Blunt Abdominal Trauma in Children: A Score to Predict the Absence of Organ Injury

Oliver Karam, MD, Oliver Sanchez, MD, Christophe Chardot, MD, PhD, and Giorgio La Scala, MD

Objectives To evaluate the initial workup and design a score that would allow ruling out significant intra-abdominal organ injuries following blunt abdominal traumas (BAT).

Study design Data were collected prospectively from 147 consecutive patients admitted for BAT in a tertiary care hospital, over a 30-month period.

Results Statistical significance of various parameters (trauma mechanism, clinical examination, laboratory tests, and ultrasound findings) were analyzed in relation to intra-abdominal injuries. The 10 parameters with the best negative predictive values (NPV) were then used to build a score (BATiC). The following points were attributed for these items: abnormal abdominal Doppler ultrasound (4 points), abdominal pain (2 points), peritoneal irritation (2 points), hemodynamic instability (2 points), aspartate aminotransferase >60 IU/L (2 points), alanine aminotransferase >25 IU/L (2 points), white blood cell count >9.5 g/L (1 point), LDH >330 IU/L (1 point), lipase >30 IU/L (1 point), and creatinine >50 μg/L (1 point). A score of ≤7 has a NPV of 97% and includes 67% of the studied population.

Conclusions These results suggest that in hemodynamically stable patients with a normal abdominal Doppler ultrasound and a BATiC score of ≤7, intra-abdominal lesions are very unlikely, and systematic CT scan or hospital admission may be avoided. *(J Pediatr 2009;xx:xxx)*

Blunt abdominal trauma (BAT) is a frequent reason for hospital admission and a significant cause of death in children older than 1 year of age. Mechanisms causing abdominal injuries are predominantly motor vehicle accidents, falls, and intentional injuries.[1,2] BAT can produce solid organ injury, mainly to the spleen, liver, and kidneys; early diagnosis of the nature and extent of abdominal injuries is important to reduce the mortality and morbidity secondary to these lesions. Computed tomography (CT) scan is currently the best diagnostic tool in terms of sensitivity and specificity to detect intra-abdominal injuries.[1,3-5] Yet, it is irradiating, expensive, and may be hampered by patient movement, requiring sedation or general anesthesia. As a result, the indications to CT scan may be limited to cases in which the diagnosis of intra-abdominal lesions remains uncertain after the initial workup. Therefore, after minimal to moderate trauma in hemodynamically stable patients, the abdominal workup in the emergency setting may be limited to abdominal Doppler ultrasound scan (US) and routine blood tests. If the results of the initial workup are normal, the risk of missing life-threatening intra-abdominal lesions is considered to be low, and clinical observation can advantageously replace systematic CT scan.[6]

Admitting all these patients may induce familial stress and represents an important economic burden. However, apart from CT scan, no test has a sufficiently high negative predictive value (NPV) to reasonably exclude an intra-abdominal organ injury during the initial medical assessment and therefore to allow discharge of the patient under the supervision of an adult.[5,7]

The present study was undertaken to assess the NPV of clinical examination, laboratory, and radiology results. On the basis of these data, we determined a score with an optimal NPV to rule out significant intra-abdominal organ injury during the initial medical assessment.

ALT	Alanine aminotransferase	ED	Emergency department
AST	Aspartate aminotransferase	NPV	Negative predictive value
AUC	Area under the ROC curve	γ-GT	Gamma-glutamyltransferase
aPTT	Activated partial thromboplastin time	LDH	Lactate dehydrogenase
BAT	Blunt abdominal trauma	OIS	Organ injury score
BATiC score	Blunt abdominal trauma in children score	PPV	Positive predictive value
		PT	Prothrombin time
BUN	Blood urea nitrogen	PTS	Pediatric trauma score
CK	Creatinine kinase	ROC	Receiver operating characteristic
CK-MB	Creatinine kinase MB isoenzyme	US	Ultrasound scan
CT	Computed tomography	WBC	White blood cell

From the Pediatric Surgery Clinic, University of Geneva Children's Hospital, Geneva, Switzerland.

The authors declare no conflicts of interest.

Submitted for publication Sep 18, 2008; last revision received Dec 4, 2008; accepted Jan 5, 2009.

