ELSEVIER

European Journal of Radiology 51 (2004) 91–96

EJR
EUROPEAN JOURNAL OF RADIOLOGY

www.elsevier.com/locate/ejrad

# The efficacy of ultrasonography in hemodynamically stable children with blunt abdominal trauma: a prospective comparison with computed tomography

Fikret Taş [a,*], Canan Ceran [b], Mehmet H. Atalar [a], Sema Bulut [a], Bilge Selbeş [a], A. Oktay Işık [a]

[a] *Department of Radiology, Faculty of Medicine, Cumhuriyet University, 58140 Sivas, Turkey*
[b] *Department of Pediatric Surgery, Faculty of Medicine, Cumhuriyet University, 58140 Sivas, Turkey*

Received 24 February 2003; received in revised form 9 May 2003; accepted 12 May 2003

**Abstract**

*Purpose:* In this prospective study we aimed to investigate the diagnostic value of ultrasonography (US) in hemodynamically stable children after blunt abdominal trauma (BAT) using computed tomography (CT) as the gold standard. *Materials and methods:* Between 1997 and 2001, 96 children with BAT were evaluated prospectively. CT was performed first, followed by US. US and CT examinations were independently evaluated by two radiologists for free fluid and organ injury. The sensitivity, specificity, positive predictive value, negative predictive value and overall accuracy of US were assessed regarding CT as the gold standard. *Results:* Overall 128 organ injuries were determined in 96 patients with CT; however, 20 (15.6%) of them could not be seen with US. Free intraabdominal fluid (FIF) was seen in 82 of 96 patients by CT (85.4%) and eight of them (9.7%) could not be seen by US. We found that sensitivity, specificity, positive predictive value, negative predictive value and overall accuracy of the US for free intra-abdominal fluid were 90.2, 100, 100, 63.6 and 91.7%, respectively. *Conclusions:* US for BAT in children is highly accurate and specific. It is highly sensitive in detecting liver, spleen and kidney injuries whereas its sensitivity is moderate for the detection of gastrointestinal tract (GIT) and pancreatic injuries.


*Keywords:* Blunt abdominal trauma; Ultrasonography; Computed tomography; Children

## 1. Introduction

In children, to choose the appropriate imaging method for evaluation of intra-abdominal organ injury (IAI) is very important because non-operative management of blunt abdominal trauma (BAT) has gained wide acceptance recently. Accurate and prompt assessment of injuries is critical, since unrecognized injuries may have potentially serious consequences. Abdominal computerized tomography (CT) is considered to be the most accurate, noninvasive imaging modality for evaluating trauma victims. Since 1980's CT has been accepted as a definitive imaging modality for injured patients in the United States [1,2]. However, in Canada, Europe and Japan, ultrasonography (US) is widely used in the examination of children with BAT [3]. High cost, radiation exposure, need for contrast media and lack of immediate availability are some of the disadvantages of CT. Therefore, US has been accepted by many clinicians. Focused abdominal sonography for trauma (FAST) is designed to evaluate trauma patients based on the presence or absence of free fluid. In pediatric population, the experience is limited and the accuracy is less certain with US [4,5].

In this prospective study, by using CT as the gold standard, we aimed to assess the diagnostic value of US in hemodynamically stable children after BAT. For this purpose we compared sensitivity, specificity, positive predictive value, negative predictive value and overall accuracy of US.

## 2. Materials and methods

All of the patients with BAT who were admitted to emergency service between 1997 and 2001, and who were younger than 16 years old were examined by a pediatric

* Corresponding author. Tel.: +90-346-219-1280; fax: +90-346-219-1284.
*E-mail address:* ftas@cumhuriyet.edu.tr (F. Taş).

0720-048X/$ – see front matter © 2003 Published by Elsevier Ireland Ltd.
doi:10.1016/S0720-048X(03)00145-1

surgeon. All of the cases who were suspected to have an intraabdominal injury and who were hemodynamically stable were sent to the radiology department. These patients underwent an abdominopelvic CT and US examination. 96 patients having an intraabdominal injury detected by CT and/or US examination were included into this study. Children with normal radiologic findings were excluded from the study. CT and US evaluations were done by two different faculty radiologists. In all patients CT was performed followed by US and the time interval between CT and US examinations was less than 2 h. Data obtained from CT and US examinations were recorded separately.

