Pediatric abdominal Injury
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Chapter 5

External validation of the Blunt Abdominal Trauma in Children (BAtiC) score: ruling out significant abdominal injury in children


J Trauma Acute Care Surg. 2014; 76: 1282-7
ABSTRACT

Background
The aim of this study is to validate the use of the Blunt Abdominal Trauma in Children (BATiC) score. The BATiC score uses only readily available laboratory parameters, ultrasound results and results from physical examination, and does therefore not carry any risk of additional radiation exposure.

Methods
Data of pediatric trauma patients admitted to the shock room between 2006 and 2010 were retrospectively analyzed. Blunt abdominal trauma was defined radiologically or surgically. The BATiC score was computed using 10 parameters: abnormal abdominal ultrasound, abdominal pain, peritoneal irritation, hemodynamic instability, ASAT >60 U/l, ALAT >25 U/l, WBC >10 x10^9/l, LDH >330 U/l, amylase >100 U/l and creatinine >110 µmol/l. Sensitivity, specificity, NPV and PPV were computed. Missing values were replaced using multiple imputation and BATiC scores were calculated based on imputed values.

Results
Included were 216 patients, 144 male, 72 female, median age 12. 18 patients (8%) sustained abdominal injury. Median BATiC scores of patients with and without intra-abdominal injury were 9.2 (6.6 -15.4) and 2.2 (0.0 -10.6) resp. (p < 0.001). When the BATiC score is used with a cut-off point of 6, the test showed a sensitivity of 100% and a specificity of 87%. Negative and positive predictive values were 100% and 41% resp. The AUC was 0.98.

Conclusions
The BATiC score can be a useful adjunct in the assessment of the presence of abdominal trauma in children, and can help determine which patients might benefit from a CT scan and/or further treatment and which might not.
INTRODUCTION

In children, the Computed Tomography (CT) scan is by many considered the gold standard for assessment of intra-abdominal injury in hemodynamically stable patients. Initial assessment of pediatric trauma patients with CT permits accurate detection of intraperitoneal and extraperitoneal fluid or hemorrhage. Furthermore, it can detect and quantify severity of injuries to solid and hollow organs.

Computed tomography however has multiple disadvantages. Radiation has severe long-term risks, especially in children. The ratio of the risk of any abdominal or pelvic cancer occurring due to a single CT examination to the risk of a naturally occurring cancer over the lifetime in a child is estimated to be 2:1000 to 3:1000. The younger the child, the higher the estimated risk. Furthermore, in > 90% of the cases, a CT-scan does not influence the choice of treatment, especially in the era of non-operative management of injuries to the parenchymatous organs. CT imaging has never been validated for grading abdominal injuries in children, and intra- and interobserver variation are significant. Transport of the patient to and from the CT-scan can be dangerous and timeconsuming and CT diagnostics are costly. The use of procedural sedation in restless pediatric patients undergoing CT can also pose risks.

Given these disadvantages, a non-invasive scoring system for the presence or absence of intra-abdominal injury, using only readily available parameters, can be of clinical importance. To this end, Karam et al. devised the BATiC score. This score can be calculated using readily available parameters such as physical examination findings, abdominal ultrasound, and routine laboratory parameters. Karam et al. described promising results (with a negative predictive value of 97%). In this study, we validated the score in a larger cohort of pediatric trauma patients and evaluated its generalisability to an independent sample of new patients.

METHODS

Included were all consecutive pediatric trauma patients (<18 years of age) who were admitted to the shock room of the University Medical Centre Groningen (UMCG) between April 2006 and September 2010. The UMCG is a level I trauma centre covering the north of the Netherlands. Patients are admitted to the shock room when serious injury is suspected based on vital signs, clinical suspicion or (high-energy) trauma mechanism.

Excluded were all patients that sustained penetrating trauma, patients not primarily admitted to our hospital, and patients with 5 or more missing BATiC variables (out of 10).
All data were generated from a prospective trauma database. Clinical and routine laboratory outcomes were used for analysis.

