Predicting the need for abdominal hemorrhage control in major pelvic fracture patients: The importance of quantifying the amount of free fluid

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BACKGROUND: In our institution, the computed tomographic (CT) scan has largely replaced the ultrasound for the rapid detection of intraperitoneal free fluid (FF) and abdominal injuries in severely injured patients. We hypothesized that in major pelvic fracture patients, quantifying the size of FF on CT improves the predictive value for the need for abdominal hemorrhage control (AHC).

METHODS: The CT scans of major pelvic fracture (pelvic ring disruption) patients (January 1, 2004, to June 31, 2012) were reviewed for the presence of FF (small, moderate, or large amount) and abdominal injuries. AHC was defined as requiring a surgical intervention for active abdominal bleeding or angiographic embolization for an abdominal arterial injury. Positive predictive value (PPV) and negative predictive value (NPV) (95% confidence interval [CI]) were calculated for all patients and in a subgroup of patients with a high risk for significant hemorrhage (base deficit ≥ 6 mEq/L).

RESULTS: Overall, 160 patients were included in the study. Of the 62 FF patients, 26 required AHC (PPV, 42%, 95% CI, 30–55%). Of the 98 patients without FF, none required AHC (NPV, 100%; 95% CI, 95–100%). For a moderate-to-large amount of FF, the PPV and NPV in all patients were 81% (95% CI, 60–93%) and 96% (95% CI, 91–99%), respectively. In the subgroup of 49 high-risk patients (31%), 17 of 26 FF patients required AHC (PPV, 65%; 95% CI, 44–82%), and none of the 23 patients without FF required AHC (NPV, 100%; 95% CI, 82–100%). For a moderate-to-large amount, the PPV and NPV in high-risk patients were 93% (95% CI, 64–100%) and 89% (95% CI, 72–96%), respectively.

CONCLUSION: In major pelvic fracture patients, the predictive value of FF on CT for the need for AHC is closely related to the amount present. A moderate-to-large amount of FF is highly predictive for the presence of abdominal bleeding that requires hemorrhage control. [J Trauma Acute Care Surg. 2014;76: 1259–1263. Copyright © 2014 by Lippincott Williams & Wilkins]

LEVEL OF EVIDENCE: Therapeutic study, level IV; prognostic study, level III.
KEY WORDS: Pelvic fracture; computed tomography; Focused Assessment with Sonography in Trauma; free fluid; laparotomy.

The computed tomographic (CT) scan is increasingly used for the detection of traumatic injuries in the chest, abdomen, and pelvis. As such, it has become an essential diagnostic tool in the management of trauma patients.1,3

Traditionally, Focused Assessment with Sonography for Trauma (FAST) has been the preferred modality for initial abdominal screening of trauma patients. Similar to FAST, the CT scan can accurately detect intra-abdominal free fluid (FF) but it can also identify the potentially injured organ and the presence of active arterial bleeding (or contrast extravasation). In major pelvic fracture patients, accurate abdominal assessment is critical considering the high risk (HR) for an abdominal injury (up to 40%).4-6 In pelvic fracture patients with major hemorrhage, abdominal and extra-abdominal (pelvic, thoracic, and extremity) injuries are potential sources of significant bleeding. In these critically injured patients, rapid detection of the primary source of bleeding is crucial to allow timely hemorrhage control and improve patient outcome.7-9

In 2004, a multidetector CT scanner was placed in our institution’s trauma resuscitation room.10 In recent years, this modality has largely replaced FAST for the rapid detection of FF and abdominal injuries and for directing early management of severely injured patients. In this study, we examined the association between FF on CT and the presence of abdominal bleeding that requires hemorrhage control in patients with a major pelvic fracture.

We hypothesized that in major pelvic fracture patients, quantifying the size of FF on CT improves the predictive value for the need for abdominal hemorrhage control.

