Screening US for Blunt Abdominal Trauma: Objective Predictors of False-Negative Findings and Missed Injuries

PURPOSE: To determine the risk for missed injury in patients with blunt abdominal trauma and negative findings at screening ultrasonography (US) and with coexistent hematuria or fracture of the sixth through 12th ribs, lumbar spine, or pelvis.

MATERIALS AND METHODS: From a database of 4,000 patients screened with US for blunt abdominal trauma at a level 1 trauma center, the 3,679 patients with negative US findings were retrospectively classified by consensus of two authors into high-risk (n = 494) and low-risk (n = 3,185) groups based on the presence of hypothetical predictors of missed injury: hematuria (n = 96) or fracture of the sixth through 12th ribs (n = 216), lumbar spine (n = 105), or pelvis (n = 174). Outcome in each patient was determined by the same two authors consensually after retrospective review of the trauma registry and all radiologic, surgical, and autopsy reports. The risk for missed abdominal injury was determined for each patient risk group and for each hypothetical predictor. Risks were statistically compared by using the Pearson \( \chi^2 \), Fisher exact, or Fisher-Freeman-Halton exact test, depending on expected frequencies.

RESULTS: High-risk patients were 24 times more likely to have abdominal injuries after negative US findings (30 [6.1%] of 494) than were low-risk patients (eight [0.25%] of 3,185) (\( P < .001 \)). Among high-risk patients, the absolute risks for missed abdominal injury associated with specific predictors were 15.6% (15 of 96 patients) for hematuria, 6.0% (13 of 216) for lower rib fractures, 7.6% (eight of 105) for lumbar spine fractures, and 5.2% (nine of 174) for pelvic fractures. Each of these risks was significantly higher for patients in the high-risk group than for those in the low-risk group (\( P < .001 \)).

CONCLUSION: Hematuria and fracture of the lower ribs, lumbar spine, or pelvis are objective predictors of missed abdominal injury in patients with blunt abdominal trauma and negative US findings, and such patients may benefit from additional screening with computed tomography.

\( \odot \) RSNA, 2003

Ultrasoundography (US) is the primary method used to screen for blunt abdominal trauma at several trauma centers in Europe and Asia, as well as at selected centers in the United States (1–10). Although false-negative results with screening US are rare (1%) (10–14), they may cause a delay in diagnosis and management of abdominal injuries. Most abdominal injuries missed at screening US are detected at subsequent computed tomographic (CT) examinations ordered because of clinical suspicion of missed injuries (15). Reliance on clinical symptoms as a prompt for further screening is problematic, however, because many symptoms (eg, abdominal pain) are subjective, and others (eg, decreasing hematocrit levels) may take time to develop. Therefore, we sought to define objective factors that could help identify patients with blunt abdominal trauma who are at high risk for false-negative findings at screening US. The delineation of such factors, we believed, would not only expedite diagnosis and management of abdominal injury but also could help decrease morbidity and mortality associated with missed injury.
We hypothesized that hematuria and fractures of the sixth through the 12th ribs, lumbar spine, and pelvis might be predictors of missed abdominal injury in patients with negative US findings. Thus, the primary purpose of our study was to determine the risk for missed abdominal injury in patients with blunt abdominal trauma and negative findings at screening US and with coexistent hematuria or fracture of the sixth through the 12th ribs, lumbar spine, or pelvis.

MATERIALS AND METHODS

Patients

From a database of 4,000 patients who underwent US for blunt abdominal trauma at a level 1 trauma center between April 1994 and July 2001 and who qualified for the Major Trauma Outcome Study (MTOS) (16), we retrospectively identified 3,679 patients in whom the results of screening US were prospectively interpreted as negative for abdominal injury. The average age of the 3,679 patients was 40 years (range, 1–99 years): 2,597 patients were male (mean age, 38; range, 1–95 years) and 1,082 were female (mean age, 42; range, 4–99 years). The difference in mean age between the sexes was statistically significant (P < .001, unpaired two-tailed Student t test). This study received full approval from the institutional review board. Informed consent was not routinely obtained for the use of patient data, because the institutional review board waives this requirement for records of patients in whom abdominal US is performed in the trauma setting.