BATiC scores were retrospectively computed as follows. See also table 1. Patients with abnormal ultrasound findings were given 4 points. Abnormal ultrasound findings were defined as: free fluids or injuries to hollow or visceral organs. Ultrasound examinations were performed and examined by a radiologist or a senior resident. Presence of abdominal pain and peritoneal irritation on physical examination were both given 2 points. Two points were added if hemodynamic instability occurred. Aspartate aminotransferase (ASAT) > 60 IU/l and alanine aminotransferase (ALAT) > 25U/L both accounted for 2 points. One point was given to all of the following laboratory findings: white blood cell count (WBC) > 10 x 10^9 /l, Lactate dehydrogenase (LDH) > 330 IU/l, amylase > 10 IU/l and creatinine > 110 µmol/l. Three parameters differ from the original score and were altered due to the following reasons. WBC concentration was changed from g/l to WBC count/l, since our center uses this as a standard (WBC > 10 x 10^9 /l is considered abnormal). For serum creatinine a different cut-off point was used as this was the standard used in our center. Creatinine > 110 µmol/l was considered abnormal, where Karam et al. considered creatinine > 50 mcg/l as abnormal. Serum lipase is not routinely determined in our center and thus replaced by amylase (amylase > 10 IU/l is considered abnormal). An overview of changes is shown in table 1. In the shock room, all laboratory values are available within one hour after obtaining the samples.

The total BATiC scores were computed by summing the points of each item. The scores range from 0-18, with higher values indicating a greater likelihood of the presence of intra-abdominal injury. These scores were correlated to the absence or presence of abdominal injury in patients. In our center, it is common practice to perform a CT scan of the abdomen and pelvis in case of an abnormal abdominal ultrasound, highly suspect injuries (e.g. blunt abdominal trauma with the presence of a seatbelt sign) and head injury necessitating CT scan. Abdominal injury was therefore defined as the presence of intra-abdominal injury on CT scan or during surgical intervention. Patients who did not undergo an abdominal CT scan and had an asymptomatic clinical course were considered not to have abdominal organ injury.

<table>
<thead>
<tr>
<th>WBC*</th>
<th>WBC &gt; 9.5 g/l</th>
<th>WBC &gt; 10 x 10^9 /l</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDH</td>
<td>LDH &gt; 330 IU/l</td>
<td>LDH &gt; 330 IU/l</td>
<td>1</td>
</tr>
<tr>
<td>Lipase (Amylase)*</td>
<td>Lipase &gt; 30 IU/l</td>
<td>Amylase &gt; 10 IU/l</td>
<td>1</td>
</tr>
<tr>
<td>Creatinine*</td>
<td>Creatinine &gt; 50 mcg/l</td>
<td>Creatinine &gt; 110 µmol/l</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1: Shows the construction of the BATiC score by both studies. The total BATiC score is calculated by summing the points of each item. *Differences can be found with regard to WBC, lipase and creatinine.
CT costs were acquired from the Dutch DBC (DRG) system. This is a predefined average care package, which is applied with a fixed price when a specific diagnosis occurs. The cost of a single CT scan is €148.

STATISTICS

Data was processed using PASW Statistics 18. Missing values were replaced using multiple imputations (5 imputations) and BATiC scores were calculated based on imputed values. The average BATiC score was calculated across these imputations. Categorical data were presented as counts and percentages. Normally distributed data were summarized as mean and standard deviation (SD) whereas continuous data with a non-normal distribution were expressed as median and range. Chi square test was used to compare categorical data. Normally distributed continuous variables were compared using Student’s t test. The Mann Whitney U test was used to compare continuous data with a nonparametric distribution. All tests were two sided, and a p-value of < 0.05 was considered statistically significant.

Sensitivity, specificity, negative predictive value (NPV) and positive predictive value (PPV) were computed. A receiver operating characteristic curve (ROC- curve) was constructed to determine the optimal cut off point for the presence of intra-abdominal injury. The optimal cut off point was based on the highest sensitivity and specificity combined. The area under the curve (AUC) was calculated to assess the discriminative power of the BATiC score.

RESULTS

Patient characteristics

A total of 272 patients were admitted between April 2006 and September 2010. Excluded were 56 patients on the basis of penetrating trauma mechanisms (4), no primary admission to the UMCG (15) or missing of more than 5 variables (37). Patient characteristics, such as gender, ISS, length of stay (LoS) and mortality did not differ significantly between included and excluded patients. The only variable that varied significantly between both groups was age, with a median of 11.5 (0-17) in included group vs. 5.5 (1-17) in the excluded group (p = 0.001).