Reprint requests: Dr Giorgio La Scala, Paediatric Surgery Clinic, University of Geneva Children's Hospital, 6 Rue Willy Donzé, CH – 1211 Geneva, Switzerland. E-mail: giorgio.lascala@hcuge.ch.

0022-3476/$ - see front matter

10.1016/j.jpeds.2009.01.001

METHODS

A prospective study was designed following the guidelines in use in our institution and received research ethics board approval. Data were collected for all patients consecutively admitted after blunt abdominal trauma from October 1, 2003, to March 31, 2006.

According to the guidelines existing in our institution, children with BAT admitted to our emergency department (ED) were clinically assessed and submitted to the following tests (initial workup): full blood cell count, coagulation tests, liver enzyme tests, lactate dehydrogenase (LDH), troponin, creatinine kinase (CK), blood urea nitrogen (BUN), and creatinine determination. Normal values were those within the range defined by our laboratories. We considered as near-normal values those that were <10% over the higher end of the normal range. Hematuria was searched for by using a urinary dipstick.

All patients also underwent an abdominal Doppler US by a radiologist (including Doppler examination of the renal arteries). Patients who did not have normal or near-normal laboratory results or who had abnormal US (free fluid or a visible solid organ injury) underwent an abdominal single-contrast (IV) CT scan.

All patients were then either admitted for treatment as required by clinical condition or simply for observation. After 24 hours, patients who had still no evidence of intra-abdominal organ lesion were discharged. Patients who had persisting abdominal pain underwent an abdominal CT scan, if not performed previously.

Our hospital uses a single-record chart for each patient and is the only tertiary care pediatric center of the region. Therefore, we also looked for possible subsequent readmissions related to the trauma. A patient was considered to have no abdominal organ injury if the CT scan was normal or if the patient had an asymptomatic clinical course, normal laboratory and US results, and did not require readmission.

The following data were collected for all patients at the time of admission: age, sex, mechanism of trauma, energy of trauma (high energy being defined as motor vehicle accident >60 km/h, fall from a height >5 meters, fall from a horse in movement, projection far away from a bicycle, or loss of consciousness at the scene for more than 15 minutes), how the patient was brought to the ED (by parents or bystanders, by ambulance, or by helicopter), pediatric trauma score (PTS),[8] time from trauma to blood workup, results for hemoglobin, hematocrit, white blood cell (WBC) count, absolute neutrophil count, absolute immature (band) neutrophil count, platelets, prothrombin time (PT), activated partial thromboplastine time (aPTT), throponine, creatinine kinase (CK), creatine kinase MB isoenzyme (CK-MB), lactate dehydrogenase (LDH), aspartate aminotransferase (AST), alanine aminotransferase (ALT), amylase, lipase, gamma-glutamyltransferase (γ-GT), bilirubin, blood urea nitrogen (BUN), creatinine levels, and urinary dipstick results, evaluated for presence of blood (results expressed as red blood cells/field equivalent). We also collected the abdominal Doppler US findings, CT scan results, nature and severity of extra-abdominal lesions, and hospital course.

All ultrasound images and CT scans were interpreted by a pediatric radiologist. Ultrasounds were considered abnormal if the radiologist described either free fluid, whatever the quantity or location, or an abnormal finding that could suggest an organ injury. The organ injuries were graded according to the Organ Injury Score (OIS) described by Moore.[9]

The patients were separated into 2 groups: (1) the intra-abdominal organ injury group, who had a positive diagnosis of intra-abdominal organ injury, based on the single-contrast CT scan findings; and (2) the no-injury group, which encompassed patients with a normal CT scan as well as children who did not undergo a CT scan because their initial workup, including Doppler US, was normal and were free of abdominal symptoms at the end of the observation.

The aim of the first part of the study was to describe the significance of the different parameters that are commonly used to assess a patient with a BAT. Therefore, patients who were not investigated per protocol, either because they had a CT scan before a Doppler US, or because they were not admitted for observation as required by the study protocol, were excluded from the analysis. Patients who had only 1 missing laboratory examination were included in the initial description of the other biological values. However, these patients were excluded from the BATiC analysis because the score could not be computed.

