The Utility of Sonography for the Triage of Blunt Abdominal Trauma Patients to Exploratory Laparotomy

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OBJECTIVE. The purpose of this study was to assess the utility of focused abdominal sonography for trauma (FAST) in the triage of hypotensive and normotensive blunt abdominal trauma patients to exploratory laparotomy.

MATERIALS AND METHODS. Data entered in a trauma registry database were retrospectively reviewed and were correlated with medical records, radiology reports, and surgical laparotomy reports. In the setting of blunt abdominal trauma, hypotensive patients were compared with normotensive patients who underwent FAST.

RESULTS. During the 6-year study period, 4,029 patients with blunt abdominal trauma underwent sonography, 122 of whom were hypotensive on arrival and underwent FAST. Of 87 hypotensive patients with positive findings on FAST, 69 (79%) were taken directly to exploratory laparotomy without the need for CT. In predicting the need for therapeutic laparotomy in hypotensive patients, the sensitivity of FAST was 85%, specificity was 60%, and accuracy was 77%. Of the 3,907 normotensive patients, 3,584 had negative FAST findings, whereas 323 had positive FAST findings. In normotensive patients, the sensitivity of FAST was 85%, specificity was 96%, and accuracy was 96%. In the combined patient population (all hypotensive and normotensive patients), 4,029 patients with blunt abdominal trauma underwent sonography: 3,619 had negative and 410 had positive FAST findings. In all patients regardless of blood pressure, the sensitivity of FAST was 85%, specificity was 96%, and accuracy was 95%.

CONCLUSION. Hypotensive patients screened in the emergency department with positive FAST findings may be triaged directly to therapeutic laparotomy, depending on the results of the sonography examination, without the need for CT.

Keywords: abdominal imaging, blunt trauma, emergency radiology, exploratory laparotomy, FAST, focused abdominal sonography for trauma, sonography

DOI:10.2214/AJR.05.2100

Received December 12, 2005; accepted after revision February 28, 2006.

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AJR 2007; 188:415–421

0361–803X/07/1882–415

Sonographic free fluid has been shown to be a useful predictor of surgical injury in patients with blunt abdominal trauma. However, few studies have examined the utility of free fluid in hypotensive patients with blunt abdominal trauma. In the setting of blunt abdominal trauma, determining which patients have signs or symptoms that warrant surgical exploration and repair is a diagnostic dilemma. For the unstable patient, rapid and accurate triage is crucial because delayed treatment is associated with increased morbidity and mortality [1]. Clinical history, physical examination, and laboratory tests are often unreliable in the evaluation of blunt abdominal trauma [2].

Diagnostic peritoneal lavage had been used for decades to detect hemoperitoneum but is ineffective for detecting retroperitoneal injuries and solid organ injuries not associated with hemoperitoneum [3, 4]. Furthermore, diagnostic peritoneal lavage is an invasive procedure with sensitive but nonspecific findings that may lead to unnecessary laparotomies and the associated complications [5]. Increasingly, noninvasive methods such as CT and sonography have gradually replaced diagnostic peritoneal lavage. CT can effectively depict hemoperitoneum, retroperitoneal injury, and solid organ injury, but CT is less accurate in showing pancreatic, diaphragmatic, and hollow viscus injuries [6]. However, CT has disadvantages including ionizing radiation, IV injection of radioiodinated contrast material, and time required for patient transport and scanning of critically injured or unstable patients. Sonography is a fast, simple, noninvasive, and readily available screening examination.

Focused abdominal sonography for trauma (FAST) scanning has been previously described in the setting of blunt abdominal trauma to evaluate for free fluid in the abdomen or pelvis [7]. Sonography is useful as a diagnostic tool for detecting intraabdominal in-

juries but is less sensitive for detecting bowel and mesenteric injuries. Sonography has limited utility in the trauma setting for spinal and pelvic fractures, retroperitoneal (pancreatic and adrenal) injuries, vascular injuries, and diaphragmatic rupture [8]. However, in the evaluation of the hypotensive patient with blunt abdominal trauma, sonography is increasingly used because of its rapid results, portability, and lack of ionizing radiation. Prior studies have evaluated the accuracy of sonography for detecting hemoperitoneum and solid organ injury [6, 9–17]. The use of sonography in triaging blunt abdominal trauma patients, particularly those with hypotension, has only recently been explored [18, 19], to our knowledge. To mitigate morbidity and mortality, rapid determination of which patients with intraabdominal injuries require surgical exploration is critically important.