PATIENTS AND METHODS

All adult patients with a major pelvic fracture admitted to the trauma resuscitation room of our Level I trauma center from January 1, 2004, to June 31, 2012, were identified from our prospective trauma registry and the hospital’s DRG International Classification of Diseases—9th Rev. database. Patients...
who had an intravenous contrast-enhanced abdominopelvic CT scan were considered for inclusion. A major pelvic fracture was defined as a disruption of the pelvic ring in (at least) two places. Patients with a single break of the pelvic ring (i.e., single acetabular, iliac wing, or pubic ramus fractures), transfer patients, and patients declared dead on arrival were excluded from analysis. Medical records were reviewed for age, sex, mechanism of injury, Injury Severity Score (ISS), systolic blood pressure and base deficit on arrival, packed red blood cell transfusion in 24 hours of arrival, as well as (hospital and hemorrhage related) mortality. Pelvic fractures were classified using the Young and Burgess classification; major ligamentous disruption was defined as anteroposterior Type II and III, lateral compression Type III, vertical shear and combined mechanism.\textsuperscript{11-13} Operative and radiology (angiography) reports were examined for the presence of abdominal (arterial) injuries and any surgical or radiologic interventions performed for hemorrhage control.

For the purpose of the study, all CT scans were reviewed in consensus by two senior radiology residents who were blinded for the clinical course and findings at laparotomy. CT scans were examined for the presence of FF and abdominal (liver, spleen, kidney, and/or bowel/mesenteric) injuries.

FF was recorded as present or absent for the following abdominal regions: left and right upper quadrant (perisplenic, perihpatic, and pericolic gutters) and pelvis or diffuse in the abdominal cavity. A small amount of FF was defined as present in one region, a moderate amount in two regions, and a large amount in three abdominal regions or diffuse in the abdominal cavity.

Solid organ injuries were graded according to the American Association for the Surgery of Trauma Organ Injury Scale (OIS).\textsuperscript{14}

\section*{Patient Management}

Initial patient assessment followed our institutional protocol and Advanced Trauma Life Support (ATLS) principles. According to the local imaging protocol, all high-energy trauma patients receive a chest and pelvic radiography within 5 to 10 minutes of arrival. Major pelvic fracture patients also have an abdominopelvic intravenous contrast-enhanced CT scan. The location of the multislice CT scanner (SOMATOM Sensation 4 and 64 [from 2008], Siemens Medical Systems, Erlangen, Germany) in the trauma resuscitation room allows us to safely perform a rapid CT scan without moving the patient from the table or interrupting resuscitation, as described elsewhere.\textsuperscript{10} Patients with refractory hemorrhagic shock despite adequate fluid resuscitation (ATLS “nonresponders”) did not have a CT scan but underwent a FAST. Diagnostic peritoneal lavage was not used for initial evaluation of trauma patients in our institution.

Further management was at the discretion of the attending trauma surgeon in conjunction with the (interventional) radiologist who is available on a 24-hour basis. In general, patients with abdominal (solid organ) injuries receive nonoperative management in the absence of clinical signs of ongoing bleeding (stable vital signs without the need for continuing transfusion) regardless of the amount of FF present. Patients with clinical signs of ongoing bleeding (unstable vital signs and a continuing transfusion requirement) receive surgical and/or radiologic hemorrhage control (in the presence of CT contrast extravasation). Patients with refractory hemorrhagic shock (ATLS “nonresponders”) have no CT scan but receive an immediate laparotomy if FF is detected on FAST or pelvic hemorrhage control in the absence of FF. Patients with a pelvic blush on CT and signs of ongoing bleeding generally receive pelvic angiographic embolization as primary intervention; rarely, (primary) extra-abdominal pelvic packing is performed in our institution.

\section*{Definitions}

The need for abdominal hemorrhage control was defined as requiring a surgical intervention for active abdominal bleeding or angiographic embolization for an abdominal arterial injury.

The need for extra-abdominal (pelvic, thoracic, or extremity) hemorrhage control was defined as requiring a surgical intervention for active extra-abdominal bleeding or angiographic embolization for an extra-abdominal arterial injury.

