Which pediatric blunt trauma patients do not require pelvic imaging?

Maya Haasz, MD, Laura A. Simone, MD, Paul W. Wales, MD, Jennifer Stimec, MD, Derek Stephens, MSc, Suzanne Beno, MD, and Suzanne Schuh, MD, Toronto, Ontario, Canada

BACKGROUND: This study aimed to develop a tool in identifying traumatized children at low risk of pelvic fracture and to determine the sensitivity of this low-risk model for pelvic fractures. We hypothesized that the proportion of children without predictors with pelvic fracture is less than 1%.

METHODS: This is a retrospective trauma registry analysis of previously healthy children 1 year to 17 years old presenting to the pediatric emergency department with blunt trauma. Postulated predictors of pelvic fracture on radiograph or computed tomography included pain/abnormal examination result of the pelvis/hip, femur deformity, hematuria, abdominal pain/tenderness, Glasgow Coma Scale (GCS) score of 13 or lower, and hemodynamic instability. We used multivariable logistic regression to identify independent predictors of fracture.

RESULTS: Of 1,121 eligible patients (mean [SD] age, 8.5 [4.6] years), 87 (7.8%) had pelvic fracture. Independent predictors included pain/abnormal examination result of the pelvis/hip (odds ratio [OR], 16.7; 95% confidence interval [CI], 9.6–29.1), hematuria (OR, 6.6; 95% CI, 3.0–14.6), femoral deformity (OR, 5.9; 95% CI, 3.1–11.3), GCS score of 13 or lower (OR, 2.4; 95% CI, 1.3–4.3), and hemodynamic instability (OR, 3.4; 95% CI, 1.7–6.9). One of 590 children (0.2%; 95% CI, 0–0.5%) without predictors had pelvic fractures versus 86 (16.2%) of 531 in those with one or more predictors (OR, 119; 95% CI, 16.6–833). One of 87 children with pelvic fractures had no predictors (1.1%; 95% CI, 0–3%). When assuming a 100% radiography rate, this tool saves 53% pelvic radiographs.

CONCLUSION: Children with multiple blunt trauma without pain/abnormal examination result of the pelvis/hip, femur deformity, hematuria, abdominal pain/tenderness, GCS score of 13 or lower, or hemodynamic instability constitute a low-risk population for pelvic fracture, with less than 0.5% risk rate. This population does not require routine pelvic imaging. (J Trauma Acute Care Surg. 2015;79: 828–832. Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic study, level IV.

KEY WORDS: Pelvic fracture; pelvic radiograph; predictors; pediatrics.

Compared with adults, pediatric pelvic fractures are less frequent and carry lower morbidity and mortality.1–7 Although previous Advanced Trauma Life Support (ATLS) guidelines recommended routine pelvic radiography for the evaluation of all blunt trauma patients, there is growing evidence showing that the clinical examination may be sufficiently sensitive to obviate routine pelvic imaging.3,4,8–12 and current ATLS guidelines suggest that a more judicious use of pelvic radiography may be useful.13

Although adult studies have found the physical examination to be a sensitive predictor for pelvic fracture,3,6,8,9,14–18 they did not include the pediatric trauma patients in their recommendations. Importantly, pediatric trauma studies examining the indications for pelvic radiographs are scarce and methodologically limited by a small number of pelvic fractures.1,4,7,19–22 A recent key multicenter study concluded that plain pelvic radiographs have limited sensitivity in identifying clinically important pelvic fractures in pediatric blunt trauma.23 However, the authors did not identify predictors for the need for pelvic imaging and recommend future work in this area.24 As a result, we do not have a sensitive instrument that reliably identifies traumatized children who can safely forego screening pelvic imaging.

Unnecessary pelvic radiography in the pediatric trauma increases radiation exposure to an immature skeleton as well as to the developing gonads,21,24 impedes efficient patient flow in an acute care setting, and adds cost to the health care system. A recent adult study stresses the need to minimize the radiation exposure during the initial trauma assessment.25 This concept is particularly important in children who are more ionizing radiation sensitive and have a longer window of opportunity to express radiation damage compared with adults, with a significantly increased risk of computed tomography (CT)–related future malignancies.26,27 For these reasons, identification of traumatized children who do not require pelvic imaging would be of benefit.