The purpose of this study was to investigate the possible role of sonography (FAST) in patients with blunt abdominal trauma. Prior studies have examined the use of sonography in blunt abdominal trauma; however, this study is the first, to our knowledge, to investigate and compare the utility of sonography in hypotensive patients versus normotensive patients in a consecutive study population.

Materials and Methods

This retrospective study was performed at a regional level 1 comprehensive trauma center. All patients, regardless of age, who presented with blunt abdominal trauma over a 6-year period, from January 1995 to January 2001, were enrolled in a trauma registry database. Patients who underwent FAST were then selected from the database, and the FAST findings were correlated with clinical data, imaging results, and laparotomy findings. Patients were excluded from the study if clinical, radiologic, or surgical information was incomplete. This retrospective study was approved by the hospital's institutional review board.

FAST was performed by registered diagnostic medical sonographers with at least 2 years' experience on an XP10-128 (Acuson), 5200S (Acoustic Imaging), or Sequoia 512 (Acuson-Siemens) unit using phased-array or convex linear 2.5-5.0–MHz transducers. Image acquisition was performed solely by experienced radiology department sonographers available 24 h/d, and images were reviewed and the sonographers were supervised by the radiology attending physician or a radiology resident.

The determination of which blunt abdominal trauma patients underwent FAST was at the discretion of the emergency department attending physician or trauma surgeon caring for the patient. FAST was usually performed within a 30-minute period of the patient's arrival to the emergency department.

Scans were obtained with the patient in the supine position to evaluate for the presence of free fluid in the bilateral upper quadrants, including the hepatorenal and splenorenal regions, and paracolic gutters. The pelvis was also scanned for free fluid, although this scan was sometimes obtained without the benefit of a well-distended bladder providing an optimal acoustic window. Subxiphoid views of the heart were obtained when there was a history of possible chest trauma. A detailed evaluation of the solid organs was not performed, although limited images of the solid organs were obtained if there was adjacent free fluid and if time permitted. Given the lack of dedicated scanning for abdominal organ injury, parenchymal abnormalities were not considered and only free fluid was used for analysis.

CT scans were obtained on a LightSpeed scanner (GE Healthcare) using a 100- to 150-mL bolus of IV contrast material (iohexol [Omnipaque 300, Nycomed]) injected at 2–3 mL/s. No oral contrast material was administered. Patients were initially scanned from the xiphoid to the symphysis pubis with 3-minute delayed images from the xiphoid through the kidneys.

All images were interpreted immediately by the on-call radiology attending physician, radiology fellow, or radiology resident. The findings were reviewed, and a report was finalized by the radiology faculty if the sonography examination was initially reviewed by a fellow or resident.

Sonography reports were retrospectively reviewed, and the location and amount of free fluid were recorded. The amount of free fluid was subjectively categorized as small, moderate, or large (Figs. 1–3). Small amounts of free fluid in three or more locations were graded as moderate, and moderate amounts of free fluid in three or more locations were graded as large. If there was ambiguity in the report, hard-copy sonography images were reviewed, and the results were confirmed. Sonography finding were graded as positive if any free fluid was present.

Patient demographics and history of injury mechanism were collected. Blood pressure on arrival in the emergency department was used for categorization as hypotensive (systolic blood pressure ≤ 90 mm Hg) or normotensive (systolic blood pressure > 90 mm Hg). Laparotomy results were obtained from medical records and grouped into those requiring surgical intervention versus those not requiring surgical intervention. The concept of therapeutic versus nontherapeutic laparotomy is derived from clinical and surgical perspectives. We categorized injuries retrospectively by whether they required surgical repair (i.e., therapeutic laparotomy) or not (nontherapeutic laparotomy).

