Patterns of Fluid Accumulation on Screening Ultrasonography for Blunt Abdominal Trauma

Comparison With Site of Injury

Claude B. Sirlin, MD, Giovanna Casola, MD, Michèle A. Brown, MD, Nirav Patel, MD, Eli J. Bendavid, MD, David B. Hoyt, MD

The objectives of this study were to define where fluid accumulation is shown on screening ultrasonography after blunt abdominal trauma and to determine how fluid accumulation patterns are associated with the site of injury. From 1994 to 1998, 2693 screening examinations for blunt abdominal trauma were performed, in which 7 regions were examined for fluid. On the basis of a preliminary analysis of patients with solitary injuries, all 194 patients with sonographically detected fluid were grouped by fluid accumulation pattern. Fluid patterns were compared with sites of injury. The patterns differed between hepatic and splenic injuries. Fluid in the left upper quadrant, in both upper quadrants, or diffusely distributed suggested splenic injury, whereas fluid in the right upper quadrant or the right upper quadrant and lower recesses suggested hepatic injury (P < .0001). Fluid accumulation was random after enteric injury. Patients with extraperitoneal injury had no fluid or had fluid focally at the injury site. The ability to predict the injury site on the basis of fluid patterns should expedite treatment of hemodynamically unstable patients with blunt abdominal trauma. Key words: ultrasonography; blunt abdominal trauma; free fluid.
criterion for the Major Trauma Outcome Study were considered for inclusion. Patients qualified for the Major Trauma Outcome Study database if their injuries resulted in death, admission to the hospital for a minimum of 72 hours, or admission to the intensive care unit. Six patients were excluded. In 3, the ultrasonography was limited because of subcutaneous emphysema (n = 2) or morbid obesity (n = 1). The other 3 refused further evaluation after screening ultrasonography revealed small quantities of intraperitoneal fluid, and the suspected injuries were never confirmed. The remaining 2693 patients (752 female and 1941 male; mean age, 38 years) formed the basis of this study.

Patients were admitted to the trauma surgery service, and their records were entered prospectively into a computerized database, which included updated results of all ancillary examinations and procedures performed (Table 1). The trauma service was free to pursue any additional investigation deemed appropriate for evaluation of patients. Early in our experience, most negative ultrasonographic examination findings were confirmed by ancillary tests. As experience accrued, other tests were obtained only if the ultrasonographic findings were positive or if the clinical suggestion of injury was high despite negative ultrasonographic findings. Patients with positive ultrasonographic findings and hemodynamic instability underwent laparotomy without preoperative confirmation of injury. Patients who died had postmortem examinations. To monitor potential delayed clinical complications or missed diagnoses after discharge, the trauma service participates in the county quality assurance program, the participants of which meet monthly to review trauma admissions and complications for the entire county.

Of the 2693 patients in the study, 172 (6.4%) had a total of 243 abdominal injuries (163 intraperitoneal and 80 extraperitoneal), as summarized in Table 2. In 10 patients who were otherwise healthy, small quantities of intraperitoneal fluid depicted by ultrasonography were confirmed on computed tomography (CT), but the site of injury could not be identified; although these patients had good clinical outcomes without surgical intervention, the fluid was considered to represent traumatic injury of indeterminate origin. Overall, 72 (42%) of the 172 injured patients had injuries requiring surgery, including 70 who had therapeutic laparotomies and 2 who died before surgical intervention. Two additional patients (1 with a retroperitoneal hematoma and the other with a mesenteric tear) underwent nontherapeutic laparotomies (bleeding was no longer active at the time of exploration); these were not considered injuries requiring surgery for purposes of analysis. Nine (5%) of the 172 injured patients had fatal abdominal injuries. Six patients with nonfatal abdominal injuries died of other causes.

The remaining 2521 patients had no abdominal injuries, including 57 who died of closed head or thoracic injuries, 3 who had negative exploratory laparotomy findings, 2 who underwent laparotomy for other conditions, and 4 who underwent laparotomy for organ donation.