After screening US, patients were admitted to the trauma surgery service for observation and management of other injuries (median hospital stay, 1.8 days; range, 6 hours to 430 days). Patients who were discharged after screening US without being admitted did not meet MTOS criteria and were not included in the study. Anteroposterior chest radiography and urinalysis were performed in all patients at admission. CT and other tests— including repeat US, cystography, diagnostic peritoneal lavage, exploratory laparotomy, and radiography of the spine and pelvis—were performed at the discretion of the trauma service. The number of patients in whom radiographs of the spine or pelvis were obtained was not recorded. Because all study patients met MTOS entry criteria, all were considered to have nontrivial mechanisms of trauma. Survivors were examined at follow-up appointments in the trauma clinic 1 week after discharge. Autopsies were performed in all patients who died. The results of autopsy and any additional follow-up radiologic or surgical examinations served as the standard of reference for this study. If no autopsy or additional examination was performed, clinical outcome was used as the standard, as previously described (4,10–13,15). The date and time of imaging were not recorded. Urinalysis results were typically available within 15 minutes of urine specimen collection, but the exact time was not recorded.

The trauma service entered patients prospectively into the trauma registry. The registry contains information about all documented injuries and is updated regularly by the trauma service as new injuries are discovered. To identify any missed injuries after discharge from the hospital, the trauma service performed systematic monthly audits of all trauma centers in the county. In these monthly audits, all errors and delays in diagnosis of traumatic injuries in all county trauma centers were discussed, tabulated, and entered into the trauma registry of each institution. To our knowledge, this is the only systematic county-level trauma auditing system in the United States.

US Technique

US examinations were performed during trauma resuscitation by one of 15 certified sonographers (with 1–20 years of experience) using one of two scanners (ATL HDI 3000, Advanced Technologies Laboratories, Bothell, Wash; or 128-XP, Acuson, Mountain View, Calif) and a 2.25-, 3.5-, or 5.0-MHz sector transducer or a 5.0-MHz curved-array transducer with Doppler capabilities. Prior to scanning, the patients’ bladders, if empty, were distended with 200–300 mL of sterile saline solution administered via Foley catheter. Seven abdominal regions were examined for free fluid, including the upper quadrants, the pelvis, the paracolic gutters, and the renal fossae. Visceral organs were evaluated for parenchymal abnormalities indicative of injury. Total scanning time typically was 3–5 minutes, but the precise duration of each US examination was not recorded.

US Image Interpretation

Until April 2001, US examinations were recorded with an imaging system (Kodak Image Link; Eastman Kodak Company, Rochester, NY), and images were reviewed with an alternator. After April 2001, images were archived digitally with a picture archiving and communication system (IMPAX; Agfa Healthcare, Ridgefield Park, NJ) and reviewed on a 19-inch color monitor (MWD 421; Barco Display Systems, Kortrijk, Belgium) with resolution of 1,000 × 1,000 pixels.

US images were interpreted prospectively by the resident and staff radiologist on the US service at the time of the examination. Images were considered positive for abdominal injury only if they depicted free fluid, extraparenchymal hematoma, or parenchymal abnormality indicative of injury; all other images were considered negative. In the trauma setting, any parenchymal abnormalities except fatty infiltration of the liver or clearly visualized cysts, gallstones, renal calculi, or calcified granulomas are considered to indicate possible injury. On the basis of a previously reported study (12) and in the absence of other suspicious findings, we considered small accumulations of anechoic fluid measuring less than 3 cm in the anteroposterior dimension and isolated in the cul-de-sac in women of reproductive age to be physiologically normal and not indicative of traumatic injury.