The therapeutic laparotomy categorization includes those patients who were the most critical and required emergent intervention. Positive therapeutic laparotomy criteria included bleeding liver laceration requiring packing or hemostasis, splenic laceration requiring splenorrhaphy or splenectomy, bowel laceration or perforation, diaphragm laceration, bleeding renal laceration requiring nephrectomy or embolization, bleeding mesenteric injury requiring repair, and expanding retroperitoneal hematoma requiring repair.

The nontherapeutic laparotomy group comprises those patients who had injuries that were not severe enough to require surgical repair. Nontherapeutic laparotomy criteria included liver laceration not requiring packing or hemostasis, splenic laceration not requiring splenorrhaphy or splenectomy, bowel contusions, mesenteric hematomas not requiring repair, and retroperitoneal hematomas not requiring repair.

Comparisons between the amount of fluid (small, moderate, or large) and the need for laparotomy were examined in hypotensive patients, normotensive patients, and all patients. In hypotensive patients, the use of CT during triage was also examined. Finally, comparisons in therapeutic laparotomy rates between normotensive and hypotensive patients with varying amounts of fluid were made. Fisher's exact test was used for statistical analysis with statistical significance set at a p value of less than or equal to 0.05.

Results

During the 6-year study period, 4,029 blunt abdominal trauma patients underwent FAST.

Hypotensive Patients

Patients with hypotension on arrival were identified (n = 122). The mean age of the 122 hypotensive patients was 31.8 ± 17.8 (SD) years. The mechanism of injury in 61% was motor vehicle crash; 18%, automobile-versus-pedestrian collision; 11%, fall; 7%, assault; and 3%, motorcycle crash.

Table 1 summarizes the results of the hypotensive subgroup correlated with whether therapeutic laparotomy, nontherapeutic laparotomy, or no laparotomy was performed. Of the 35 hypotensive patients with negative FAST findings, 13 (37%) underwent therapeutic laparotomy. Of the 87 patients with positive FAST, an increased amount of free fluid was associated with a higher rate of therapeutic laparotomy: 70% (30/43) of patients with a small amount of free fluid, 97% (33/34) with a moderate amount of free fluid, and 90% (9/10) with a large amount of free fluid underwent therapeutic laparotomy. Of all 87 hypotensive pa-

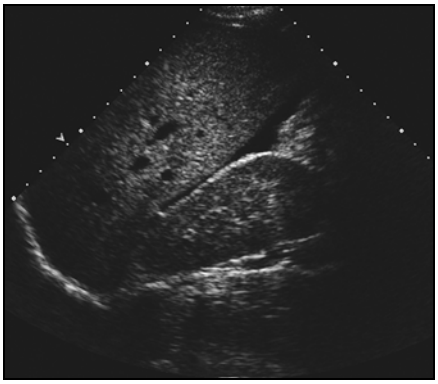

Fig. 1—37-year-old hypotensive man being evaluated after motor vehicle collision with only finding of small right upper quadrant fluid on focused abdominal sonography for trauma (FAST). Patient was taken emergently to laparotomy and underwent hemostasis of liver laceration and repair of colon serosal tears.