216 patients were included for analysis, of which 144 male and 72 female. The median age was 12 years (range 0-17). Trauma mechanisms included pedestrians struck (15.3%), falls from height (27.8%), motor vehicle crashes (14.4%), motorcycle crashes (19.9%) and bicycle crashes (16.7%), and miscellaneous mechanisms (6.0%). 18 patients (8.3%)
sustained abdominal injury. ISS was significantly higher in patients who sustained intra-abdominal injury, 16.0 (1-66) vs. 9.0 (0-75) (p=0.02), see table 2. Abdominally injured patients stayed in the hospital for a longer period of time, 9.1 (0-93) vs. 1.9 (0-89.5) days (p<0.01). The length of stay in the ICU did not differ significantly between abdominally and non-abdominally injured patients, 0.0 (0-38) vs. 0.0 (0-43) resp. (p=0.16). Mortality in patients with and without abdominal injuries was 11.1% and 5.1% respectively. This is not statistically significant (p=0.28).

Most prevalent sustained injuries were ruptures of the spleen (7) and/or liver (7), perforations of the small intestines (3) or damage to the kidneys (2). Injuries to diaphragm (1), bladder (1) and pancreas (1) occurred incidentally. Computed tomography of the abdomen was performed in 34 patients. Intra-abdominal injury was seen in 17 of these scans. In one patient, a jejunal perforation was missed on CT but diagnosed during laparotomy 24 hours after admission. Within the group that sustained abdominal injury, 7 out of 18 patients required surgical intervention (OR). Apart from the jejunal perforation mentioned above, no additional injuries were seen during laparotomy. All patients observed without imaging were available for follow-up and did not propose any clinical suspicion of intra-abdominal injury.

### Table 2: Patient characteristics

<table>
<thead>
<tr>
<th></th>
<th>Total group N= 216</th>
<th>No abdominal injury N=198</th>
<th>Abdominal injury N= 18</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td>144M (67%)</td>
<td>131M (66%)</td>
<td>13M (72%)</td>
<td>0.60</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td>12 (0-17)</td>
<td>12 (0-17)</td>
<td>12 (3-17)</td>
<td>0.70</td>
</tr>
<tr>
<td><strong>ISS</strong></td>
<td>9 (0-75)</td>
<td>9 (0-75)</td>
<td>16 (1-66)</td>
<td>0.02*</td>
</tr>
<tr>
<td><strong>LoS Hospital (days)</strong></td>
<td>2.6 (0.0-93.0)</td>
<td>1.9 (0.0-89.5)</td>
<td>9.1 (0.0-93.0)</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td><strong>LoS ICU (days)</strong></td>
<td>0.0 (0.0-42.8)</td>
<td>0.0 (0.0-42.8)</td>
<td>0.0 (0.0-38.0)</td>
<td>0.160</td>
</tr>
<tr>
<td><strong>Mortality (%)</strong></td>
<td>5.6</td>
<td>5.1</td>
<td>11.1</td>
<td>0.28</td>
</tr>
<tr>
<td><strong>Ultrasound performed</strong></td>
<td>31/216 (14.4%)</td>
<td>18/198 (9.1%)</td>
<td>13/18 (72.2%)</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td><strong>Abdominal pain</strong></td>
<td>120/216 (55.6%)</td>
<td>103/198 (52.0%)</td>
<td>17/18 (94.4%)</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td><strong>Peritoneal irritation</strong></td>
<td>41/216 (19.0%)</td>
<td>36/198 (18.2%)</td>
<td>5/18 (27.8%)</td>
<td>0.045*</td>
</tr>
<tr>
<td><strong>Hemodynamic instability</strong></td>
<td>21/216 (9.7%)</td>
<td>14/198 (7.1%)</td>
<td>7/18 (38.9%)</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td><strong>ASAT (IU/L)</strong></td>
<td>42 (8-1990)</td>
<td>40 (8-450)</td>
<td>162 (40-1990)</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td><strong>ALAT (IU/L)</strong></td>
<td>20 (4-1237)</td>
<td>20 (4-419)</td>
<td>101 (15-1237)</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td><strong>WBC (10 x 10^9 /L)</strong></td>
<td>11 (2-41)</td>
<td>10 (2-41)</td>
<td>13 (2-22)</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td><strong>LDH (IU/L)</strong></td>
<td>297 (58-1655)</td>
<td>294 (58-875)</td>
<td>431 (223-1655)</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td><strong>Amylase (IU/L)</strong></td>
<td>59 (7-992)</td>
<td>58 (7-334)</td>
<td>99 (41-991)</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td><strong>Creatinine (µmol/L)</strong></td>
<td>50 (15-115)</td>
<td>50 (15-115)</td>
<td>55 (30-105)</td>
<td>0.16</td>
</tr>
<tr>
<td><strong>BATiC score</strong></td>
<td>2.4 (0.0-15.4)</td>
<td>2.2 (0.00-10.60)</td>
<td>9.2 (6.60-15.40)</td>
<td>&lt;0.01*</td>
</tr>
</tbody>
</table>