The laboratory tests were analyzed using a receiver operating characteristic (ROC) curve.[10] The cutoff limits were determined according to the value with the highest accuracy (minimal false-negative and false-positive results) among the parameters that differed significantly between the 2 groups. Sensitivity, specificity, and positive and negative predictive values (PPV and NPV) were calculated for each of these parameters. The tests with NPV >80% or PPV >95% were then selected and integrated in a score named Blunt Abdominal Trauma in Children (BATiC).

To determine the weighting for each item, the relative risk of organ injury was calculated for each item in the score, using the cutoff of the score. Arbitrarily, a relative risk between 1 and 4, 4 and 7, 7 and 10, and >10 warranted, respectively, a relative weight of 1, 2, 3, and 4 for that item. Once the score was constructed, it was analyzed to determine the area under the ROC curve (AUC), and the cutoff for the score was determined using the value with the higher accuracy.[10,11]

All the patients were then analyzed according to this score, to determine if the score is clinically useful. Sensitivity, specificity, and PPV and NPV, as well as positive (sensitivity/[1-specificity]) and negative ([1-sensitivity]/specificity) likelihood ratios were calculated for each of these parameters.[10]

Statistical analysis was carried out where applicable after $\log_n$ transformation, using the independent-samples t test procedure (when comparing 2 variables of normal distribution) and Pearson χ^2 test (for nominal and ordinal data correlations). The analyses were performed on an IBM-compatible personal computer, using the SPSS 15.0 software (SPSS Inc; Chicago, Illinois). Results are expressed as mean ± standard deviation. Differences were considered significant for $P < .05$.

RESULTS

During the 30-month study period, 163 patients were admitted following BAT; the mean age was 10.1 ± 3.9 years, with a sex ratio (male to female) of 1.71. The mean time from trauma to blood workup was 1.7 ± 0.7 hours. Sixteen patients were excluded a posteriori, because they were not managed per protocol (either because they had a CT scan before a Doppler US or because they were not admitted for observation). Among the other 147 patients, 48 were excluded from the BATiC analysis because there were missing laboratory values in their initial workup, preventing the computation of the score.

Description of the Population and the Initial Workup

The clinical, biological, and radiological findings of the study patients are summarized in Table I.

When analyzing the laboratory tests, 113 patients had normal or near-normal values; of those, 14 (12%) were subsequently diagnosed with an abdominal organ injury. Among the 34 patients with abnormal laboratory values, 17 (50%) had abdominal organ injury. Therefore the sensitivity, specificity, PPV and NPV of the laboratory test were 55%, 85%, 50%, and 87%, respectively. The positive and negative likelihood ratios were 3.74 and 0.53.

One hundred sixteen patients had normal abdominal Doppler US, of which 8 (7%) were subsequently diagnosed with an abdominal organ injury. Among the 31 patients with abnormal laboratory values, 23 (74%) had abdominal organ injury. Therefore the sensitivity, specificity, PPV and NPV of the US were 74%, 93%, 74%, and 93%, respectively. The positive and negative likelihood ratios were 10.7 and 0.28.

In total, 31 patients belonged to the intra-abdominal injury group and 116 to the no-injury group. There was no significant age difference (9.9 ± 3.9 vs 10.9 ± 3.9, $P = .21$) or male to female sex ratio (1.8 vs 1.4, $P = .75$) between the 2 groups.

The study patients presented the following lesions: 8 liver injuries, 9 spleen injuries, 5 kidney injuries, 2 adrenal gland injuries, 4 gut injuries, and 3 patients had multiple injuries.

Two patients died, one because of a supra-hepatic inferior vena cava laceration and the other of severe traumatic brain injury.

Three patients underwent urgent abdominal procedures: 1 for duodenal perforations, 1 for a perimortem emergency laparotomy for massive intra-abdominal hemorrhage (secondary to inferior vena cava laceration), and 1 for multiple intestinal perforations. Ten other patients were operated, 3 for craniotomies performed to relieve severe intracranial hypertension, 3 for extremities fractures requiring internal fixation, 1 for cervical spine instrumentation and stabilisation, 2 for mandibular internal fixation, and 1 for an upper extremity wound revision. One other patient underwent a laparoscopy 30 days after a duodenal trauma, which led to adhesions and a bowel obstruction.

