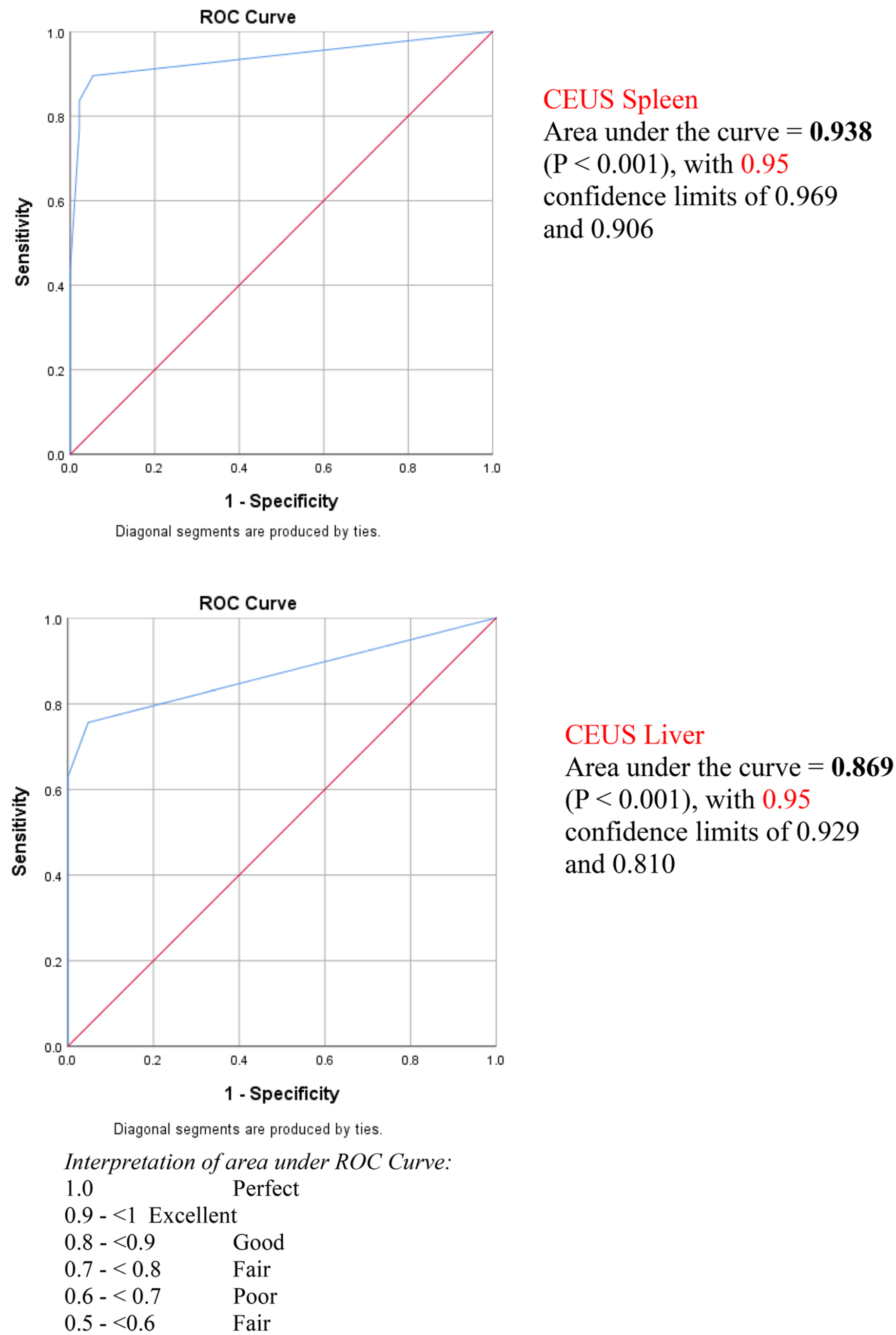
Fig. 9 CEUS handle bar splenic injury

The most common reason is handlebar injury [20–22]. Special age for pediatric trauma is not yet well formalized. The current study population's age was 10.5 ± 1.3 years, contradicting others who reported a mean age of 6.6 ± 0.8 for pediatric trauma [23]. Nevertheless, some reported the mean age for pediatric trauma to be 8.9 years [22]. The current study showed boys (61%) to be more injured compared to girls (39%). This coincides with previously published data [23–25]. The reason may be attributed to the fact that males are more active and usually exposed to violence more than females. We reported RTA as the most common cause of pediatric abdominal injury followed by falling from heights, which is in line with the previous studies [23–25]. Lower road safety standers may be the most accused drive for such data. Splenic injuries were recorded to be more common (65%) compared to liver injuries (35%) simulating other data [26–29]. Many imaging modalities are used for the diagnosis of stable trauma patients who sustained blunt abdominal injuries. CEUS is one of these used modalities.

CEUS was diagnostic in 209 (85%) of a total of 246 studied patients. On the other hand, those 246 underwent CECT scan as the confirmatory test. Solid agreement exists as regards the role of CECT in confirming the diagnosis of blunt abdominal trauma in stable patients as it identifies many injuries. Moreover, it plays a crucial role in grading the severity of injuries [30, 31]. We assessed CEUS in comparison CECT in previously mentioned reports that represented the control pinch mark [32].

Some authors reported CEUS sensitivity of 92.9%, specificity (100%), negative predictive value (100%), and positive predictive value (93.8%) when used to detect solid abdominal organs injuries [31]. This could be compared to our results of CEUS sensitivity and specificity for both

Fig. 10 Specificity and sensitivity of CEUS spleen and liver



liver and spleen injuries. CEUS is reported to play an important role in decision-making of trauma patient management [32]. On the other hand, accuracy of CECT scan in diagnosing blunt solid injuries is (97.6%) [33]. Many authors have compared CEUS to CECT in evaluation of pediatric trauma [31, 34–36]. However, other literature by Pediatric Emergency Care Applied Research Network (PECARN) proposed CEUS rather than CECT in diagnosis of pediatric trauma. This is particularly valuable in pediatric population to avoid the unwanted effect of ionizing radiation [37]. Although the accuracy of CEUS is an operator dependent, the current study showed a substantial to perfect agreement between radiologists in diagnosing and classifying liver and splenic injuries as indicated by the value of weighted Kappa. Yet, most published similar studies did not utilize the Cohen Kappa to quantify their inter-rater reliability measures. Therefore, comparing inter-rater reliability assessment measures taken in our research with the results is difficult. However, others have reported the use of kappa statistic test to evaluate the inter-rater reliability when using the CT scan for liver and spleen injuries [38, 39].

Currently, many centers are moving away from using the CECT alone to grade abdominal injury to dictate non-operative management protocols [40, 41]. They involve CEUS as an aid for further evaluation of uncertain CECT findings, and follow-up of conservatively managed traumatic injuries [42].

The current report studied a relatively limited number of patients. Hence, future extra prospective cohort studies may be needed to avoid any bias that may have occurred within this study.

Conclusion

CEUS may be a useful diagnostic tool among hemodynamically stable children who sustained low-to-moderate energy isolated blunt abdominal trauma. Moreover, it could be an asset for verification of uncertain CECT findings. Therefore, it may help for accurately following-up children during conservative management of traumatic liver and/or splenic injuries.

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Declarations

Competing interests The authors declare that they have no competing interests.

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

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