The primary objective of this study was to develop a model aimed at identifying pediatric blunt trauma patients at a very low risk of pelvic fracture who can safely forego pelvic imaging. We hypothesized that the probability of pelvic
fracture in children without any independently significant predictors is less than 1%, with a 95% confidence interval (CI) of 0% to 2%. Secondary objectives included determining the proportion of pelvic radiographs saved using the derived tool.

**PATIENTS AND METHODS**

**Study Design and Population**

This was a retrospective analysis of a prospectively collected trauma database performed at a Level 1 tertiary care pediatric hospital. We included a consecutive sample of children 0 year to 17 years of age who were previously healthy and presented to the emergency department between 2000 and 2004 with blunt trauma and meeting criteria for trauma team activation. We excluded patients with penetrating trauma or congenital bone disease and those without plain pelvic radiographs or pelvic CTs.

**Data Collection**

The trauma database and hospital records of the eligible patients were reviewed by a trained data abstractor for relevant demographic and clinical information including age, sex, mechanism of injury, clinical and imaging outcomes, and a priori postulated plausible predictors of pelvic fracture. These were chosen according to a review of the literature and included the complaint of pelvic/hip pain or abnormal examination of the pelvis/hip (defined later), hematuria (gross or microscopic), abnormal level of consciousness defined by a Glasgow Coma Scale (GCS) score of 13 points or lower, femoral deformity, abdominal pain/tenderness, and hemodynamic instability defined as a blood pressure below the fifth percentile for age or a requirement for 40 mL/kg or greater fluid resuscitation. Abnormal examination of the pelvis included the presence of any of the following: ecchymoses/abrasions/tenderness over the anterior or posterior aspects of the pelvis, pelvic instability, painful hip movement, or rotational hip positioning. A previous meta-analysis of severely injured adults and children confirmed that a thorough clinical examination is highly sensitive in detecting pelvic fractures. The study was approved by the research ethics board of this hospital.

Pelvic fracture was defined as a fracture of the pelvic bones (ilium, ischium, pubis, sacrum), hip fracture/dislocation or disruption of sacroiliac joint identified by a staff pediatric radiologist at the initial trauma imaging, either on a plain radiograph or on a CT. Based on these imaging interpretations, eligible children were divided into those with and without pelvic fracture. The primary outcome was the association between pelvic fracture and the aforementioned plausible predictors. Secondary outcomes included (1) the proportion of patients without any significant predictors, our “low-risk group,” who had a pelvic fracture; (2) the test characteristics such as the sensitivity, specificity, and negative predictive values of the low-risk model with respect to ruling out pelvic fractures; and (3) the proportion of pelvic radiographs omitted if the low-risk group were to forego this investigation. To characterize the pelvic fractures, a study radiologist reviewed the study images independently of the original reports and classified all fractures on the radiographs and CT scans according to a modified Torode classification. Since CT has superior accuracy compared with radiography in defining pelvic fractures in children, CT interpretation was used for fracture classification in children who underwent both imaging modalities.

**Statistical Analyses**

The sample size was based on the requirement of 10 outcomes of interest (pelvic fractures) per predictor variable analyzed by a multiple logistic regression analysis. Assuming a 5% pelvic fracture rate, we needed 60 eligible cases with pelvic fracture and 1,040 cases without pelvic fracture. Furthermore, using an estimated proportion of pelvic fractures in children without significant predictors of 1% and a 95% CI around this proportion of 0% to 2% requires 422 predictor-free low-risk cases.

We compared the normally distributed continuous characteristics of the participating patients with and without pelvic fractures using the Student’s t test for and categorical data using the χ² test. We initially used the univariate regression analyses to determine the degree of association between “pelvic fracture” as a dependent variable and the a priori defined potential predictors of this outcome as independent variables. To control for collinearity, only relatively uncorrelated variables (pairwise associations < 0.1) were used in the multiple regression. These uncorrelated variables with a univariate significance level of less than 0.2 were entered into the multiple regression stage. At the final stage of the multiple regression analysis, all such variables were assessed for statistical significance using the likelihood ratio and Wald test statistics at the 5% significance level. We used the generalized χ² test/df as a goodness-of-fit test for the model. The model was validated using a bootstrap simulation of 1,000 samples.