CT examinations were made with a spiral computed tomography machine (Picker$^{TM}$ PQS model, USA). Oral contrast material (1–2% urografine diluted with water) was given to 64 of 96 patients 30–45 min before CT examination. In all patients, 20 s after the intravenous bolus injection of 2 mg/kg contrast media, abdominopelvic region was scanned with 5 or 10 mm slice thickness and was evaluated by the same radiologist.

After CT examination, all patients were examined by another radiologist with Hitachi 550 EUB or General Electric Radius US equipment using 3.5-5-7.5 MHz probes. All of the US examinations were performed by a faculty radiologist working in the US department. Sonographist was not aware of the patients' clinical history, physical examination, laboratory and other imaging findings. Upper and lower quadrants of the abdomen were examined at least in two planes (longitudinal and transverse). Detected organ injuries and existence of free intraabdominal fluid (FIF) was recorded.

To determine the diagnostic value of US in detecting organ injury and FIF, all data obtained from US were compared with CT findings. Sensitivity, specificity, positive predictive value, negative predictive value and overall accuracy of the US were assessed.

Children diagnosed to have intraabdominal injury were hospitalized and treated conservatively or surgically as indicated. US had been used for the follow up of patients who did not undergo any surgical operation whereas patients who underwent surgical operation were controlled by CT initially and then by US.

Table 1
The mechanisms of the trauma

| The mechanisms of traumas | Number of patients (%) |
|---|---|
| Traffic accident | 59 (61.5%) |
| Fall | 18 (18.7%) |
| Animal attack | 8 (8.3%) |
| Sports accident | 4 (4.2%) |
| Other | 7 (7.3%) |
| Total | 96 (100%) |

## 3. Results

Twenty one girls (21.8%) and seventy five boys (78.2%), totally 96, aged between 0 and 16 years (mean 9 years of age) were investigated in this study. The mechanisms of the trauma are presented in Table 1.

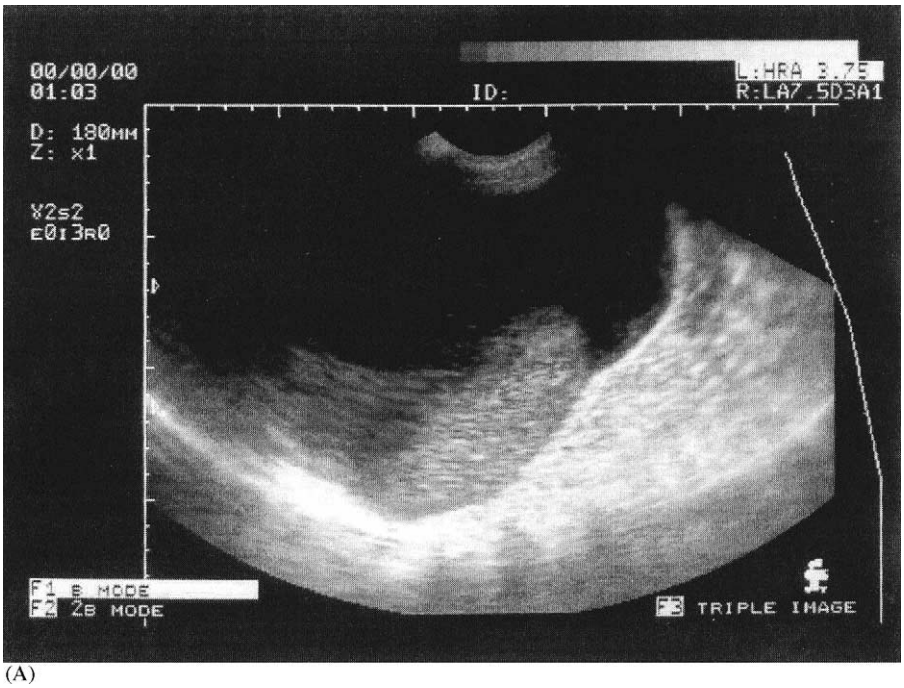
FIF were seen in 82 of 96 patients by CT (85.4%) and in 8 of these 82 patients (9.7%) FIF could not be seen by US. 14 of 96 (14.6%) patients had intraabdominal organ injury without FIF (six liver, five spleen, and three kidney injury). Sensitivity, specificity, positive predictive value, negative predictive value and overall accuracy of the US for FIF are 90.2, 100, 100, 63.6 and 91.7%, respectively (Table 2).