Patients with an HR for significant hemorrhage (high transfusion requirement) were defined as having a base deficit of 6 mEq/L or greater on arrival.\textsuperscript{15-17}

\section*{Statistical Analysis}

The association between FF on CT and the need for abdominal hemorrhage control in all patients as well as in the subgroup of HR patients was examined by constructing contingency tables. The positive predictive value (PPV) and negative predictive value (NPV) with 95% confidence intervals (CIs) were calculated for patients with any FF and in patients with a moderate-to-large amount of FF.

Continuous variables are presented as mean values with SDs and compared with the independent \( t \) test or as median values with interquartile ranges (IQRs) and compared using the Mann-Whitney U-test, depending on data distribution. Categorical values were calculated as percentage of frequency of occurrence. Discrete variables were compared using Fisher’s exact analyses. Statistical significance was declared at the 0.05 level. All management and statistical analysis were performed using SPSS version 20.0.0 software (IBM, Armonk, NY).

\section*{RESULTS}

A total of 172 patients with a major pelvic fracture were identified. Of those, 12 patients (7%) were excluded from analysis; 6 patients did not have a complete intravenous contrast-enhanced abdominopelvic CT scan or were excluded owing to the nondiagnostic quality of the images (none required hemorrhage control), 3 patients had an incomplete medical chart, and 3 patients were unable to have a CT scan owing to refractory hemorrhagic shock (all required hemorrhage control). The remaining 160 patients with a CT scan were included in the study. Sixty-two patients had FF (39%), and 98 (61%) had no FF (Table 1).

Between groups, the age \((p = 0.31)\), sex \((p = 0.35)\), and type of fracture \((p = 0.34)\) were equally distributed. More patients with FF had a motor vehicle accident \((p = 0.02)\), and FF patients had a significantly higher ISS \((p < 0.001)\), lower systolic blood pressure on arrival \((p < 0.001)\), higher base deficit on arrival \((p < 0.001)\) as well as a larger 24-hour packed red blood cell requirement \((p < 0.001)\), and any packed red blood cells. Group with high transfusion requirement had significantly higher ISS than the group with low transfusion requirement (Table 1).

\textbf{Acknowledgments}

I would like to thank [names and affiliations] for their contributions to this research.

\textbf{Conflict of Interest}

The authors declare that they have no conflict of interest.

\textbf{References}


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TABLE 1. Patient Characteristics

<table>
<thead>
<tr>
<th></th>
<th>All Patients (n = 160)</th>
<th>Present (n = 62)</th>
<th>Absent (n = 98)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>40 (19)</td>
<td>38 (19)</td>
<td>41 (18)</td>
<td>0.31</td>
</tr>
<tr>
<td>Sex, male, n (%)</td>
<td>122 (76)</td>
<td>44 (71)</td>
<td>78 (80)</td>
<td>0.35</td>
</tr>
<tr>
<td>Mechanism of injury, MVC, n (%)</td>
<td>36 (23)</td>
<td>20 (32)</td>
<td>16 (16)</td>
<td>0.02</td>
</tr>
<tr>
<td>ISS, mean (SD)</td>
<td>27 (14)</td>
<td>32 (15)</td>
<td>24 (12)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Type of fracture, MLD, n (%)</td>
<td>56 (35)</td>
<td>20 (32)</td>
<td>36 (37)</td>
<td>0.34</td>
</tr>
<tr>
<td>SBP* mean (SD), mm Hg</td>
<td>119 (34)</td>
<td>108 (34)</td>
<td>126 (30)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Base deficit, median (IQR), mEq/L</td>
<td>4 (5)</td>
<td>4 (5)</td>
<td>3 (4)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>PRBC in 24 h, median (IQR), U</td>
<td>3 (11)</td>
<td>5 (17)</td>
<td>2 (8)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Any PRBC, n (%)</td>
<td>111 (69)</td>
<td>49 (79)</td>
<td>62 (63)</td>
<td>0.03</td>
</tr>
<tr>
<td>Hemorrhage control, overall, n (%)</td>
<td>61 (38)</td>
<td>38 (61)</td>
<td>23 (24)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Abdominal, n (%)</td>
<td>26 (16)</td>
<td>26 (42)</td>
<td>0 (0)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Extra-abdominal,** n (%)</td>
<td>38 (24)</td>
<td>17 (27)</td>
<td>21 (21)</td>
<td>0.18</td>
</tr>
<tr>
<td>Hospital mortality, overall, n (%)</td>
<td>19 (12)</td>
<td>14 (23)</td>
<td>5 (5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Hemorrhage related, n (%)</td>
<td>9 (6)</td>
<td>7 (11)</td>
<td>2 (2)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