Data Collection and Statistical Analysis

The trauma registry and all radiologic, surgical, and autopsy reports for each patient in the study were reviewed by two authors (C.B.S., M.A.B.) in consensus to determine the presence of fracture of the lower ribs, lumbar spine, or pelvis, or of hematuria at admission urinalysis. Lower rib fractures were defined as those involving one or more of the lower seven ribs (the sixth through 12th ribs). The exact portion of a rib that was fractured was not documented. Fractures involving the first through the fifth ribs were not considered because they did not satisfy our a priori hypothesis. Any documented fractures of the lumbar spine or pelvis qualified. For lumbar spine fractures, we recorded whether fractures were limited to the posterior elements (transverse or spinous processes, pedicles, and laminae) or involved at least one vertebral body. We did not record the exact site or type of pelvic fracture. We did not grade the severity or score the number of individual fractures involving the ribs, lumbar spine, or pelvis. Hematuria was defined as more than 50 red blood cells per high-power field, because this was the definition used in the trauma registry. The
gross appearance of the urine specimen was not recorded in the trauma registry and therefore was not included in our analysis.

On the basis of our hypothesis, patients were retrospectively divided into two risk groups by the same two authors in consensus. The high-risk group (n = 494) consisted of patients with hypothetical predictors of missed injury: hematuria (n = 96) or one or more fractures in the lower ribs (n = 216), lumbar spine (n = 105), or pelvis (n = 174). The low-risk group (n = 3,185) had no hematuria or fractures.

The sum of the numbers of patients with each individual hypothetical predictor exceeded the number of patients in the high-risk group because some high-risk patients had more than one predictor. Whereas 408 patients had a single predictor, 76 patients simultaneously had two predictors, nine simultaneously had three predictors, and one simultaneously had all four predictors.

Outcomes in high- and low-risk groups were then compared by calculating the absolute and relative risks for missed abdominal injury. Whereas 408 patients had a single predictor, 76 patients simultaneously had two predictors, nine simultaneously had three predictors, and one simultaneously had all four predictors.

Outcomes in high- and low-risk groups were then compared by calculating the absolute and relative risks for missed abdominal injury (any, surgical, and nonsurgical). Absolute risk was defined as the percentage of patients with negative findings and missed injury at screening US. Relative risk was calculated by dividing the absolute risk in a given group by the absolute risk in the low-risk group. Comparisons were repeated with data stratification according to patient sex.

Abdominal injuries were defined as concussion, laceration, or hematoma of intra-abdominal structures, or as an unexplained intraabdominal fluid if no discrete injury was identified. Surgical injuries were defined as those for which laparotomy was performed. Nonsurgical injuries were defined as those treated successfully without surgical intervention or considered minor at autopsy. The general location of injuries (intraperitoneal, extraperitoneal, or both) and the specific organs involved were documented. The delay in hours between negative findings at screening US and eventual diagnosis of missed injury was recorded.

Each of the four hypothetical predictors (hematuria, rib fracture, lumbar spine fracture, and pelvic fracture) was analyzed as an independent risk factor for missed injury. This analysis was performed in two separate stages. In the first stage, absolute risk and relative risk were calculated for missed injury associated with each of the parameters. Patients were included in the risk calculation for each hypothetical predictor that they had; thus, patients who had more than one predictor were counted more than once in the analysis. The specific sites and general locations (intraperitoneal, extraperitoneal, or both) of missed abdominal injuries associated with each predictor were recorded.

In the second stage of analysis, the individual hypothetical predictors were statistically compared. To achieve accurate statistical comparison, we had to ensure that patients with more than one predictor were not counted more than once. In contrast to the first stage, in which patients were counted as many times as the number of predictors they had, in the second stage, patients with more than one predictor were excluded from analysis. For example, to compare the three categories of fracture, we restricted our analysis to the 378 patients who had fractures involving only one part of the skeleton (ribs [n = 182], lumbar spine [n = 71], and pelvis [n = 125]), regardless of whether they had hematuria. To compare hematuria with the various fractures, we restricted our analysis to 408 patients: the 60 patients with hematuria and no fracture, and the 348 patients with only one type of fracture and no hematuria (169 with fracture of the ribs, 70 with fracture of the lumbar spine, and 109 with pelvic fracture). To further evaluate lumbar fracture as a predictor of missed abdominal injury, we restricted our analysis to the 105 patients with lumbar fracture (independent of hematuria or other fractures): 39 with one or more fractures limited to the posterior elements of the spine, and 66 with one or more fractures involving at least one vertebral body.