Table I. Clinical data and initial trauma workup

History, clinical findings, laboratory tests	Abdominal organ injury: No (n = 116)	Abdominal organ injury: Yes (n = 31)	*P*
Patient brought to ED by parents	52 (45%)	12 (39%)	.89*
High-energy trauma	58 (50%)	19 (61%)	.18*
Presence of associated injuries	64 (55%)	10 (32%)	.004*
Abdominal pain	80 (69%)	29 (94%)	<.001*
Signs of peritoneal irritation	2 (2%)	9 (29%)	<.001*
Dermabrasions	20 (17%)	9 (29%)	.12*
Abdominal wall hematoma	8 (7%)	2 (6%)	.64*
Lower back pain	13 (11%)	6 (19%)	.18*
Hemodynamic instability	0 (0%)	2 (6%)	.04*
PTS <8	2 (2%)	2 (6%)	.24*
Hemoglobin (g/L)	130 ± 13	123 ± 22	.13†
Hematocrit (%)	37.2 ± 3.7	35.6 ± 6.2	.18†
WBC count (g/L)	10.6 ± 4.0	13.4 ± 5.4	.007†
Absolute band count (g/L)	0.61 ± 0.95	0.77 ± 1.16	.48†
Platelets (g/L)	280 ± 71	258 ± 63	.08†
PT (%)	87 ± 12	83 ± 13	.08†
aPTT (s)	27.6 ± 6.8	25.3 ± 2.8	.25†
Troponin (mg/mL)	0.07 ± 0.36	0.12 ± 0.48	.36†
CK (IU/L)	289 ± 277	420 ± 635	.12†
CK-MB (IU/L)	58 ± 58	61 ± 55	.51†
LDH (IU/L)	372 ± 241	489 ± 273	.005†
AST (IU/L)	53 ± 103	153 ± 205	<.001†
ALT (IU/L)	38 ± 81	156 ± 250	<.001†
γ-GT (IU/L)	15.5 ± 6.5	17.4 ± 11.3	.25†
Bilirubin (μmol/L)	11.7 ± 4.5	10.6 ± 4.5	.28†
Amylase (IU/L)	89 ± 39	99 ± 83	.83†
Lipase (IU/L)	28 ± 11	52 ± 71	.02†
BUN (mmol/L)	4.7 ± 1.3	4.6 ± 1.0	.62†
Creatinine (μg/L)	47.8 ± 13.1	60.1 ± 19.9	<.001†
Hematuria (cell/mL)	4.1 ± 9.0	13.3 ± 13.3	.17†
Normal Doppler US	89.6%	25.8%	<.001*
Free fluid in the Douglas pouch	7.7%	45.2%	<.001*
Free fluid elsewhere	3.4%	58.1%	<.001*
Organ lesion visible on Doppler US	0.9%	48.4%	<.001*

PTS, Pediatric Trauma Score[4]; band, immature neutrophil; PT, prothrombin time; aPTT, activated partial thromboplastin time; CK, creatine kinase; CK-MB, creatine kinase MB isoenzyme; LDH, lactate dehydrogenase; AST, aspartate aminotransferase; ALT, alanine aminotransferase; γ-GT, γ-glutamyltransferase; BUN, blood urea nitrogen; US, ultrasound.

Significance was determined by *Pearson χ^2 test or †t test after $\log_n$ transformation.

Description of the Initial Workup According to the Presence or Absence of Abdominal Organ Injury

Among the 31 parameters evaluated, 11 differed significantly between the 2 groups: presence of other injuries,

Table II. Sensitivity, specificity, positive and negative predictive values, and relative risks of the parameters significantly different between the groups with and without abdominal organ injury