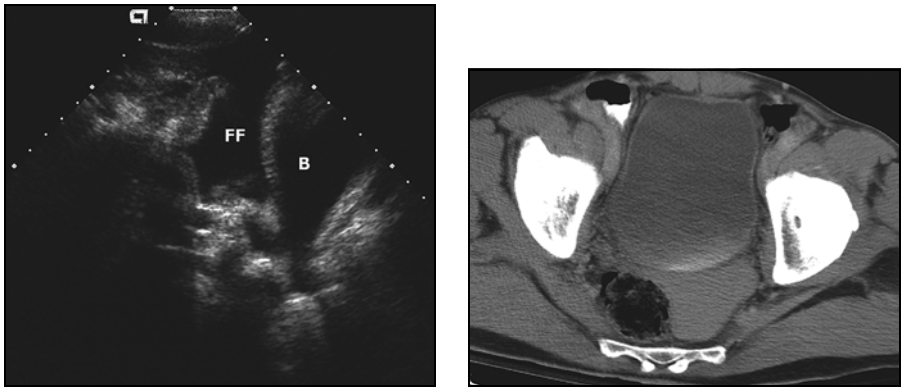

Fig. 2—44-year-old man being evaluated after motor vehicle collision.
A and **B,** Focused abdominal sonography for trauma (FAST) image (**A**) and CT image (**B**) show moderate amount of pelvic free fluid (FF, **A**) adjacent to bladder (B, **A**). Patient underwent exploratory laparotomy for hemostasis of liver laceration.

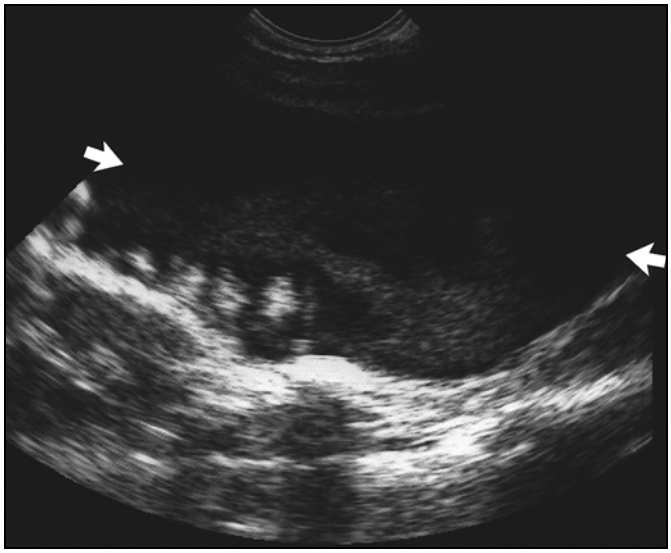

Fig. 3—26-year-old woman with hypotension being evaluated after assault. Scan of left lower quadrant shows large amount of complex fluid/hematocrit level with layering echogenic blood (*arrows*). Patient was taken emergently for exploratory laparotomy and found to have ruptured spleen requiring splenectomy.

tients with positive FAST, 72 (83%) underwent therapeutic laparotomy.

In further examination of the hypotensive patients, most of the patients with positive FAST findings were taken directly to laparotomy without undergoing CT (Table 2). In hypotensive patients with a small amount of free fluid on FAST, 23% (10/43) underwent CT; of those 10 patients who underwent CT, two went on to therapeutic laparotomy and eight did not undergo laparotomy. All 34 hypotensive patients with a moderate amount of free fluid on FAST went directly to laparotomy without undergoing CT. Nine (90%) of 10 hypotensive patients with a large amount of free fluid went directly to laparotomy without undergoing CT and the patient who underwent CT also had a therapeutic laparotomy. In hypotensive patients with positive FAST who went directly to laparotomy without CT, therapeutic laparotomy rates of 85% (28/33), 97% (33/34), and 89% (8/9) were found in patients with small, moderate, and large amounts of free fluid, respectively. In hypotensive patients with no free fluid on FAST, 80% (28/35) went on to CT.

An increasing number of discrete fluid collections or fluid pockets detected on FAST was associated with a higher rate of therapeutic laparotomy. For hypotensive patients with one fluid pocket, 68% (23/34) underwent therapeutic laparotomy, and 83% (15/18) with two fluid pockets had a therapeutic laparotomy. Hypotensive patients with three, four, and five fluid pockets had therapeutic laparotomy in 92% (11/12), 100% (5/5), and 100% (18/18) of the cases, respectively.