The study received full approval of the institution's Investigational Review Board.

**Ultrasonographic Examinations**

Examinations were performed during trauma resuscitation by experienced sonographers using 2.25-, 3.5-, or 5.0-MHz sector or 5.0-MHz curved array transducers of an ATL HDI 3000 scanner (Advanced Technology Laboratories, Bothell, WA) or an Acuson 128-XP (Acuson Corp, Mountain View, CA) scanner with Doppler capabilities. All examinations were performed in the presence of a staff or resident radiologist and interpreted prospectively by radiologists. Patients' bladders were distended with 200 to 300 mL of sterile saline via Foley catheter if empty at the start of the examination. Seven regions were examined for fluid, including the right upper quadrant (RUQ), the left upper quadrant (LUQ), the pelvis, the paracolic gutters, and the renal fossae. Visceral organs were also evaluated for parenchymal abnormalities suggesting injury. Studies were filmed with a Kodak Image Link system (Eastman Kodak Co, Rochester, NY).

Retrospectively, ultrasonographic images from all studies in which abnormalities were identified
(true- and false-positive results) and all studies that yielded negative results but in which patients had actual injuries (false-negative results) were reviewed by an experienced radiologist blinded to final outcome. The presence or absence of fluid (free or loculated) in each of the 7 regions examined was recorded. On the basis of a previous study, isolated anechoic pockets of fluid in the cul-de-sac in women of reproductive age were considered physiologic and not included.

**Analysis**

As a preliminary step, we retrospectively identified all patients with isolated splenic, hepatic, enteric, and extraperitoneal injuries and correlated the site of injury with the location of fluid pockets seen on ultrasonography.

Because this preliminary analysis suggested that fluid accumulates in distinct patterns after isolated injuries, we hypothesized that sono- graphic fluid patterns might help predict the site of injury in trauma patients at the time of ultrasonographic screening, when the presence, number, and location of injuries are unknown. To test this hypothesis, we divided all patients with positive ultrasonographic studies into groups on the basis of the sonographic pattern of fluid. We then calculated and compared the incidence of different organ injuries in each group.

Statistical comparisons were done using the $\chi^2$ test, except when minimum expected values were less than 5; then Fisher’s exact test was used.

**Results**

**Fluid Accumulation in Patients With Isolated Injuries**

**Intraperitoneal Injuries**

Ninety patients had isolated injuries of the spleen (n = 43), liver (n = 27), and bowel or mesentery (n = 17). Two patients had isolated bladder lacerations with intraperitoneal extravasation but are not discussed because of the small sample size. Six basic patterns of fluid accumulation were observed: (1) RUQ only; (2) LUQ only; (3) pelvis only; (4) both upper quadrants; (5) RUQ and lower (1 or more pelvic or paracolic) recesses; and (6) both upper quadrants and lower recesses. No patient had fluid in the LUQ and lower recesses or isolated to a paracolic gutter. Fluid tended to accumulate in somewhat different patterns after splenic, hepatic, and extraperitoneal injuries, as summarized in Table 3 and Figure 1 and discussed below.

Ultrasoundography depicted fluid in 38 (88%) of 43 patients with isolated splenic injuries. Fluid was identified in the LUQ in 32 (74%) of 43 patients. Fluid was isolated to regions remote from the site of injury in 6 (14%) of 43 patients (Table 3): either the RUQ only or the RUQ and lower recesses. Ten (23%) of 43 patients had fluid in a single recess, and 28 (65%) of 43 had fluid in more than 1 region examined. The 3 most common patterns of fluid accumulation after splenic injury were, in decreasing order, both upper quadrants and lower recesses, both upper quadrants, and the LUQ only. No patient had fluid in the LUQ and lower recesses without having fluid in the RUQ (Figure 1).