	Sensitivity	Specificity	PPV	NPV	AUC	RR
Abdominal pain	0.94	0.31	0.27	0.95		5.05
Abnormal abdominal US	0.74	0.93	0.74	0.93		10.76
WBC count >9.5 g/L	0.69	0.58	0.29	0.88	0.68	2.69
AST >60 IU/L	0.61	0.76	0.40	0.88	0.75	4.15
ALT >25 IU/L	0.48	0.85	0.47	0.86	0.72	6.99
LDH >330 IU/L	0.75	0.37	0.22	0.86	0.68	3.37
Lipase >30 IU/L	0.57	0.62	0.9	0.84	0.65	2.07
Creatinine >50 μg/L	0.43	0.85	0.44	0.84	0.72	3.8
Signs of peritoneal irritation	0.29	0.98	0.82	0.84		5.05
Hemodynamic instability	0.06	1	1	0.80		5.00
Presence of associated injuries	0.32	0.45	0.14	0.71		0.47

PPV, positive predictive value; NPV, negative predictive value; AUC, area under the ROC curve; RR, relative risk; US, ultrasound; WBC, white blood cell; LDH, lactate dehydrogenase; AST, aspartate aminotransferase; ALT, alanine aminotransferase; Hb, hemoglobin; PT, prothrombin time.

Table III. Blunt Abdominal Trauma in Children score

	BATiC score value for each item
Abnormal abdominal Doppler US	4
Abdominal pain	2
Signs of peritoneal irritation	2
Hemodynamic instability	2
AST >60 IU/L	2
ALT >25 IU/L	2
WBC count >9.5 g/L	1
LDH >330 IU/L	1
Lipase >30 IU/L	1
Creatinine >50 μg/L	1

US, Ultrasound; AST, aspartate aminotransferase; ALT, alanine aminotransferase; WBC, white blood cell; LDH, lactate dehydrogenase.
The Blunt Abdominal Trauma in Children (BATiC) score is calculated by summing the points for each item. The score range is 0 to 18.

abdominal pain, signs of peritoneal irritation, hemodynamic instability, WBC count, LDH, AST, ALT, lipase, creatinine, and abdominal ultrasound (Table I). The AUC for the laboratory examinations that differed significantly between both groups ranged from 0.65 for lipase to 0.75 for AST.

Generation of the BATiC Score

For the 6 laboratory examinations, cutoff limits were determined using the ROC curves: AST >60 IU/L, ALT >25 IU/L, LDH >330 IU/L, WBC count >9.5 g/L, lipase >30 IU/L, and creatinine >50 IU/L. The sensitivity, specificity, and PPV and NPV values of the 11 tests are shown in Table II. Nine tests had an NPV ≥80% and 1 had a PPV ≥95%. These were integrated into the BATiC score (Table III).

The relative risk of an abdominal organ injury was also calculated for each of the BATiC item (Table II). These relative risks were then used to determine the weight of each item in the score (Table III).

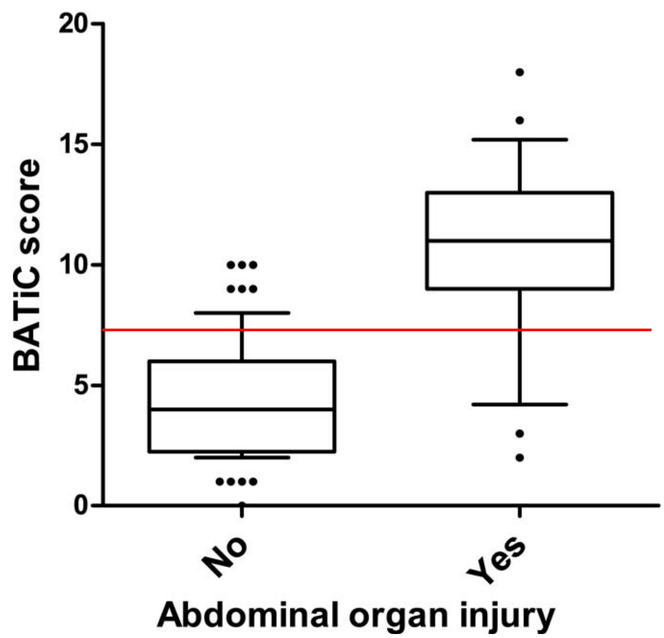

Figure. Box plot of the BATiC score, comparing patients with and without abdominal organ injury, with a mean score of 11.1 ± 3.6 vs 4.4 ± 2.5, respectively ($P < .0001$).