Overall 128 organ injuries were detected in 96 patients with CT, however, 20 (15.6%) of them could not be seen with US. The spleen was the most commonly affected organ and 22 of 51 splenic injuries were associated with other organ injuries (Fig. 1). US failed to demonstrate 8 of 51 splenic injuries. There were 46 liver injuries and 21 of them were accompanied by associated organ injuries. The most commonly injured site was the posterior segment of the right lobe ($n = 35$, 76%). US failed to demonstrate 5 of 46 liver injuries. Overall 19 kidney injuries were demonstrated by CT (Fig. 2A, B). However, two kidney injuries were overlooked by US. All of the injuries were unilateral (11 left, 8 right) and six of them were associated with other organ injuries. There were gastrointestinal injuries in nine children with BAT (two gastric, four small bowel, one colon perforation and two mesenteric injuries), in eight of nine there were associated other organ injuries. US failed to demonstrate

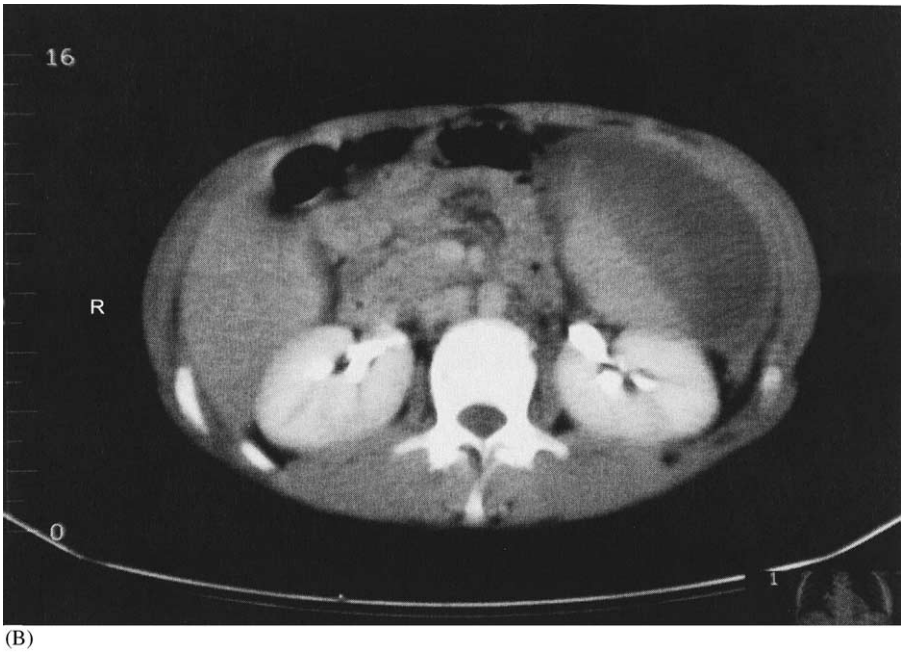
Table 2
Diagnostic values of US in detecting FIF and intraabdominal organ injury

| | TP | TN | FN | FP | Sensitivity (%) | Specificity (%) | Predictive value | | Accuracy (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Positive | Negative | |
| Free fluid | 74 | 14 | 8 | 0 | 90.2 | 100 | 100 | 63.6 | 91.7 |
| Spleen | 43 | 45 | 8 | 0 | 84.3 | 100 | 100 | 84.9 | 91.7 |
| Liver | 41 | 50 | 5 | 0 | 89.1 | 100 | 100 | 90.9 | 94.8 |
| Kidney | 17 | 77 | 2 | 0 | 89.5 | 100 | 100 | 97.5 | 97.9 |
| Intestine | 5 | 87 | 4 | 0 | 55.5 | 100 | 100 | 95.6 | 95.8 |
| Pancreas | 2 | 93 | 1 | 0 | 66.7 | 100 | 100 | 98.9 | 99.0 |

TP, True positive; TN, true negative; FN, false negative; FP, false positive.