**Table 2. Abdominal Injuries (243 in 172 patients)**

<table>
<thead>
<tr>
<th>Injury</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraperitoneal</td>
<td>163</td>
</tr>
<tr>
<td>Liver</td>
<td>49</td>
</tr>
<tr>
<td>Gallbladder</td>
<td>1</td>
</tr>
<tr>
<td>Spleen</td>
<td>64</td>
</tr>
<tr>
<td>Enteric*</td>
<td>36</td>
</tr>
<tr>
<td>Bladder</td>
<td>3</td>
</tr>
<tr>
<td>Nonspecific traumatic fluid</td>
<td>10</td>
</tr>
<tr>
<td>Extraperitoneal</td>
<td>80</td>
</tr>
<tr>
<td>Kidney</td>
<td>25</td>
</tr>
<tr>
<td>Adrenal</td>
<td>20</td>
</tr>
<tr>
<td>Pancreas</td>
<td>5</td>
</tr>
<tr>
<td>Duodenum</td>
<td>5</td>
</tr>
<tr>
<td>Retroperitoneal hematoma</td>
<td>20</td>
</tr>
<tr>
<td>Placenta</td>
<td>2</td>
</tr>
<tr>
<td>Rectus sheath</td>
<td>1</td>
</tr>
<tr>
<td>Bladder</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>243</td>
</tr>
</tbody>
</table>

*Enteric indicates confirmed intraperitoneal small-bowel, colonic, and mesenteric injuries; it does not include duodenal injuries.

**Table 3. Presence and Location of Fluid With Respect to Injury Site**

<table>
<thead>
<tr>
<th>Injury</th>
<th>Fluid, n (%)</th>
<th>Fluid at Injury Site, n (%)</th>
<th>Remote Fluid Only, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spleen</td>
<td>43 (88)</td>
<td>32 (74)</td>
<td>6 (14)</td>
</tr>
<tr>
<td>Liver</td>
<td>27 (85)</td>
<td>21 (78)</td>
<td>8 (7)</td>
</tr>
<tr>
<td>Enteric</td>
<td>17 (88)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>EP</td>
<td>35 (49)</td>
<td>17 (49)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

EP indicates extraperitoneal; and NA, not applicable (because of the multifocal nature of enteric injuries and the difficulty of scanning the midabdomen, it was not possible to correlate the location of fluid with the precise site of bleeding in these cases).
Ultrasonography depicted fluid in 23 (85%) of 27 patients with isolated hepatic injuries. Overall, 21 (78%) of 27 had fluid in the RUQ, and 8 (30%) of 27 had fluid in this region only. Fluid was isolated to recesses remote from the site of injury in 2 (7%) of 27 patients (Table 3), both of whom had fluid in the pelvis. Ten (33%) of 27 patients had fluid in a single recess, and 13 (48%) of 27 had fluid in more than 1 region examined. The 2 most common patterns of fluid accumulation after hepatic injuries were the RUQ only and the RUQ and lower recesses. No patient had fluid isolated to the LUQ or both upper quadrants (Figure 1).

Seventeen patients had isolated enteric (small bowel, colon, and mesenteric) injuries. Ultrasonography depicted fluid in 15 (88%). In 7 (41%) of 17 patients, the fluid was in a single recess, either the RUQ or pelvis. In 8 (47%) of 17, the fluid was in more than 1 region. In these cases, the fluid always involved the RUQ, with variable involvement of the LUQ and lower recesses. The 2 most common patterns were RUQ only and both upper quadrants and lower recesses (Figure 1).

Extraperitoneal injuries

Thirty-five patients had a total of 43 isolated extraperitoneal (1 extraperitoneal bladder, 1 rectus sheath, 2 placenta, 1 duodenum, 14 adrenal, 12 kidney, and 12 retroperitoneal hematoma) injuries. Twenty-seven had solitary injuries, and 8 had 2 injuries each. Overall, ultrasonography depicted fluid in 17 (49%) of 35. When present, the fluid invariably was located locally at the site of injury. No patients had fluid involving multiple abdominal recesses, and none had fluid only in abdominal recesses remote from the site(s) of injury (Table 3).