P-values were computed comparing the columns: ‘No abdominal injury’ and ‘Abdominal injury’ Median and range are shown for variables as applicable.
When assessing the difference in laboratory findings (ALAT, ASAT, WBC, LDH, Amylase and Creatinine) between the abdominally and non-abdominally injured groups the abdominally injured group shows significantly higher values for all variables except for creatinine. Abnormal ultrasound findings, abdominal pain, peritoneal irritation and hemodynamic instability all occurred significantly more often in the abdominally injured group, see table 2.

Of 2160 data points used to calculate BATiC values, 18.5% (400) were based on imputation, see table 3. Median BATiC scores of patients with and patients without intra-abdominal injury were 9.2 (6.6 -15.4) and 2.2 (0.0 -10.6) resp. (p < 0.001). The median BATiC score in the operatively (OR) treated group was 11.6, and 8.1 in the non-OR group (p= 0.174). Figure 1 shows the distribution of BATiC scores and the percentage of patients with abdominal injury per BATiC score. When a BATiC score with a cut-off point of 6 (> 6 is considered abnormal) is used, the sensitivity was 100% and the specificity was 87%. Negative and positive predictive values were 100% and 41%, respectively. When the score is used with a cut-off point of 7, the sensitivity was 89% and the specificity was 94%. The negative and positive predictive values were 99% and 59%, respectively. The area under the ROC-curve was 0.98 (figure 2). When we performed this analysis in only those patients who underwent imaging, results were similar (data not shown).

An overview of statistical values of both cut-off points is shown in table 4. The level of evidence was II.

When a BATiC cut-off value of 6 would have been used, 16 of the 34 performed abdominal CT scans (47%) could have been avoided. When a cut-off value of 7 would have been
Figure 1: Percentage of patients with abdominal injury per BATiC score.

Figure 1 shows the distribution of patients among the different BATiC scores. Furthermore the percentage of abdominally injured patients per BATiC score is displayed.

Figure 2: ROC curve

The ROC curve displays the relation between sensitivity and specificity for different cut-off points. For every cut-off point of the BATiC score, a corresponding sensitivity and specificity value can be determined.
used, 19/34 (56%) would have been unnecessary in the present cohort. This would have led to a decrease in healthcare costs of €2368 or €2812 resp.

**DISCUSSION**

The present series confirmed the usefulness of the BATiC score in a large cohort of 216 pediatric trauma patients. Sensitivity and specificity were around 90% depending on the chosen cut-off value, with negative predictive values > 99%. BATiC therefore seems to be able to reliably rule out intra-abdominal injury. A method of ruling out intra-abdominal injury rather than confirming its presence has greater clinical value in our opinion. A positive score indicating the presence of intra-abdominal injury would inevitably lead to a subsequent CT-scan.

CT scans still play an important role in the diagnosis of intra-abdominal injuries. However, CT scans are associated with a relatively high radiation exposure and subsequent radiation risk. As most hemodynamically stable pediatric patients with parenchymatous injury are treated non-operatively and CT scanning is not able to grade the extent of injury reliably and therefore rarely leads to change in management, the use of CT scan as the gold standard might be questioned. The BATiC score may help in differentiating between patients that need CT and patients that do not. This way, the BATiC score can help reduce the amount of unnecessary CT scans, reducing radiation and thereby radiation induced cancer incidence and lastly costs.