Secondary analyses consisted of determining a 95% CI around the proportion of patients without significant predictors who sustained a pelvic fracture and of a χ² test to compare the rate of fractures in the low-risk group with no significant predictors versus the group with at least one significant predictor of pelvic fracture. We also calculated the area under the receiver operating characteristic curve for the low-risk tool using the pelvic fracture as an outcome. PROC GENMOD and LOGISTIC in SAS version 9.3 were used in all of the analyses.

**RESULTS**

Of the 1,356 trauma records reviewed, 186 patients were excluded because of a lack of any pelvic imaging. Of the remaining 1,170 patients, 49 met other exclusion criteria; 48 had a penetrating trauma and 1 experienced a congenital bone disease. There were a total of 1,121 participating children, with a median age 9.0 years (range, 2–17 years); 63% were males. The characteristics and outcomes of patients with versus without pelvic fractures are summarized in Table 1. The presence of a pelvic fracture was significantly associated with a female sex, motor vehicle crash mechanism, coexistent abdominal trauma, need for a blood transfusion, and more frequent pelvic imaging (Table 1).

Of the 1,121 study patients, 87 or 7.8% (95% CI, 6.5–9.6%) had a pelvic fracture. According to the modified Torode pelvic fracture classification, 1 child had Type 1 fracture pattern (pelvic avulsion fracture), 4 had Type 2 fractures...
(fracture involving the iliac wing), 20 had Type 3A fractures (involving only the anterior portion of the pelvic ring), 31 had Type 3B fractures (involving both the anterior and posterior portions of the pelvic ring, such as including the sacrum or sacroiliac joint), and 31 had Type 4 fractures (unstable fractures including gross clinical instability; >2 mm of displacement on CT, acetabular fractures, or multiple anterior and posterior pelvic ring fractures).

Table 2 illustrates the differences in the frequencies of the postulated predictors between children who did versus did not sustain pelvic fracture. All of these differences were statistically significant. The strongest predictors of pelvic fracture were the complaint of pelvic/hip pain, abnormal physical examination result with pelvic tenderness/instability or pelvic contusions/abrasions/hip held in rotation, and the presence of hematuria. All of the predictors were also independently predictive of pelvic fracture, with the exception of the abdominal pain (Table 3). The bootstrap validation found that all but one variable were significant more than 80% of the time, demonstrating the nonspurious association between the variables and the outcome.

There were 590 children without any independent predictors; 1 (0.2%) of these had a pelvic fracture (95% CI, 0.0–0.5%). In contrast, children with one or more independently significant predictors had 86 (16.1%) of 531 probability of a pelvic fracture (odds ratio [OR], 119.1; 95% CI, 16.6–833). In other words, children with at least one independent predictor had 119 times higher odds of having a fracture compared with their counterparts without predictors. The clinical risk stratification of pelvic fractures according to the independent predictors in the descending order of importance is summarized in Figure 1. The low-risk group without predictors represents 52.6% of the total study cohort.

Of the 87 children with pelvic fractures, 1 patient (1.1%) had no independent predictors thereof. The sensitivity of the model with one or more predictors versus no predictors of fracture is 86 (98.9%) of 87, specificity of 589 (57%) of 1,034, positive predictive value of 86 (16.2%) of 531, negative predictive value of 589 (99.9%) of 590, and an area under the receiver operating characteristic curve of 90% (95% CI, 87–93%). Omitting this procedure in children without predictors would save 590 (52.6%) of 1,121 pelvic radiographs performed during the study period.

The single patient in the low-risk group with a pelvic fracture was initially diagnosed with an incomplete left pubic ramus fracture on the plain radiograph, with a normal CT finding. The study radiologist interpreted both the radiograph and the CT as showing no fracture.