Normotensive Patients

Of all patients with blunt abdominal trauma who underwent sonography, 3,907 were normotensive: 3,584 had negative and 323 had positive FAST findings (Table 3). The average patient age was 32.5 ± 18.9 years. The mechanism of injury in 65% was motor vehicle crash; 14%, automobile-versus-pedestrian crash;11%, fall; 7%, assault; and 3%, motorcycle crash. Thirty-three (1%) of 3,584 patients with negative FAST required therapeutic laparotomy, and 42% (87/205) of patients with a small amount of free fluid went on to have a therapeutic laparotomy. There were 71 (86%) of 83 patients with a moderate amount of fluid and 31 (89%) of 35 with a large amount of free fluid who required surgical intervention. For all normotensive patients with positive FAST, 59% (189/323) required therapeutic laparotomy.

TABLE 1: Correlation of Amount of Free Fluid Detected on Focused Abdominal Sonography for Trauma (FAST) with Therapeutic Laparotomy for Hypotensive Patients

FAST Finding	% of Patients Who Underwent Therapeutic Laparotomy	No. of Cases			
		Total	Therapeutic Laparotomy	Nontherapeutic Laparotomy	No Laparotomy
No free fluid	37	35	13	5	17
Small amount of free fluid	70	43	30	2	11
Moderate amount of free fluid	97	34	33	1	0
Large amount of free fluid	90	10	9	1	0
Positive findings for free fluid	83	87	72	4	11

In normotensive patients, 67 (44%) of 153 patients with free fluid in one location had a therapeutic laparotomy, and 49% (40/82) of patients with free fluid in two locations had surgical intervention. In patients with fluid in three, four, and five locations, therapeutic laparotomy rates were 85% (35/41), 100% (6/6), and 100% (41/41), respectively.

All Patients (Normotensive and Hypotensive)

Table 4 summarizes the FAST results of all the patients regardless of blood pressure correlated with therapeutic laparotomy, nontherapeutic laparotomy, or no laparotomy. Of 4,029 patients with blunt abdominal trauma who underwent sonography, 3,619 had negative FAST findings and 410 had positive FAST findings. One percent (46/3,619) of patients with negative FAST required therapeutic laparotomy. Forty-seven percent (117/248) of patients with a small amount of free fluid underwent therapeutic laparotomy. Eighty-nine percent (104/117) of patients with a moderate amount of free fluid and 89% (40/45) with a large amount of free fluid went on to surgical intervention. Of all 410 patients who had positive FAST, 64% ($n = 261$) went on to therapeutic laparotomy.

As seen in both hypotensive and normotensive patient groups, an increasing number of free fluid pockets directly correlated with therapeutic laparotomy in all patients. Forty-nine percent (92/187) of patients with free fluid in one location had a therapeutic laparotomy. Fifty-six percent (56/100) of patients with free fluid in two locations required surgical intervention. In patients with fluid in three, four, and five locations, therapeutic laparotomy rates were 87% (46/53), 100% (11/11), and 100% (56/56), respectively.

Because the amount of free fluid and number of locations are codependent variables (i.e., the larger the amount of fluid, the greater the number of fluid pockets), the results were sorted by amount of fluid and number of pockets (Table 5); no significant difference was observed among the patient groups. Forty-four percent (74/168) of patients with a small amount of fluid in one location had a therapeutic laparotomy, whereas 54% (43/80) of patients with a small amount of fluid in two or more locations required a therapeutic laparotomy. For patients with a moderate amount of free fluid, the laparotomy rate of those with free fluid in one location versus the laparotomy rate of those with free fluid in more than one location was not significantly different (94% vs 88%, respectively). Patients with a large amount of free fluid also showed similar laparotomy rates: 100% for those with fluid in one location and 88% for those with free fluid in multiple locations. This finding was also seen in hypotensive and normotensive patients.

In comparing therapeutic laparotomy rates for normotensive and hypotensive patients, statistically significant differences were found between hypotensive and normotensive patients with no free fluid ($p < 0.001$) and a small amount of free fluid ($p = 0.001$). No statistical significance was seen between hypotensive and normotensive patients with a moderate amount of free fluid ($p = 0.62$) and those with a large amount of free fluid ($p = 0.69$).