In 9 of the 17 patients with fluid, the fluid was interpreted correctly as being extraperitoneal. In 8 patients, an intraperitoneal component was questioned in the ipsilateral hepatorenal or splenorenal recess; in 1 of these patients, follow-up CT revealed a small quantity of intraperitoneal fluid corresponding to the ultrasonographic finding; in the others, CT showed retroperitoneal fluid only.

Patterns of Fluid Accumulation

Excluding physiologic collections in 34 women of reproductive age, ultrasonography depicted fluid in 194 patients. Of the 194 patients, 169 had purely intraperitoneal fluid corresponding to 1 of the 6 patterns of fluid accumulation identified in the preliminary analysis, and 17 had purely extraperitoneal fluid. Figure 2 shows, for each of these fluid patterns, the percentage of patients who had various types of injuries. Because some patients had multiple injuries, whereas others had no injuries or injuries other than those specified in Figure 2, the percentages do not add up to 100%. Eight patients had miscellaneous fluid patterns and are not analyzed.

Hepatic ($P < .02$) and splenic ($P < .0001$) injuries were not distributed randomly among the 169 patients with 1 of the defined intraperitoneal fluid patterns, allowing statistical comparisons between groups. Three fluid patterns favored splenic (43 of 79, or 54% combined incidence) over hepatic (15 of 79, or 19%) injuries: isolated fluid in the LUQ, fluid in both upper quadrants, and diffuse fluid involving both upper quadrants and the lower recesses. Despite the greater number of splenic injuries overall, 2 patterns favored hepatic (24 of 73, or 33% combined incidence) over splenic (10 of 73, or 14%) injuries: isolated fluid in the RUQ only and fluid in the RUQ and lower recesses. The difference between each of the 2 patterns that favored hepatic injury and each of the 3 patterns that favored splenic injury was statistically significant ($P < .02 - .001$). Pooling the 2 patterns that favored

![Figure 1. Patterns of intraperitoneal fluid accumulation in patients with solitary splenic, hepatic, and enteric injuries. The stacked bar graph shows for each type of solitary injury the percentage of patients with various fluid patterns. Percentages do not add up to 100%, because some patients had no fluid. Recesses include pelvis only, 1 or both paracolic gutters, and pelvis and 1 or both gutters; n indicates number of patients. No patient had fluid in the LUQ and lower recesses only.](image-url)
hepatic injuries and pooling the 3 patterns that favored splenic injuries made the differences more significant ($P < .0001$).

In contrast, enteric injuries had random intraperitoneal fluid patterns ($P = .19$). Extra-peritoneal injuries also occurred randomly ($P = .57$) in patients with intraperitoneal fluid. In these cases, the fluid was usually related to a concomitant intraperitoneal injury (28 of 36, or 78%) or to a misinterpretation of retroperitoneal fluid as being intraperitoneal (7 of 36, or 19%). In the 1 patient with an isolated extraperitoneal injury in whom intraperitoneal fluid was documented on CT, the fluid probably represented extraperitoneal blood that had spread into the intraperitoneal compartment. When fluid was identified in 1 or both renal fossae, on the other hand, retroperitoneal injuries were discovered in the majority of patients, invariably at the site of fluid.

### Discussion

To date, most investigators have focused on the sensitivity and accuracy of screening ultrasonography for detecting abdominal trauma. A few studies have addressed injury location rather than detection and have documented limited accuracy in determining the source of hemoperitoneum based on sono-graphic assessment of organ parenchyma. Two previous studies analyzed posttraumatic fluid by recording the relative frequency with which fluid accumulates in individual recesses after abdominal injury, but these studies did not attempt to define patterns of fluid accumulation and did not determine whether fluid patterns might be helpful for injury location.