(A)




(B)

Fig. 1. Splenic subcapsular hematoma. (A) Transverse sonogram shows a linear area of decreased echogenicity in the lateral aspect of the spleen, (B) CT scan of the same patient.

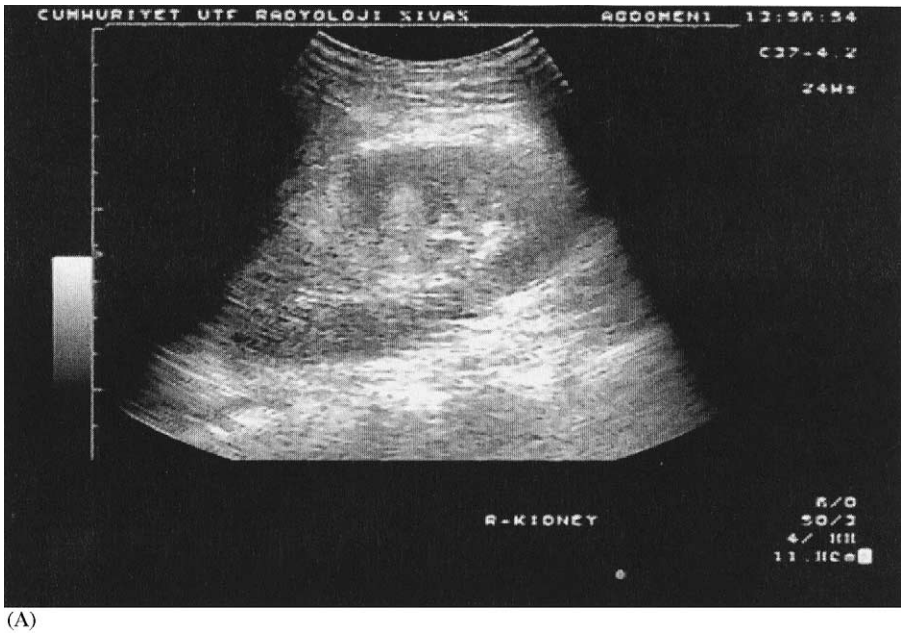
four gastrointestinal tract (GIT) injuries. There were three pancreatic injuries demonstrated by CT, all of which were associated with other organ injuries (two liver, one spleen). US failed to demonstrate one of these pancreatic injuries.

Table 2 presents the diagnostic values of US in detecting FIF and intraabdominal organ injuries.