Of the 87 patients with pelvic fractures, 80 had both plain pelvic radiographs and CTs. In this subpopulation, the pediatric staff radiologists identified 77 fractures on CT, 67 fractures on radiographs, and 64 fractures on both modalities. With the use of the CT interpretation as a reference, the sensitivity of the plain radiograph for pelvic fracture was 64 (83%) of 77. Of the 13 children with positive CT results but negative plain films, one child underwent operative repair of a femoral head fracture (modified Torode Type 4 fracture) with a hip spica cast immobilization; the remaining children were managed nonoperatively.

A total of 5 (7.5%) of 87 patients with pelvic fractures underwent operative repair: 3 children required external fixation

### Table 1. Clinical Characteristics and Outcomes of Children With and Without Pelvic Fractures

<table>
<thead>
<tr>
<th>Characteristic, n (%)</th>
<th>Pelvic Fracture, n = 87</th>
<th>No Pelvic Fracture, n = 1,034</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, median (range)</td>
<td>10.0 (2–17)</td>
<td>8.0 (2–17)</td>
<td>Not significant</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>47 (54)</td>
<td>661 (64)</td>
<td>0.02</td>
</tr>
<tr>
<td>MVC vs. other</td>
<td>61 (70)</td>
<td>498 (48)</td>
<td>0.002</td>
</tr>
<tr>
<td>Abdominal trauma</td>
<td>27 (31)</td>
<td>43 (4)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>History of pelvic</td>
<td>62 (71)</td>
<td>147 (14)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>pain/abnormal pelvic</td>
<td>Examination result</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelvic x-ray</td>
<td>85 (98)</td>
<td>774 (89)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Pelvic CT</td>
<td>83 (95)</td>
<td>463 (45)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Blood transfusion</td>
<td>10 (11)</td>
<td>9 (1)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Pelvic surgery</td>
<td>5 (6)</td>
<td>0</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Mortality</td>
<td>3 (3)</td>
<td>23 (2)</td>
<td>Not Significant</td>
</tr>
</tbody>
</table>

MVC, motor vehicle crash.

### Table 2. Clinical Signs and Symptoms in Children With and Without Pelvic Fractures

<table>
<thead>
<tr>
<th>Type of Injury</th>
<th>Frequency in Pelvic Fractures, Total = 87, n (%)</th>
<th>Frequency in No Pelvic Fractures, Total = 1,034, n (%)</th>
<th>Unadjusted OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelvic/hip pain/abnormal pelvis/hip examination result</td>
<td>209</td>
<td>62 (74)</td>
<td>147 (14)</td>
<td>15.2</td>
</tr>
<tr>
<td>Hematuria</td>
<td>49</td>
<td>18 (21)</td>
<td>31 (3.0)</td>
<td>8.3</td>
</tr>
<tr>
<td>Abdominal pain/tenderness</td>
<td>190</td>
<td>39 (45)</td>
<td>151 (15)</td>
<td>4.0</td>
</tr>
<tr>
<td>GCS score ≤ 13</td>
<td>260</td>
<td>31 (36)</td>
<td>229 (22)</td>
<td>1.8</td>
</tr>
<tr>
<td>Femur deformity</td>
<td>107</td>
<td>26 (30)</td>
<td>81 (8)</td>
<td>4.7</td>
</tr>
<tr>
<td>Hemodynamic instability</td>
<td>91</td>
<td>17 (20)</td>
<td>74 (7)</td>
<td>3.1</td>
</tr>
</tbody>
</table>
of the pelvis, 1 was treated with internal fixation, and 1 underwent acetabular pinning. No patient required angiography or embolization. The characteristics and outcomes of the children in the low- versus high-risk groups are summarized in Table 4. The low-risk group required no pelvic surgery and had a very low rate of coexistent abdominal trauma, blood transfusions, and mortality.

**DISCUSSION**

To our knowledge, this is the largest pediatric study to date identifying multiple blunt trauma patients at a low risk for pelvic fractures. We found that the complaint of pelvic/hip pain or abnormal examination result of the pelvis/hip, hematuria, femoral deformity, hemodynamic instability, and GCS score of 13 or lower constitute independent predictors of this outcome. Children without these features have less than 0.5% probability of pelvic fracture.