The present study assessed fluid accumulation in patients with BAT to determine whether fluid patterns may be useful in predicting injury location. As a preliminary step, we evaluated the location of fluid after isolated injuries. For splenic, hepatic, enteric, and extraperitoneal injuries, the patterns of fluid accumulation were different but had overlapping features. Fluid was evident in more than 85% of isolated splenic injuries and usually followed 1 of 3 patterns: isolated in the LUQ, in both upper quadrants, or in both upper quadrants and in 1 or more lower recesses. Although a component of the fluid usually was present at the site of injury, fluid occasionally was isolated to remote recesses. Fluid was not evident in the LUQ and lower recesses without a component in the RUQ as well. One explanation is that splenic hemorrhage first accumulates in the LUQ and then extends to the RUQ before involving the paracolic and pelvic recesses. This is plausible because the phrenicocolic ligament acts as a relative barrier to the efflux of fluid from the LUQ to the left paracolic gutter.

In isolated hepatic injuries, fluid was evident in 85% of cases and usually involved the RUQ only or the RUQ and lower recesses. Occasionally, fluid extended into the LUQ, but only when fluid occupied the RUQ and lower recesses as well. These observations suggest that hepatic fluid first accumulates around the liver and then extends into the paracolic gutters and pelvis before involving the LUQ. A plausible explanation is that the falciform ligament impedes spread of fluid from the right to the left subphrenic space, whereas the mesentery directs fluid from the subhepatic space into the right lower quadrant.

In isolated enteric injuries, fluid was evident in more than 85% of cases, but the pattern was
variable. Generally, fluid occupied the RUQ, the pelvis, the paracolic gutters, or some combination of the 3 locations. Fluid in the LUQ was associated with concomitant fluid in the RUQ, usually in association with fluid in 1 or more lower recesses. Similar relative frequencies were observed by Rozycki et al. These observations suggest that fluid from enteric injuries tends to accumulate first in the RUQ or in one of the lower recesses and extends to the LUQ only when the quantity of fluid is large. Focal collections of fluid adjacent to injured bowel or mesentery were not assessed, because the midabdomen is difficult to scan with ultrasonography and was not part of the screening protocol.

For isolated extraperitoneal injuries, fluid was either focal at the site of injury (49%) or was absent (51%). It often was difficult to ascertain whether the fluid was purely extraperitoneal or whether it had an intraperitoneal component. On 1 occasion, intraperitoneal fluid was confirmed after an isolated extraperitoneal injury, probably representing extraperitoneal blood that had spread into the intraperitoneal compartment.

We next assessed whether sonographic fluid patterns could predict the sites of injury. Because of the overlap between different patterns, and because many patients (47 of 172, or 36%) had combined rather than isolated injuries, we could not reliably predict the sites of injury based on fluid patterns alone. Nevertheless, because hepatic and splenic injuries did not occur randomly in patients with different sonographic fluid patterns, certain generalizations could be made. Fluid in the RUQ only or in the RUQ and lower recesses significantly suggested hepatic over splenic injuries, whereas fluid in the LUQ, in both upper quadrants, or diffusely distributed throughout the abdomen and pelvis suggested splenic injury. Enteric injuries occurred unpredictably, with a similar injury rate for most of the described patterns. Fluid in one of the renal fossae usually indicated retroperitoneal injury.

We conclude that splenic, hepatic, and extraperitoneal injuries have overlapping but different patterns of fluid accumulation, which may prove beneficial in predicting the site of injury in the clinical setting. All of the recesses examined were useful in defining the pattern of fluid accumulation and hence had prognostic value. On the basis of these observations, we recommend that an acceptable sonographic screening examination should include the upper quadrants, paracolic gutters, renal fossae, and pelvis. The ability to predict the site of injury on the basis of patterns of fluid accumulation should expedite appropriate treatment of the patient with trauma and hemodynamic instability in whom emergent clinical decisions must be made without preoperative confirmation of ultrasonographic findings.

References