*In 153 patients.
**Thoracic, pelvic and extremity.
MLD: major ligamentous disruption; MVC: motor vehicle collision; SBP: systolic blood pressure; PRBC: packed red blood cell.
Italics indicate statistical significance.

blood cell requirement (p = 0.03). The need for hemorrhage control overall and for abdominal bleeding specifically was significantly higher in FF patients (p < 0.001 and p < 0.001), but the need for hemorrhage control for extra-abdominal bleeding was equal between groups (p = 0.18). Furthermore, the hospital and the hemorrhage-related mortality rate in FF patients was significantly higher (p < 0.001 and p < 0.02).

Abdominal Injuries
One or multiple abdominal injuries were found in 61 patients (38%). In total, 29 liver injuries (14 Grade 1–3 and 15 Grade 4–6), 24 splenic injuries (14 Grade 1–3 and 10 Grade 4–5), 22 renal injuries (18 Grade 1–3 and 4 Grade 4–5), and 6 bowel/mesenteric injuries were detected. Twenty-four of these injuries were associated with contrast extravasation on CT.
Of 62 patients with FF, 44 had an abdominal injury (71%) and 18 patients (29% of FF patients or 11% of all patients) had FF without an abdominal injury.

Hemorrhage Control
A total of 61 patients (38%) required (surgical or radiologic) hemorrhage control for abdominal or extra-abdominal bleeding. Hemorrhage control for abdominal bleeding (from one or multiple injuries) was required in 26 patients (16%). Surgical hemorrhage control was performed for eight liver injuries (local hemostatic measures or packing), eight splenic injuries (five local hemostatic measures or packing and three splenectomies), and eight bowel/mesenteric injuries (two resection, six primary repair or suture ligation). Intra-abdominal pelvic packing was performed for three pelvic hematomas that had ruptured into the peritoneal cavity. Radiologic hemorrhage control for abdominal bleeding was performed for 10 splenic injuries, 1 liver injury, 2 renal injuries, and 1 injury of a branch of the mesenteric artery.

Hemorrhage control for extra-abdominal bleeding (from one or multiple injuries) was required in 38 patients (24%) (5 also had abdominal bleeding). Radiologic hemorrhage control for pelvic bleeding was required for 32 pelvic arterial injures, and radiologic or surgical hemorrhage control was required for 5 thoracic and 2 major extremity injuries (one of these patients also had a pelvic arterial injury).

FF and the Need for Abdominal Hemorrhage Control in all Patients
The association between FF and the need for abdominal hemorrhage control is presented in Table 2.
Of 62 patients with FF, abdominal hemorrhage control was required in 26 patients (16 large, 5 moderate, 5 small amount) (PPV, 42%; 95% CI, 30–55%). Of the remaining 36 FF patients (3 large, 2 moderate, and 31 small amount), 23 patients had abdominal injuries that were treated non-operatively and 13 patients had no abdominal injuries. Of these 36 FF patients, 13 (36%) without abdominal hemorrhage control did have extra-abdominal hemorrhage control, 9 patients for pelvic bleeding, 3 patients for thoracic injuries, and 1 for a major extremity injury.
Of 98 patients without FF, no patients required hemorrhage control (NPV, 100%; 95% CI, 95–100%).
For a moderate-to-large amount of FF, the PPV and NPV for the need for abdominal hemorrhage control were 81% (95% CI, 60–93%) and 96% (95% CI, 91–99%), respectively.