When BATiC scores are ≤ 6, none of the patients have intra-abdominal injury in this series. When BATiC scores are ≤ 7, 99% of the patients will not have intra-abdominal injury. This taken together with the suggestion that repeated abdominal examination by the same physician might be the best diagnostic tool for diagnosing intra-abdominal injury, and that a late diagnosis often does not necessarily influence outcome, suggests that in patients with a BATiC score ≤ 6, CT scans could be avoided altogether. This would lead to a 47% reduction in CT scans.

<table>
<thead>
<tr>
<th>BATiC cut-off: 6</th>
<th>BATiC cut-off: 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV</td>
<td>100%</td>
</tr>
<tr>
<td>PPV</td>
<td>41%</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>100%</td>
</tr>
<tr>
<td>Specificity</td>
<td>87%</td>
</tr>
<tr>
<td>AUC</td>
<td>0.98</td>
</tr>
</tbody>
</table>
In the abdominally injured group CT-scans led to a change in management in 1 of the 18 patients (6%). The CT-scan showed intra-abdominal air and during laparotomy a jejunal perforation was observed. Initially this patient was hemodynamically unstable but responded to fluid resuscitation with no abnormalities during ultrasonography. The BATiC score would have been 8 indicating likelihood of the presence of intra-abdominal injury and justifying a CT-scan. The indication for laparotomy or embolization in the other 6 patients requiring intervention was based on hemodynamic instability. CT-scans aided in targeting the treatment. CT-scans missed one jejunal perforation for which laparotomy was performed based on hemodynamic instability, which developed a few hours after admission. The BATiC score was designed to rule out abdominal injury. When a patient has a BATiC score \( \leq 6 \), a CT-scan seems unnecessary.

The BATiC score was based upon the original score by Karam et al\(^{10}\). The blood tests used in the original article were shown, among others, to have the strongest power to discriminate between patients with and without abdominal injuries. Furthermore they were deemed part of the standard workup in most emergency departments. However, this study uses a slightly altered protocol. Scores of WBC and creatinine were based on other reference values (those used in our center) and lipase was replaced by amylase as lipase is not routinely measured in our center.

The fact that lipase was used instead of amylase, might limit the BATiC score since Karam et al. showed a more significant predictive value for lipase. When looking at the data, creatinine seems strikingly less important in our analysis. In this series only 1 patient showed an abnormal value. This patient sustained no abdominal injury. The origin of this finding might lay in the fact that creatinine is not a very specific marker for any abdominal organ. Holmes et al. recently published a prediction rule consisting of 7 patient history and physical examination variables without blood tests or ultrasonography\(^{11}\). This algorithm was tested in over 12,000 patients, and is an ever further step towards minimizing diagnostic procedures in children, especially as these variables are available in any emergency room around the world. However, while their results are very promising, some of the missed diagnoses in their cohort may not have been missed when utilizing FAST and blood tests\(^{13-16}\). FAST has a relatively low sensitivity, but a high specificity for abdominal injury\(^{17,18}\). The strong risk stratifying capacity, combined with the added benefits of being fast, cheap, non-invasive and readily available in most emergency rooms, suggests that ultrasonography is an important adjunct in the care for children with suspected intra-abdominal injury. It would be of great interest to compare the BATiC with the Holmes algorithm in a prospective study.

When comparing our population to the population of Karam et al. a difference in prevalence of abdominal injury is observed. Karam et al. reported 31/147 (21.1%) having sustained abdominal injury whilst our population consisted of 18/216 (8.3%). When taking this into account a higher NPV and lower PPV can be expected in our population based on a lower prevalence of abdominally injured patients.
Since this was a retrospective analysis, it was inevitable that data was not complete. This is why multiple imputations were used, to give a more reliable view on the scores. When assessing the values before imputations however, similar conclusions can be drawn (table 3). However, the necessity to use imputations does limit the accuracy of the conclusions to some extent. The retrospective nature furthermore limits the possibility of assessing uniformity in parameters such as hemodynamic stability. Further prospective studies into the use of the BATiC score are needed to further validate this as a screening tool for intra-abdominal injury.

In the present era, CT scan will remain the gold standard for diagnosing intra-abdominal injury. To avoid unnecessary CT scans and subsequent radiation risks and costs, the BATiC score seems a reliable tool to assess the presence of intra-abdominal injury. When BATiC scores are $\leq 6$, CT scan seems unnecessary.
REFERENCES