Junkins et al.\(^7,19\) have identified a low sensitivity between abnormal examination result of the pelvis/hip, hematuria, femoral deformity, hemodynamic instability, and GCS score of 13 or lower constitute independent predictors of this outcome. Children without these features have less than 0.5% probability of pelvic fracture.

Importantly, our low-risk model reliably excluded all but one pelvic fracture and eliminated all pelvic fractures requiring surgery. Interestingly, the pelvic injury in the single child in the low-risk group initially diagnosed with fracture of the right pubic ramus seems to have been of minor significance since both the radiograph and CT were subsequently interpreted by the study radiologist as showing no fracture and this child required no orthopedic follow-up.

The low-risk model relies on clinical parameters available to all ED physicians, which enhances the generalizability of the study results to other pediatric trauma centers. The results of this study may be particularly helpful to our adult-oriented colleagues who may be less comfortable to forego imaging of traumatized children. The retrospective design of this study limited our ability to rule out the unlikely possibility of fractures missed on the initial imaging. Although the study period may seem somewhat dated, our trauma practice patterns have remained similar, and related impact on the study results is likely small. Since we have excluded only a small proportion of patients for lack of imaging, the resulting bias is likely also minor. However, there may have been a recent decrease in the pelvic imaging rates in traumatized children because of

### TABLE 4. Characteristics and Outcomes of Children in the High- Versus Low-Risk Groups

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Low Risk (n = 590), n (%)</th>
<th>High Risk (n = 531), n (%)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, Mean (SD)</td>
<td>8.4 (4.6)</td>
<td>8.6 (4.6)</td>
<td>0.33</td>
</tr>
<tr>
<td>Sex</td>
<td>379 (74)</td>
<td>329 (62)</td>
<td>0.5</td>
</tr>
<tr>
<td>MVC mechanism</td>
<td>292 (49)</td>
<td>267 (50)</td>
<td>0.89</td>
</tr>
<tr>
<td>Abdominal trauma</td>
<td>14 (2)</td>
<td>56 (11)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Transfusion</td>
<td>2 (0.3)</td>
<td>17 (3)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Pelvic surgery</td>
<td>0 (0.0)</td>
<td>5 (0.9)</td>
<td>0.02</td>
</tr>
<tr>
<td>Pelvic x-ray</td>
<td>429 (73)</td>
<td>433 (82)</td>
<td>0.007</td>
</tr>
<tr>
<td>Pelvic CT</td>
<td>189 (32)</td>
<td>356 (67)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Mortality</td>
<td>2 (0.3)</td>
<td>24 (4)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

MVC, motor vehicle crash.
“intuitive practice change” preceding related published evidence. Therefore, the potential for future reduction in pelvic imaging based on our results may be lower than estimated. Importantly, the low-risk model needs to be validated prospectively at other pediatric trauma centers. If this proves successful, future knowledge translation of this model may indeed obviate the use of pelvic radiography in many traumatized children. This robust evidence may also help guide future ATLS recommendations and help standardize the future care of injured children.

CONCLUSION

We found that previously healthy children with multiple blunt trauma without a complaint of pelvic/hip pain who also do not have a normal examination result of the pelvis/hip and do not have hematuria, femoral deformity, hemodynamic instability, or a GCS score of 13 or lower constitute a low-risk population for a pelvic fracture, with a less than 0.5% probability of pelvic fracture. This population does not require routine pelvic imaging.

AUTHORSHIP

L.A.S., M.H., P.W., and S.S. conceived the study and wrote the protocol. L.A.S. also supervised the data collection and created the database for analysis. S.B. contributed to the study design and manuscript preparation and revision. D.S. provided statistical advice on the study design and analyzed the data. J.S. reviewed and classified all pelvic fractures and critically revised the manuscript. All authors contributed substantially to its revision. All authors take responsibility for the article as a whole.

DISCLOSURE

The authors declare no conflicts of interest.

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