BATiC Score in the Studied Population

When applying the BATiC score to our study population, we found a significant difference between the 2 groups, with, respectively, a mean score of 11.1 ± 3.6 for the patients with an intra-abdominal organ injury (n = 23) versus 4.4 ± 2.5 for the patients without intra-abdominal organ injury (n = 76) ($P < .0001$; Figure). Using a cutoff value of ≤7, the sensitivity was 91%; specificity, 84%; PPV, 64%; and NPV, 97% (95% IC: 89% to 99%). The positive and negative likelihood ratios were 5.69 and 0.11, respectively.

Sixty-seven percent of our population had a BATiC score ≤7. Among these patients, 2 (3%) were diagnosed with intra-abdominal organ injury by CT scan performed after 24 hours because of persisting abdominal pain (1 spleen OIS grade 3 injury and 1 kidney OIS grade 1 injury), Their BATiC score was 3 and 2, respectively. The first had abdominal pain and a creatinine level of 55 μg/L, whereas the second only had abdominal pain.

Among the patients without abdominal organ injury and a BATiC score ≤7, only 1 had an initial abdominal Doppler ultrasound anomaly, with free fluid in the pouch of Douglas. No lesion was found on her CT scan, and her clinical evolution was uneventful.

No patient was hemodynamically unstable, and none had initial signs of peritoneal irritation.

The patient who died of suprahepatic inferior vena cava laceration had a BATiC score of 18; the patient who died after severe traumatic brain injury (normal abdominal CT scan) had a BATiC score of 2 (WBC count: 15.5 g/L; LDH: 360 UI/L). Of the 4 patients who underwent abdominal procedures, their BATiC scores ranged from 9 to 18.

DISCUSSION

After BAT in a child, the physical examination is not reliable enough to rule out all significant intra-abdominal organ lesions.[12-14] Therefore, physicians rely on biological markers of organ injury, such as AST and ALT, and on radiological assessment. The most sensitive and specific examination for the identification of an intra-abdominal injury is an abdominal CT scan, with an estimated NPV of 99.8%.[1,3] Nevertheless, this examination is irradiating, expensive, and may necessitate general anesthesia to avoid movement. Brenner et al[15] evaluated the lifetime attributable risk of cancer due to a CT scan to be more than 2 per 10 000 patients. A recent study concluded that the use of CT should be restricted to selected patients.[16] For example, an abdominal CT scan should be performed when the findings of the initial workup (blood tests and abdominal Doppler US) cannot definitely identify or rule out an intra-abdominal injury.

Noninvasive tests, such as blood tests or ultrasound, have been evaluated to determine values that could per se rule out abdominal organ injury. For example, Hennes et al[17] suggested in 1990 that AST <450 IU/L and ALT <250 IU/L had an NPV of 100% for liver injury. Since then, these cutoff values have been challenged, and recent data suggest that some patients have liver injuries with AST and/or ALT far below these values.[18,19] In our previous study, 63% of a pediatric population with liver injury secondary to a blunt abdominal trauma had AST <450 IU/L and 43% had ALT <250 IU/L.[18] Capraro et al evaluated other biological markers of abdominal injury but have not found any test with a high enough NPV to rule out intra-abdominal injury.[7]

We identified which parameters differed significantly between patients with and without abdominal organ injury. Until now, most clinicians interpret pathological values as relevant or not, relying on their own experience. Our data suggest that the absence of high-energy trauma cannot rule out an abdominal organ injury and that abdominal wall hematoma or dermabrasions were not associated with a higher risk of such lesions. Furthermore, most laboratory examinations were not useful in the initial workup, such as hemoglobin and platelet count, coagulation tests, BUN, or the presence of hematuria. Our results confirm those of Capraro et al,[7] who suggest that routine trauma "panels" should not be obtained as a screening tool in children with BAT being evaluated for intra-abdominal injury because no laboratory test has per se a high enough NPV. Systematic prescription of numerous laboratory tests could possibly be avoided in many patients because in the present study only 6 tests are significantly different in both groups.