Finally, each patient was assigned a numeric risk score from 0 to 3+, according to the number of hypothetical predictors present in that patient. The risk for missed injury was then calculated for each risk score.

For relative risk, 95% CIs were calculated. Proportions were statistically compared by using the Pearson \( \chi^2 \) test, Fisher exact test, or Fisher-Freeman-Halton exact test, depending on the expected frequencies. A Wilcoxon rank sum test was used to determine differences in number of injuries per patient between risk groups. The Somer D test for association was applied to assess for a trend of increasing risk for missed injury as the risk score increased from 0 to 3+. \( P \) values less than .05 were assumed to indicate statistically significant difference for each analysis, with no adjustments being made for multiple comparisons. Power to detect reported differences was calculated post hoc by using two-tailed tests. Statistical software was used for these analyses (JMP version 5.0, SAS Institute, Cary, NC; SPSS version 10.1.0 for Windows, SPSS, Chicago, Ill; and StatXact-5 version 5.0.3, Cytel Software, Cambridge, Mass).

### RESULTS

#### Comparison between Risk Groups

Of 3,679 patients with negative findings at screening US, 494 (13.4%) retrospectively were assigned to the high-risk group because of hematuria (>50 red blood cells per high-power field) at admission urinalysis or because of fracture of the sixth through the 12th ribs, the lumbar spine, or the pelvis. A total of 60 patients had hematuria only, 398 had fractures only, and 36 had both fractures and hematuria. Of the 494 high-risk patients, 30 (6.1%) had missed abdominal injuries, including 10 (2.0%) with surgical and 20 (4.0%) with nonsurgical injuries (Fig 1). The 30 injured patients in the high-risk group included 16 with isolated intraperitoneal injuries, 10 with isolated extraperitoneal injuries, and four with combined intra- and extraperitoneal injuries. There were 55 cumulative injuries in this group (1.8 injuries per injured patient), including 10 retroperitoneal hematomas and eight renal, seven adrenal, 10 bowel or mesenteric, nine hepatic, nine splenic, and two other injuries (Table 1).

For comparison, 3,185 patients with negative findings at screening US retrospectively were assigned to the low-risk group because they had no fractures and no hematuria. Of the 3,185 low-risk patients, eight (0.25%) had missed abdominal injuries, including four (0.1%) with surgical injuries and four (0.1%) with nonsurgical injuries (Fig 1). The eight injured patients in the low-risk group included three with isolated intraperitoneal injuries, four with isolated extraperitoneal injuries, and one with combined intra- and extraperitoneal injuries. There were 10 cumulative injuries in this group (1.3 injuries per injured patient), including three retroperitoneal hematomas and two bowel or mesenteric injuries (Table 1). The difference between the numbers of injuries per injured patient in the two patient risk groups (ie, 1.8 vs 1.3) was not statistically significant (\( P = .06 \)).

Patients in the high-risk group were 24 times more likely than patients in the low-risk group to have a missed abdominal injury (relative risk, 24; 95% CI: 11,
The relative risk was 16 (95% CI: 5, 51) for surgical injuries and 32 (95% CI: 11, 94) for nonsurgical injuries (Fig 2). The differences in risk for missed injury (any, surgical, or nonsurgical) between high-risk and low-risk patient groups were statistically significant ($P < .001$ for each comparison). Our study had higher than 99% power to detect these reported differences.

The risks for missed abdominal injury were virtually identical for male patients and female patients. Of the 494 high-risk patients, 337 were male and 157 were female. Of the 337 male patients, 21 (6%) had missed abdominal injuries detected after negative screening US, including 10 (3%) with surgical injuries. Similarly, of the 157 female patients, nine (6%) had missed injuries, including four (3%) with surgical injuries.