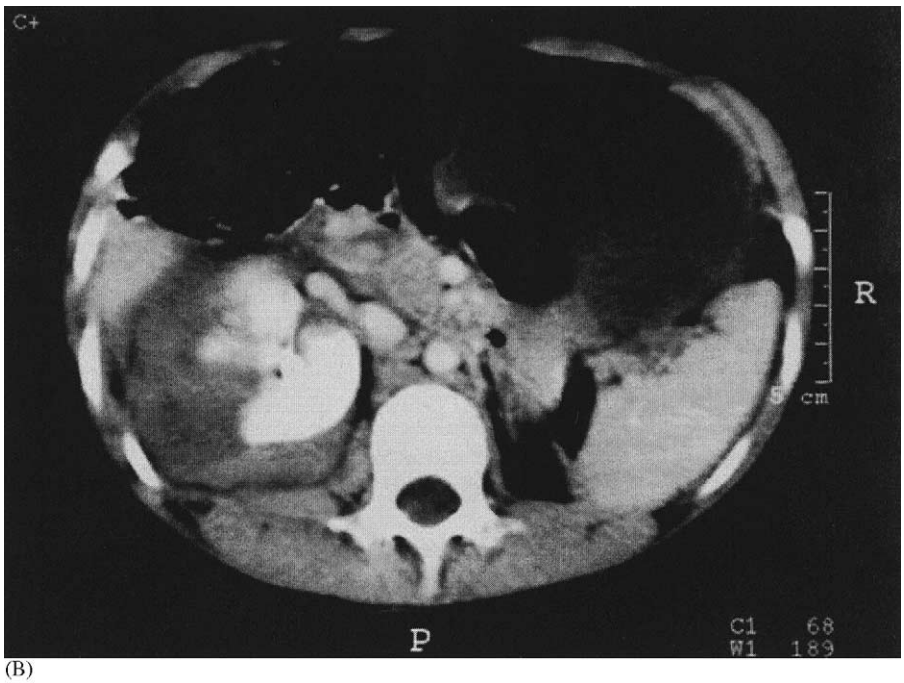
Affected organs from trauma determined by CT, distribution of associated organ injuries and success rate of US in demonstrating these injuries are shown in Table 3.

## 4. Discussion

Abdominal CT scanning is the diagnostic imaging modality of choice for the initial evaluation of the hemodynamically stable child sustaining BAT. Accuracy of abdominal CT in detecting solid organ injuries is well documented [6]. However, despite the diagnostic superiority of CT in the evaluation of patients with BAT, the absence of CT imaging units in some centers, the risk of exposure to ionizing




(A)




(B)

Fig. 2. (A) Transverse sonogram shows perinephric hematoma and absence of normal renal echogenicity. (B) Post contrast CT scan of the same case reveals a perinephric hematoma and laceration of the right kidney.

radiation, the need for sedation for some patients, being limited to stabile patients and being expensive are some of the disadvantages of CT imaging [7]. Therefore, there has been considerable interest regarding the use of US for the initial evaluation of these patients. US offers the potential for rapid diagnosis at the bedside, since patients can be examined in the emergency unit [8–11].

Few studies exist about diagnostic value of US in comparison with abdominal CT imaging in children with BAT. Our study is the third study, which includes all intraabdominal organ injuries preceded by the studies performed by Liu et al. [12] and Kshitish et al. [7].

The most common cause of abdominal trauma in children is motor vehicle accidents (MVA) followed by falls [5]. Similarly, MVA and falls are the first and second most common causes of abdominal trauma, respectively, in our study. The third common cause of abdominal trauma is reported to be the sports accidents. In contrast to other studies, the third common cause was animal attack in our study (8.3%) because cattle breeding are very common in our region.

Table 3
Distribution of injured organs according to US and CT findings

| Injured Organ | Detected by CT | Associated other organ injuries | | Failed US |
|---|---|---|---|---|
| | | Detected by CT | Detected by US | |
| Spleen | 51 | 22 (43.1%) | 43 (84.4%) | 8 (15.6%) |
| Liver | 46 | 21 (45.6%) | 41 (89.2%) | 5 (10.8%) |
| Kidney | 19 | 6 (31.5%) | 17 (89.5%) | 2 (10.5%) |
| Intestine | 9 | 8 (88.8%) | 5 (55.6%) | 4 (44.4%) |
| Pancreas | 3 | 2 (66.6%) | 2 (66.7%) | 1 (33.3%) |
| Total | 128 | 59 (46.0%) | 108 (84.4%) | 20 (15.6%) |

FAST or complete abdominopelvic US can be performed for the evaluation of children with BAT [3]. Colley et al. [5] found that FAST has 55% sensitivity, 83% specificity, 86% positive predictive value and 50% negative predictive value in children, so they suggested that FAST has insufficient sensitivity and negative predictive value to be used as a screening imaging test in hemodynamically stable children with BAT. Nunes et al. [13] found the sensitivity, specificity, positive predictive value, negative predictive value and accuracy rate of US in the determination of free abdominal and pelvic fluid in the children with BAT as 69, 100, 100, 95 and 95%, respectively. In many studies the sensitivity and specificity range between 56 and 99%, 95 and 100%, respectively [14–17]. In our study, the accuracy of US in detecting FIF is 91.7%, with specificity, sensitivity, positive predictive value and negative predictive value of 100, 90.2, 100 and 63.6, respectively. FIF could not be detected by CT in 14 (15%) of patients with IAI. In the literature reported incidence of this finding is about 20–40% [7,18,19].