Several parameters might be used to compare the BATiC score with the usual initial workup to assess their respective efficiency. The AUC describes the performance of a test, and, in general, it is considered that ROC curves with an AUC ≤0.75 are not clinically useful, whereas an AUC >0.90 has a high clinical value.[20,21] Our data show that the usual laboratory tests that are performed to assess a BAT have a low AUC, ranging from 0.65 to 0.75, which means that in more than 25% of the cases, the given result of a specific test give a wrong answer. On the other hand, the BATiC score has an AUC of 0.92.

Another way to assess the efficiency is to compare likelihood ratios, which are considered one of the best measures of diagnostic accuracy.[22] Because the aim of this study was to construct a score to safely exclude abdominal organ injury, this assessment must be conducted based on negative likelihood ratios, which correspond to the clinical concept of "ruling-out" disease. The BATiC negative likelihood ratio was 0.10, which is generally considered as a large and usually conclusive decrease in the likelihood of disease.[10] The laboratory initial workup had a negative likelihood ratio of 0.53, which can be considered as a minimal decrease in the likelihood of disease. The abdominal Doppler US has a slightly better negative likelihood ratio (0.28). Thus, a score that combines physical examination, selected laboratory tests, and abdominal US is more efficient than these items evaluated separately. The BATiC score has the advantage of containing only the items that are statistically different between the 2 groups, with specific cutoff values and a rational weighting among these different items.

A limitation of our study is that most of the patients considered as truly negative did not undergo a CT scan and were only followed clinically. However, this is an accepted standard criterion, as shown in a recent meta-analysis of the performance of abdominal ultrasonography in children in whom 15 studies of 25 based their negative cases only on clinical follow-up.[23] Another limitation is due to the relatively small number of patients evaluated in our ED over a 30-month period. However, the statistical analysis shows very significant P values, which indicates a very low probability of sampling errors. All ultrasound scans in our emergency department were performed by radiologists and not by the trauma team. However, this appears to be common practice, as in 16 studies of 23 reviewed for a meta-analysis, the ultrasound was interpreted by radiologists.[23] Because the NPV depends on the prevalence of organ injury in patients admitted in an ED for BAT, we also had to make sure that the prevalence of organ injury in our population (22.6%) was similar to that of other hospitals (21% to 28%).[2,7] Therefore, it seems reasonable to assume that our results can be generalized. However, because this score was tested on the same population it was built from, it should be tested in a larger trial.

The result of a simple score cannot replace clinical judgment and imaging findings. Our results suggest that if the patient is hemodynamically stable, has no signs of peritoneal irritation, has a normal abdominal Doppler ultrasound, and has a BATiC score ≤7, significant intra-abdominal lesion is unlikely and an immediate CT scan can be avoided and advantageously replaced by clinical reassessment. In such a patient, the need for hospital admission also depends on the ability of parents to rapidly bring the child back to hospital if needed.

In our series, 2 patients had only mild initial abdominal pain with a normal biological workup and a normal Doppler ultrasound. Both had low initial BATiC scores (2 and 3, respectively). They were reevaluated after 24 hours, and, because of persisting abdominal pain, a CT scan was performed, showing an OIS grade 3 spleen lesions in 1 patient and a OIS grade 1 kidney injury in the other. They had a favorable outcome without any intervention. Based on near-normal laboratory values and abdominal Doppler US, most physicians would have been comfortable in sending these 2 patients home on the first day without obtaining a CT scan. It has even been suggested that regardless of mechanism, if verbal children are alert, have normal laboratory data without concomitant injury, or lack abdominal examination abnormalities, they can be discharged safely without imaging of the abdomen.[24] Nonetheless, the 2 patients with injuries despite low BATiC scores illustrate the importance of the clinical reassessment the following day. On the other hand, a BATiC score >7 identified all patients who required abdominal surgery.

The proposed BATiC score appears to reliably rule out significant intra-abdominal injuries in our study population. This score supplements clinical and Doppler US findings and could help avoid unnecessary CT scans and admissions, therefore reducing healthcare costs.