The intraabdominal injuries not detected on FAST that required surgical repair are listed in Table 6. Of the hypotensive patients, 18 had negative FAST findings but went on to exploratory laparotomy due to clinical course, positive diagnostic peritoneal lavage results, positive CT findings, or a combination thereof. Thirteen hypotensive patients had intraabdominal injuries requiring surgical repair, with the most commonly missed injuries being those to the bowel ($n = 8$), spleen ($n = 5$), and liver ($n = 3$). In normotensive patients with negative FAST, 75 went on to exploratory laparotomy, with 33 requiring surgical repair. The most commonly missed injuries in normotensive patients included those to the bowel ($n = 25$), spleen ($n = 19$), and liver ($n = 8$). Various injuries to the diaphragm, gallbladder, and retroperitoneum, including the kidneys, pancreas, bladder, rectum, and urethra, were also missed.

For hypotensive patients with blunt abdominal trauma, the sensitivity of FAST for need of therapeutic laparotomy was 85% (72/85) and the specificity was 60% (22/37); the positive predictive value was 85% (72/85), negative predictive value was 63% (22/35), and accuracy was 77% (94/122) (Table 7). For the normotensive patient group, sensitivity was 85% (189/222) and specificity was 96% (3,551/3,685); the positive predictive value was 59% (189/323), negative predictive value was

TABLE 2: Correlation of Sonography Only Versus Sonography and CT with Therapeutic Laparotomy for Hypotensive Patients

FAST Findings	Total No. of Cases	% of Patients Who Underwent CT	Sonography Only (No. of Cases)			Sonography and CT (No. of Cases)		
			Therapeutic Laparotomy	Nontherapeutic Laparotomy	No Laparotomy	Therapeutic Laparotomy	Nontherapeutic Laparotomy	No Laparotomy
No free fluid	35	80	6	1	0	7	4	17
Small amount of free fluid	43	23	28	2	3	2	0	8
Moderate amount of free fluid	34	0	33	1	0	0	0	0
Large amount of free fluid	10	10	8	0	0	1	0	0

Note—FAST = focused abdominal sonography for trauma.

TABLE 3: Correlation of Amount of Free Fluid on Focused Abdominal Sonography for Trauma (FAST) with Therapeutic Laparotomy for Normotensive Patients

FAST Findings	% of Patients Who Underwent Therapeutic Laparotomy	No. of Cases			
		Total	Therapeutic Laparotomy	Nontherapeutic Laparotomy	No Laparotomy
No free fluid	1	3,584	33	42	3,509
Small amount of free fluid	43	205	87	16	102
Moderate amount of free fluid	86	83	71	4	8
Large amount of free fluid	89	35	31	1	3
Positive findings for free fluid	59	323	189	21	113

TABLE 4: Correlation of Amount of Free Fluid with Therapeutic Laparotomy for All Patients

FAST Findings	% of Patients Who Underwent Therapeutic Laparotomy	No. of Cases			
		Total	Therapeutic Laparotomy	Nontherapeutic Laparotomy	No Laparotomy
No free fluid	1	3,619	46	47	3,526
Small amount of free fluid	47	248	117	18	113
Moderate amount of free fluid	89	117	104	5	8
Large amount of free fluid	89	45	40	2	3
Positive findings for free fluid	64	410	261	25	124

TABLE 5: Correlation of Free Fluid Location and Amount with Therapeutic Laparotomy for All Patients

Amount of Free Fluid and No. of Locations	% of Patients Who Underwent Therapeutic Laparotomy	No. of Cases			
		Total	Therapeutic Laparotomy	Nontherapeutic Laparotomy	No Laparotomy
Small					
1 Location	44	168	74	11	83
> 1 Location	54	80	43	7	30
Moderate					
1 Location	94	16	15	0	1
> 1 Location	88	101	89	5	7
Large					
1 Location	100	3	3	0	0
> 1 Location	88	42	37	2	3

99% (3,551/3,584), and accuracy was 96% (3,740/3,907). In all patients, the sensitivity of FAST was 85% (261/307) and specificity was 96% (3,573/3,722); the positive predictive value was 64% (261/410), negative predictive value was 99% (3,573/3,619), and accuracy was 95% (3,834/4,029).