The delay between negative findings at screening US and eventual diagnosis of missed abdominal injuries in patients of each risk group is shown graphically in Figure 3. All missed injuries in the eight low-risk patients were diagnosed within 24 hours of initial US. By contrast, missed injuries in 26 (87%) of the 30 high-risk patients were diagnosed within 24 hours; missed injuries in the other four high-risk patients were diagnosed at 31, 63, 72, and 144 hours.

**Assessment of Individual Predictors**

A total of 216 patients had fractures in the lower ribs, 105 had fractures in the lumbar spine, and 174 had pelvic fractures. All fractures were visible on radiographs and documented in dictated reports except for three transverse process fractures in lumbar vertebrae, which were detected at CT in patients who had not undergone radiography of the spine. Because these three fractures involved gross displacements that likely would have been visible on radiographs if radiography had been performed, they were included in the analysis. Ninety-six patients had hematuria; the number with gross hematuria was not recorded. Because some patients had more than one hypothetical predictor and therefore were counted more than once, the total number of patients with predictors exceeds the number of patients in the high-risk group.

The risk for missed abdominal injury was significantly higher in patients with any of the hypothetical predictors than in patients with no predictors ($P < .001$ for each comparison). As shown in Table 2 and Figure 4, 5.2%–7.6% of patients with fractures had missed abdominal injuries (ie, the percentage varied according to the type of fracture), including 1.2%–2.9% with surgical injuries and 4.0%–4.8% with nonsurgical injuries. Moreover, 15.6% of patients with hematuria had missed injuries, including 5.2% with surgical injuries and 10.4% with nonsurgical injuries (Table 2, Fig 4). Thus, compared with the risks for patients with no predictors, the relative risks of missed injury were 24 for patients with rib fracture (95% CI: 10, 57), 30 for patients with lumbar spine fracture (95% CI: 12, 79), 21 for patients with pelvic fracture (95% CI: 8, 53), and 62 for patients with hematuria (95% CI: 27, 143) (Fig 5). Our study
had a power of 98%–99% for detection of these reported differences.

Cumulatively, the numbers of missed injuries in high-risk patients were as follows: There were 20 missed injuries in patients with lower rib fracture, 17 in those with lumbar fracture, 18 in those with pelvic fracture, and 28 in those with hematuria (Table 3). The majority of injuries were intraperitoneal for patients with rib or lumbar fracture and extraperitoneal for patients with pelvic fracture or hematuria. The most common specific injuries associated with fracture of the lower ribs were injuries to the liver (n = 5) and spleen (n = 4); with lumbar fractures, retroperitoneal hematoma (n = 5) and injuries to the spleen (n = 4) and the bowel or mesentery (n = 4); with pelvic fractures, retroperitoneal hematoma (n = 5) and injuries to the kidney (n = 4); and with hematuria, kidney (n = 7) and adrenal (n = 5) injuries.

A total of 378 patients had a single predictor, patients with more than one predictor were excluded so that they would not be compared with themselves.

Assessment of Risk Score

A total of 3,185 patients had no hypothetical predictors (risk score of 0), 408 had one predictor (risk score of 1), 76 had two predictors (risk score of 2), and 10 had three or more predictors (risk score of 3+). The percentage of patients with missed injuries increased in a stepwise fashion as the risk score increased (Fig 6): Eight (0.25%) of 3,185 patients with missed injuries had a risk score of 0, 19 (4.7%) of 408 had a risk score of 1, eight (10.5%) of 76 had a risk score of 2, and three (30.0%) of 10 had a risk score of 3+. A similar trend was observed in the group of injured patients with regard to the need for surgery: four (0.1%) of 3,185 patients with a score of 0, seven (1.7%) of 408 with a score of 1, and—with the two upper risk score categories combined to compensate for the small sample size—three (3.5%) of 86 with a score of 2–3+ had injuries that required surgery. These trends were statistically significant (P < .01, respectively). Our study had a power higher than 99% for detection of these reported trends.