REFERENCES

1. Gaines BA, Ford HR. Abdominal and pelvic trauma in children. Crit Care Med 2002;30(11 Suppl):S416-23.
2. Taylor GA, O'Donnell R, Sivit CJ, Eichelberger MR. Abdominal injury score: a clinical score for the assignment of risk in children after blunt trauma. Radiology 1994;190:689-94.
3. Richards JR, Derlet RW. Computed tomography for blunt abdominal trauma in the ED: a prospective study. Am J Emerg Med 1998;16:338-42.
4. Bixby SD, Callahan MJ, Taylor GA. Imaging in pediatric blunt abdominal trauma. Semin Roentgenol 2008;43:72-82.
5. Awasthi S, Mao A, Wooton-Gorges SL, Wisner DH, Kuppermann N, Holmes JF. Is hospital admission and observation required after a normal abdominal computed tomography scan in children with blunt abdominal trauma? Acad Emerg Med 2008;15:895-9.
6. Holmes JF, Sokolove PE, Brant WE, Palchak MJ, Vance CW, Owings JT, et al. Identification of children with intra-abdominal injuries after blunt trauma. Ann Emerg Med 2002;39:500-9.
7. Capraro AJ, Mooney D, Waltzman ML. The use of routine laboratory studies as screening tools in pediatric abdominal trauma. Pediatr Emerg Care 2006;22:480-4.
8. Tepas JJ 3rd, Mollitt DL, Talbert JL, Bryant M. The pediatric trauma score as a predictor of injury severity in the injured child. J Pediatr Surg 1987;22:14-8.
9. Moore EE, Cogbill TH, Malangoni MA, Jurkovich GJ, Shackford SR, Champion HR, et al. Organ injury scaling. Surg Clin North Am 1995;75:293-303.
10. Greenberg R, Daniels S, Flanders D, Eley JW, Boring JR. Medical Epidemiology. 4th edition. New-York: Lange Medical Books/McGraw-Hill; 2005.
11. Rosner B. Fundamentals of Biostatistics. 6th edition. Belmont, CA: Thomson Higher Education; 2006.
12. Schurink GW, Bode PJ, van Luijt PA, van Vugt AB. The value of physical examination in the diagnosis of patients with blunt abdominal trauma: a retrospective study. Injury 1997;28:261-5.
13. Livingston DH, Lavery RF, Passannante MR, Skurnick JH, Fabian TC, Fry DE, et al. Admission or observation is not necessary after a negative abdominal computed tomographic scan in patients with suspected blunt abdominal trauma: results of a prospective, multi-institutional trial. J Trauma 1998;44:273-80.
14. Poletti PA, Mirvis SE, Shanmuganathan K, Takada T, Killeen KL, Perlmutter D, et al. Blunt abdominal trauma patients: can organ injury be excluded without performing computed tomography? J Trauma 2004;57:1072-81.
15. Brenner DJ. Estimating cancer risks from pediatric CT: going from the qualitative to the quantitative. Pediatr Radiol 2002;32:228-3.
16. Brenner D, Elliston C, Hall E, Berdon W. Estimated risks of radiation-induced fatal cancer from pediatric CT. AJR Am J Roentgenol 2001;176:289-96.
17. Hennes HM, Smith DS, Schneider K, Hegenbarth MA, Duma MA, Jona JZ. Elevated liver transaminase levels in children with blunt abdominal trauma: a predictor of liver injury. Pediatrics 1990;86:87-90.
18. Karam O, La Scala G, Le Coultre C, Chardot C. Liver function tests in children with blunt abdominal traumas. Eur J Pediatr Surg 2007;17:313-6.
19. Haftel AJ, Lev R, Mahour GH, Senac M, Akhtar Shah SI. Abdominal CT scanning in pediatric blunt trauma. Ann Emerg Med 1988;17:684-9.
20. Fan J, Upadhye S, Worster A. Understanding receiver operating characteristic (ROC) curves. CJEM 2006;8:19-20.
21. Fawcett T. An introduction to ROC analysis. Pattern Recognition Lett 2006;27:861-74.
22. McGee S. Simplifying likelihood ratios. J Gen Intern Med 2002;17:646-9.
23. Holmes JF, Gladman A, Chang CH. Performance of abdominal ultrasonography in pediatric blunt trauma patients: a meta-analysis. J Pediatr Surg 2007;42:1588-94.
24. Wegner S, Colletti JE, Van Wie D. Pediatric blunt abdominal trauma. Pediatr Clin North Am 2006;53:243-56.