Discussion

The use of sonography and CT for assessment in blunt abdominal trauma has been extensively reviewed in the literature [20–23]. CT is viewed as the definitive technique because of its high sensitivity and specificity in injury detection, localization, and grading [6]. However, CT may not be an option for those patients who are clinically unstable to travel to the CT scanner, who are pregnant, or who will not fit in the scanner due to their body habitus. Sonography has some specific advantages over CT in that it is a bedside examination, is a relatively expedient examination, and uses no ionizing radiation. Furthermore, patients undergoing sonography do not require contrast agents and thus are spared the associated risk of contrast reaction and nephrotoxicity.

In our study, differences emerged between the hypotensive and normotensive patients with blunt abdominal trauma. A statistically significant difference was found between hypotensive and normotensive patients with a small amount of free fluid; this reflects the greater significance of a small amount of free fluid in hypotensive patients and the higher associated therapeutic laparotomy rate. No statistical significance was seen between hypotensive and normotensive patients with a moderate or large amount of free fluid, reflecting the high association with therapeutic laparotomy in both patient groups. A statistically significant difference was also found between hypotensive and normotensive patients with no free fluid; this likely reflects the very low likelihood of therapeutic laparotomy in normotensive patients versus the higher likelihood of therapeutic laparotomy in hypotensive patients.

Categorizing blunt abdominal trauma patients by the amount of free fluid and categorizing them by the number of fluid pockets are equally valid methods of assessment. The amount of free fluid has a direct correlation with the number of fluid pockets because both are codependent variables. In both study populations, there was no significant difference between the total amount of fluid in one location or that in more than one location. The causes for false-positive FAST findings included four cases of superficial liver laceration not requiring repair, four cases of renal laceration or contusion not requiring repair, four cases of pelvic hematomas from pelvic fractures, one case of retroperitoneal hematoma not requiring repair, and one case of ascites secondary to metastatic breast cancer. The other patients with false-positive FAST findings had negative findings at laparotomy, and the cause of the free fluid was not found.

Other studies have shown findings similar to ours. Farahmand et al. [18] used a fluid scoring system based on the number of fluid pockets (0, 1, and 2 or more) and retrospectively assigned patients to a high- or low-risk group. In 128 hypotensive patients with blunt abdominal trauma, they calculated 97% sensitivity, 82% specificity, and 86% accuracy for the detection of surgical injuries. However, that study was not a consecutive sample because 24-hour sonography coverage was not available; in our study, experienced sonographers were always present and per-

TABLE 6: Intraabdominal Injuries Requiring Surgical Repair Not Detected on Focused Abdominal Sonography for Trauma (FAST)

Missed Injuries	No. of Patients		
	Hypotensive	Normotensive	All
Bowel injury	8	25	33
Splenic injury	5	19	24
Liver injury	3	8	11
Diaphragm rupture	1	5	6
Kidney injury	1	4	5
Gallbladder injury	2	2	4
Retroperitoneal hematoma	0	3	3
Pancreas injury	0	2	2
Bladder injury	0	1	1
Rectal injury	0	1	1
Urethral injury	0	1	1

TABLE 7: Comparison of Statistics for Hypotensive, Normotensive, and All Patients

Performance Measure	Hypotensive	Normotensive	All
Sensitivity (%)	85 (75–91)	85 (80–89)	85 (80–89)
Specificity (%)	60 (42–75)	96 (96–97)	96 (95–97)
PPV (%)	83 (73–90)	59 (53–64)	64 (59–68)
NPV (%)	63 (45–78)	99 (99–99)	99 (98–99)
Accuracy(%)	77 (70–84)	96 (95–97)	95 (94–96)

Note—PPV = positive predictive value, NPV = negative predictive value. Values in parentheses are 95% CIs.

formed the FAST examination. Interestingly, Farahmand and colleagues concluded that positive sonography findings correlate with surgical injury in 64% of cases, whereas negative sonography almost always excludes surgical injury. For that study group, Farahmand and colleagues reported one case of mesenteric injury not detected on screening sonography. In contrast, our study had higher rates of false-negatives, which is likely due to more cases of isolated bowel injury being included in our study. In our experience, isolated bowel injury is often not immediately associated with hemoperitoneum and is more difficult to diagnose than other injuries [24]. The free fluid detected in patients with bowel injury is thought to be due to other concomitant abdominal injuries. Worsening abdominal tenderness during observation in the emergency department and delayed CT may help in triaging patients with suspected bowel injury that is not detected on FAST.