DISCUSSION

False-negative findings at screening US are rare in patients with suspected blunt abdominal trauma; in our experience, only 1% of patients with negative screening US have missed injuries (10,15). To detect missed injuries, trauma surgeons at our institution have usually relied on subjective or slowly developing clinical parameters—such as abdominal pain, tenderness, decreasing hematocrit levels, hemodynamic instability, and signs of sepsis (15). With the aid of these clinical parameters, 50% of missed injuries are recognized within 12 hours and 89% are found within 24 hours of screening US (15). Although this diagnostic delay is relatively short, it would be better to
identify patients at high risk for false-negative findings at US even sooner; these patients could then undergo screening CT, a more definitive test, even before missed injuries manifest clinically. This would be beneficial because the rapid diagnosis and treatment of abdominal injury is a key factor in decreasing morbidity and mortality associated with blunt trauma.

The results of this study confirm our hypothesis that hematuria and fractures of the lower ribs, lumbar spine, and pelvis are predictors of missed injury in patients with negative findings at screening US for blunt abdominal trauma. Patients with at least one of these predictors of injury were significantly more likely to have a missed injury than were patients without any predictors (6.1% vs 0.25%, relative risk of 24). The differences remained statistically significant when injuries were stratified as surgical (2.0% vs 0.1%, relative risk of 16) or nonsurgical (4.0% vs 0.1%, relative risk of 32). Thus, although high-risk patients constituted only 13% (494 of 3,679) of all patients in the study, they accounted for 79% (30 of 38) of those with missed injuries, including 71% (10 of 14) of those with surgical injuries and 83% (20 of 24) of those with nonsurgical injuries. In addition to their prognostic value, a distinct advantage of these predictors is that they are objective criteria that can be assessed at initial work-up.

As opposed to patients with coexistent predictors of injury, patients with negative findings at screening US and no predictors had abdominal injuries extremely rarely. In our study, only one in 398 low-risk patients with negative US findings had a missed abdominal injury and only one in 796 had a missed injury requiring surgery. It should be emphasized, however, that screening US examinations at our institution are performed by experienced certified sonographers using high-end US scanners and include a thorough evaluation of peritoneal and retroperitoneal compartments for free fluid and for parenchymal abnormalities. Because equipment, sonographer experience, and examination protocols may vary from institution to institution, our results may not be generalizable to all trauma centers.

Our choice of specific predictors was made a priori and was based on several observations and assumptions. We chose hematuria as a potential predictor, for example, because we assumed that in the setting of trauma, hematuria should be considered a surrogate marker of urinary tract injury. This assumption is supported by our data: The most commonly injured organs in patients with hematuria were the kidneys and the neighboring adrenal glands. We chose the various fractures as predictors because fractured
portance of transverse process fractures in the assessment of trauma patients (17). As we expected, the risk for missed abdominal injury increased as the number of predictors increased. Although patients with multiple predictors were relatively uncommon (only 2.0% [76 of 3,679] had a risk score of 2 and only 0.3% [10 of 3,679] had a risk score of 3+), they were at particularly high risk for missed injury (10.5% and 30.0%, respectively). These findings lead us to conclude that such patients should receive a more thorough initial assessment. It also should be emphasized, however, that nearly 5% of patients with only one predictor (risk score of 1) had missed abdominal injuries. Thus, even patients with a single predictor should undergo additional testing.

On the basis of these results, we propose a new procedure for triaging blunt abdominal trauma patients (Fig 7): If abdominal injury predictors are known or suspected to be present in a patient before screening US is performed, we suggest that the patient be screened instead with CT. If no predictors are known or suspected, the patient should be screened with US. However, because screening US is not a definitive test for blunt abdominal trauma injuries, patients with negative findings at US and with no known or suspected predictors should be admitted for observation. The required admittance of trauma patients with negative US findings would not impose an additional burden on most level 1 trauma centers, because trauma patients—even those with negative findings at CT—are routinely admitted. If predictors are discovered during observation, patients with negative US findings should undergo further evaluation with CT.