TABLE 2. Association Between FF on CT and the Need for Abdominal Hemorrhage Control in All Patients (n = 160)

<table>
<thead>
<tr>
<th>Abdominal Hemorrhage Control</th>
<th>FF</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>26</td>
<td>36</td>
<td>62</td>
</tr>
<tr>
<td>Present</td>
<td>0</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>Absent</td>
<td>26</td>
<td>134</td>
<td>160</td>
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</tbody>
</table>

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TABLE 3. Association Between FF on CT and the Need for Abdominal Hemorrhage Control in Patients With a HR for Significant Hemorrhage (n = 49)

<table>
<thead>
<tr>
<th>Abdominal Hemorrhage Control</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>FF Present</td>
<td>17</td>
<td>9</td>
</tr>
<tr>
<td>FF Absent</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>32</td>
</tr>
</tbody>
</table>

FF and the Need for Abdominal Hemorrhage Control in HR Patients

A total of 49 major pelvic fracture patients (31%) had an HR for significant hemorrhage. Compared with non-HR patients, HR patients had a significantly higher (SD) mean age of 41 (17) years versus 41 (17) years (p = 0.79). Furthermore, HR patients had a significantly higher mean (SD) ISS of 35 (16) versus 23 (10) (p < 0.001), and they had a significantly worse hemodynamic status on arrival as expressed by a mean (SD) systolic blood pressure of 108 (42) mm Hg versus 124 (42) mm Hg (p = 0.03) and a median base deficit of 9 mEq/L (IQR, 5 mEq/L) versus 3 mEq/L (IQR, 5 mEq/L) (p < 0.001). HR patients also had a significantly higher median packed red blood cell requirement in 24 hours of 12 U (IQR, 21 U) versus 2 U (IQR, 4 U) (p < 0.001) as well as any packed red blood cell required in 45 (92%) versus 66 (60%) (p < 0.001) non-HR patients. Lastly, the overall hospital mortality and the hemorrhage-related mortality were significantly higher in HR patients (15 [31%] vs. 4 [4%] [p < 0.001] and 8 [16%] vs. 1 [1%], respectively [p < 0.001]).

The association between FF and the need for abdominal hemorrhage control in patients with an HR for significant hemorrhage is presented in Table 3.

Of 26 HR patients with FF, abdominal hemorrhage control was required in 17 patients (10 large, 3 moderate, and 4 small amount) (PPV, 65%; 95% CI, 44–82%). Of the remaining nine FF patients (one large, and eight small amount), seven patients had nonoperative management for solid organ injuries, and two had no abdominal injuries. Seven of these nine FF patients (78%) without abdominal hemorrhage control did have extra-abdominal hemorrhage control, four patients for pelvic bleeding, two patients for thoracic injuries, and one for a major extremity injury.

Of 23 patients without FF, no patients required abdominal hemorrhage control (NPV, 100%; 95% CI, 82–100%).

For a moderate-to-large amount of FF, the PPV and NPV for the need for abdominal hemorrhage control were 93% (95% CI, 64–100%) and 89% (95% CI, 72–96%), respectively.

DISCUSSION

In this study, we found that in major pelvic fracture patients, the presence of FF on CT is not reliably associated with the need for abdominal hemorrhage control. Many FF patients had abdominal (solid organ) injuries that were treated nonoperatively. Of note is also the considerable number of patients who had FF without abdominal injuries (29% of FF patients and 11% of all patients). To our knowledge, the association between FF and the presence of an abdominal injury in pelvic fracture patients has not been reported before. Nevertheless, the significant rate of FF without abdominal injuries in our study was considerably higher than earlier reported in blunt abdominal trauma patients (3%). This finding is most likely attributable to factors directly related to the pelvic fracture itself. Major pelvic fractures are commonly associated with a large pelvic hematoma, which may rupture or cause seepage of blood into the peritoneal cavity. These pelvic fracture-related factors generally caused a small amount of FF to accumulate intra-abdominally.