We assessed the sensitivity, specificity, positive predictive value, negative predictive value and overall accuracy of US for spleen, liver, kidney, intestine and pancreas separately. In the literature, we could not find data to compare with our results except for spleen and kidney. The most common injured organ was the spleen in our series as was reported by others [4,7]. Kshitish et al. [7] reported that US has 73% sensitivity, 100% specificity, 100% positive predictive value, 87% negative predictive value and 90% accuracy in 11 splenic injuries and 67% sensitivity, 100% specificity, 100% positive predictive value, 89% negative predictive value and 91% accuracy in nine renal injuries. Our results were similar with the ones reported by Kshitish et al. [7] except for the higher sensitivity of our study.

In the literature, the incidence of liver injury among children with BAT is stated to be 10–27%, as the second most common injury after spleen injury [20,21]. It is similar in our series. The sensitivity, specificity, positive predictive value, negative predictive value and accuracy of US in detecting liver injury are found to be 89.1, 100, 100, 90.9 and 94.8%, respectively.

Kidney is the third most commonly injured organ in BAT. Usually unilateral injury is seen [7]. The findings of our series are compatible with the literature. The sensitivity, specificity, positive predictive value, negative predictive value and accuracy of US for the evaluation of kidney injuries are reported as 67, 100, 100, 89 and 91%, respectively [7]. When we compared these values with the ones in our study, we found that our values were higher (Table 2).

Injuries of GIT are relatively uncommon in BAT and the diagnosis of GIT injuries is quite difficult. Mesenteric injuries often accompany GIT injuries. Intestinal injuries can be either intraluminal or in the form of a rupture [22]. Mortality rises from 5 to 65% if there is any delay in the diagnosis and treatment [23]. Repeated physical examination is emphasized to be very important since the ratio of false negativity is 25% with CT imaging. It is also stated that free extraluminal fluid was present in 33–40% of patients with intestinal injury and oral contrast material leaked out in 0–12% of the cases [24]. The incidence of intestinal injury was 7% (nine cases) in our series and we diagnosed all these cases by CT scanning. The sensitivity, specificity, positive predictive value, negative predictive value and accuracy of US in the determination of these cases were 55.5, 100, 100, 95.6 and 95.8%, respectively. We could not find any data to compare with our results. However, US is determined to be unsuccessful in detecting GIT injuries. Our results also confirmed this statement. We suggested that the high success rate with CT scanning in our study was due to the few number of cases and to a good teamwork.

Pancreatic injuries are rare in patients with BAT [24]. Pancreatic injuries are seen in 1–2% of cases [23]. We identified pancreatic injury in three patients (2%). CT scanning showed a direct fracture in one of these cases. There were peripancreatic fluid and hematoma in the other two. In our series, the sensitivity, specificity, positive predictive value, negative predictive value and accuracy rate of US in detecting these cases were found to be 66.7, 100, 100, 98.9 and 99%, respectively. However, these data may have low accuracy since the number of cases is only a few.

In conclusion, US for BAT in children is highly accurate and specific. It is highly sensitive in detecting liver, spleen and kidney injuries whereas its sensitivity is moderate for the detection of GIT and pancreatic injuries. We suggest that US should be used to detect both FIF and intraabdominal organ injury for the evaluation of hemodynamically stable patients with BAT.

## References

[1] Berger PE, Kuhn JP. CT of blunt abdominal trauma in childhood. Am J Roentgenol 1981;136:105–10.
[2] Kaufman RA, Towbin R, Babcock DS, et al. Upper abdominal trauma in children: Imaging evaluation. Am J Roentgenol 1984;142:449–60.
[3] Benya EC, Lim-Dunham JE, Landrum O, Statter M. Abdominal sonography in examination of children with blunt abdominal trauma. Am J Roentgenol 2000;174(6):1613–6.
[4] Patel JC, Tepas III JJ. The efficacy of focused abdominal sonography for trauma (FAST) as a screening tool in the assessment of injured children. J Pediatr Surg 1999;34:44–7.