It is important to note that the presence of these various predictors may not be evident prior to US. If it is not evident, then the patient should undergo initial screening with US. Any uniform attempt to assess for these predictors prior to the performance of US may be time consuming and could incur unnecessary costs and radiation exposure to patients.

If we had followed the proposed triage procedure from the inception of screening US at our institution, only eight (0.2%) of the 3,679 patients with negative US findings who were included in this study would have been inappropriately triaged (ie, admitted for observation without undergoing CT). The missed injuries in all eight of these patients were discovered during the first 24 hours of observation, so any negative effect of ap-

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Two limitations of our study should be emphasized. Because of the retrospective nature of the study, some data could not be reliably collected. For example, the exact times at which urinalysis and radiographic examinations of the chest, lumbar spine, and pelvis were performed and interpreted were not recorded prospectively. Typically, patients underwent chest radiography initially, followed by radiographic examinations of the chest, lumbar spine, and pelvis were performed and interpreted at follow-up diagnostic testing were used as the reference standard for the majority of our patients (3,343 [90.9%] of 3,679). To optimize the validity of a clinical reference standard, we limited our study to patients who met MTOS criteria. In other words, all surviving patients were admitted either for a minimum of 6 hours to the intensive care unit or the intermediate care unit, where continuous monitoring is possible, or for a minimum of 72 hours to the surgical ward. Patients who were discharged after screening US without admission did not meet MTOS criteria and were not included in the study. Finally, all county trauma centers were audited monthly to detect potential missed injuries after discharge. Although some discharged patients with missed injuries might have received subsequent treatment at institutions outside the county, such patients would likely have been few.

Similarly, although urinalysis and chest radiography were performed in all patients, radiographs of the lumbar spine and pelvis were obtained on a case-by-case basis at the discretion of the trauma service, because our institution’s trauma assessment procedure includes selective radiographic screening of the lumbar spine and pelvis on the basis of clinical suspicion (18). Thus, an imaging reference standard for lumbar and pelvic fractures was not available in all study subjects, and it is conceivable that some patients in the low-risk group may have had undiagnosed fractures. Moreover, because radiographs were not obtained in all patients, lumbar transverse process fractures were detected at CT in three patients who did not undergo spinal radiography. In our opinion, inclusion of these fractures in our analysis was warranted because the fractures were grossly displaced and likely would have been detected on radiographs. Radiography was not performed in these patients, however, because it would have provided no benefit with regard to patient care. Moreover, our study was designed to retrospectively assess the predictive value of various fractures and included no prospective assessment of radiographically detectable fractures. Finally, because the criteria for obtaining ancillary radiographs in trauma victims may vary among institutions, our results may not be generalizable to all trauma centers.

It is noteworthy that the male patients in our study population, on average, were much younger than the female patients. One possible explanation for this divergence in age is that boys and young men are more likely than girls and young women to be trauma victims. In addition, because of the large sample size, a small absolute difference (4 years) in mean age achieved high statistical significance. Nevertheless, the age difference between the male and female patient subgroups did not bias our results, because the risk for missed injury was unaffected by patient sex.

In conclusion, the results of our study show that hematuria and fractures of the lower ribs, lumbar spine, and pelvis are objective predictors of missed abdominal injury in blunt abdominal trauma patients with negative findings at initial screening with US. It is important to note the presence of these predictors in trauma patients, because the rapid diagnosis and treatment of abdominal injury is a key factor in decreasing morbidity and mortality associated with blunt trauma. These objective predictors can be assessed immediately after the patient’s arrival in the resuscitation suite. We believe that patients with these predictors for missed injury should be screened immediately with CT rather than US, whereas appropriate care for low-risk patients can be determined on the basis of US findings alone. Patients who have no predictors for missed abdominal injury need not undergo CT or diagnostic peritoneal lavage, both of which involve a risk of associated complications. Lastly, the presence of one or more of these predictors in patients with positive US findings could indicate an increased likelihood that their injuries will require surgery, but additional study is needed to test this hypothesis.


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