While the presence of any amount of FF had limited predictive value (PPV 42%), the presence of a moderate-to-large amount of FF had a considerably higher predictive value for the need for abdominal hemorrhage control (PPV 81%). The findings in our current study illustrate the importance of quantifying the amount of FF found on imaging in major pelvic fracture patients. Measuring the size of FF can be particularly useful in pelvic fracture patients with an HR for significant hemorrhage. In these severely injured patients, accurate assessment of the abdomen for a potential source of hemorrhage is even more critical because it determines the need for primary abdominal versus pelvic hemorrhage control.9–11 Similar to our findings in the overall population, in HR patients, a moderate-to-large amount of FF had a considerably higher predictive value for the need for abdominal hemorrhage control compared with any FF (93% vs. 65%).

Based on our data, in patients with a small amount or no FF, an abdominal source of hemorrhage is highly unlikely (NPV of 96% in all patients and of 89% in HR patients). Therefore, in the presence of hemorrhagic shock, a primary pelvic source of bleeding should be strongly considered.

Clearly, performing a CT scan in HR patients is potentially hazardous. This is particularly pertinent if patients have to be transported to the radiology department and their definitive treatment is further delayed. These risks have to be carefully weighed, and in some patients, further management may have to be guided by the FAST examination.

Only one earlier study examined the association between different sizes of FF and the need for a therapeutic intervention (laparotomy) in pelvic fracture patients.12 In a patient population with comparable patient characteristics and interventions, the authors found a similar FF incidence of 37% (using a slightly different measure for quantifying the amount). In 16% of all patients, a laparotomy for abdominal bleeding was needed with a PPV of 39% and NPV of 98% for any amount of FF. The PPV and NPV for a large amount of FF in all patients were 62% and 92%, respectively, and in hypotensive patients, 70% and 86%, respectively. The presence or absence of an abdominal injury in relation to FF and the need for angiographic embolization for abdominal (solid organ) injuries were not addressed in this study.

Limitations

The limitations of this study include those inherent to its retrospective design and data collection. We were unable to collect more detailed information concerning resuscitation and fluids administered, using a central line or a crystalloid deficit. Moreover, we were unable to identify an isolated pelvic fracture. Similarly, we did not include children, and the presentation of pelvic injuries remains a potential future research area. The decision to perform an angiography in a set of pelvic trauma patients with an HR is complex and is not a standard institutional procedure. Therefore, further study in this setting is necessary.
and fluid requirement in the trauma resuscitation room. By using a widely accepted measure for hemorrhagic shock (base deficit) available immediately on arrival, we were able to identify an HR subgroup of patients with significant hemorrhage. Moreover, during the study, our 4-slice CT scanner was upgraded to a 64-slice scanner. To an extent, this may have influenced the predictive values found as more contemporary scanners are potentially able to detect smaller amounts of FF. Lastly, the decision to proceed for hemorrhage control was not predefined in a set protocol but was at the discretion of the attending trauma surgeon. Nevertheless, we feel that our clinical practice is comparable with that in other hospitals. Specific indications for performing a hemostatic intervention may differ between institutions depending on local resources and protocols. However, many hospitals have adopted a strategy of nonoperative management and angiographic embolization for selected abdominal injuries that is similar to ours.

CONCLUSION

In major pelvic fracture patients, the predictive value of FF on CT for the need for abdominal hemorrhage control is closely related to the amount present. A moderate-to-large amount of FF is highly predictive for the presence of abdominal bleeding that requires hemorrhage control. Of note is the considerable number of patients with a small amount of FF caused by the pelvic fracture itself instead of by an abdominal injury.

AUTHORSHIP


DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES


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