[5] Coley BD, Khaled MH, Martin LC, et al. Focused abdominal sonography for trauma (FAST) in children with blunt abdominal trauma. J Trauma 2000;48:902–6.
[6] McCort JJ. Caring for the major trauma victim: the role for radiology. Radiology 1987;163:1–9.
[7] Kshitish M, Sushma V, Sanjay T, Srivastava DN. Comparative evaluation of ultrasonography and CT in patients with abdominal trauma: a prospective study. Indian J Radiol Imaging 2000;10:4.
[8] Taylor GA, Sivit CS. Posttraumatic peritoneal fluid: is it reliable indicator of intraabdominal injury in children. J Pediatr Surg 1995;30:1644–8.
[9] Kimura A, Otsuka T. Emergency center ultrasonography in the evaluation of hemoperitoneum: a prospective study. J Trauma 1991;31:20–3.
[10] Ma OJ, Mateer JR, Ogata M, et al. Prospective analysis of a rapid trauma ultrasound examination performed by emergency physicians. J Trauma 1995;38:879–85.
[11] Boulanger BR, McLellan BA, Brenneman FD, et al. Emergent abdominal sonography as a screening test in a new diagnostic algorithm for blunt trauma. J Trauma 1996;40:867–74.
[12] Liu M, Lee CH, P'eng FK. Prospective comparison of diagnostic peritoneal lavage, computed tomographic scanning, and ultrasonography for the diagnosis of blunt abdominal trauma. J Trauma 1993;35:267–70.
[13] Nunes LW, Simmons S, Hallowell MJ, et al. Diagnostic performance of trauma US in identifying abdominal or pelvic injury. Acad Radiol 2001;8(2):128–36.
[14] Bode PJ, Edwards MJR, Kruit M, Van Vugt AB. Sonography in a clinical algorithm for early evaluation of 1671 patients with blunt abdominal trauma. Am J Roentgenol 1999;172:905–11.
[15] Healy MA, Simons RK, Winchell RJ, et al. A prospective evaluation of abdominal ultrasound in blunt trauma: is it useful. J Trauma 1996;40:875–83.
[16] McGaham JP, Richards JR. Blunt abdominal trauma: the role of emergent sonography and a review of the literature. Am J Roentgenol 1999;172:897–903.
[17] Richards JR, Knopf NA, Wang L, McGahan JP. Blunt abdominal trauma in children: evaluation with emergency US. Radiology 2002;222:749–54.
[18] Holmes JF, Brant WE, Bond WF, et al. Emergency department ultrasonography in the evaluation of hypotensive and normotensive children with blunt abdominal trauma. J Pediatr Surg 2001;36(7):968–73.
[19] Emery KH, McAneney CM, Racadio JM, et al. Absent peritoneal fluid on screening trauma ultrasonography in children: a prospective comparison with computed tomography. J Pediatr Surg 2001;36(4):565–9.
[20] Navarro O, Babyn PS, Pearl RH. The value of routine follow up imaging in pediatric blunt liver trauma. Pediatr Radiol 2000;30(8):546–50.
[21] Taylor GA, O'Donnell R, Sivit CJ, et al. Abdominal injury score: a clinical score for the assignment of risk in children after blunt trauma. Radiology 1994;190:689–94.
[22] Ameh EA, Chirdan LB, Nmadu PT. Blunt abdominal trauma in children: epidemiology, management and management problems in a developing country. Pediatr Surg Int 2000;16:505–9.
[23] Gay SB, Sistrom CL. Computed tomographic evaluation of blunt abdominal trauma. Radiol Clin North Am 1992;30:367–87.
[24] Frush DP. Pediatric blunt abdominal trauma. RAD 99 syllabus, Turkey 1999; pp. 151–3.