McKenney et al. [19] used a hemoperitoneum scoring system based on the anteroposterior depth of the largest fluid collection plus 1 point for each additional area with fluid. In 18 hypotensive patients with a systolic blood pressure of less than 90 mm Hg, 10 had a score of greater than 3, and all 10 patients required therapeutic laparotomy. The remaining eight patients had a score of less than 3, with three patients requiring therapeutic laparotomy. The hemoperitoneum scoring system appears to be a variation on using the total amount of fluid as a predictor for therapeutic laparotomy. Although the hemoperitoneum scoring system may be valid, its utility in a greater number of hypotensive patients remains to be seen.

Several limitations to this study exist. This study was retrospective. Patients with incomplete data were excluded. Exclusion of those cases is not thought to bias the data because the pattern was random and sporadic and occurred in all groups of patients. Another potential limitation is that because blood pressure on arrival to the emergency department was used, patients who were sporadically hypotensive in the field, during transport, or after arrival were not included; thus, patients with episodic hypotension may not have been categorized in the hypotensive subgroup. In addition, the grading of fluid amount is somewhat subjective. The use of a more qualitative fluid scoring system rather than a quantitative standard has drawbacks due to its imprecision and variability among interpreting reviewers. However, a qualitative fluid scoring system is widely used by most radiologists, and there is some general consensus about fluid grading. An additional limitation is that the time from injury to scanning was not included; these data were not consistently available, and this limitation is typical of a retrospective study.

Given our findings and those of prior studies, we believe FAST should be performed immediately after the blunt trauma patient arrives in the emergency department and is determined to be hypotensive. If the FAST findings are positive, especially in patients with moderate to large amounts of free fluid, the patients should be triaged directly to exploratory laparotomy. If the FAST findings are negative or the hypotensive patient becomes hemodynamically stable, then there may be enough time for the patient to undergo CT for further evaluation. Similarly, FAST may be used in all patients regardless of blood pressure if they are unable to undergo CT.

In conclusion, for triaging hypotensive patients with blunt abdominal trauma to laparotomy, FAST is an effective screening tool when performed by experienced sonographers. In hypotensive patients in whom moderate to large fluid collections are noted, immediate triage to the operating room, obviating CT, may be required. In hypotensive patients, bowel and mesenteric injuries may not be associated with a significant amount of free fluid and may be a cause of false-negative findings on FAST; this possibility highlights the need for heightened clinical suspicion and possibly for further evaluation with CT.

References

1. Mirvis SE, Whitley NO, Gens DR. Blunt splenic trauma in adults: CT-based classification and correlation with prognosis and treatment. *Radiology* 1989; 171:33–39
2. Richards JR, Derlet RW. CT and blunt abdominal injury: patient selection based on examination, hematocrit and hematuria. *Injury* 1997; 28:181–185
3. Ryan JJ, Kyes FN, Horner WR, Young JC, Diamond DL. Critical analysis of open peritoneal lavage in blunt abdominal trauma. *Am J Surg* 1986; 151:221–223
4. Cox EF. Blunt abdominal trauma: a 5-year analysis of 870 patients requiring celiotomy. *Ann Surg* 1984; 199:467–474
5. Shah R, Max MH, Flint LM Jr. Negative laparot-

omy: mortality and morbidity among 100 patients. *Am Surg* 1978; 44:150–154

6. ACEP Clinical Policies Committee; Clinical Policies Subcommittee on Acute Blunt Abdominal Trauma. Clinical policy: critical issues in the evaluation of adult patients presenting to the emergency department with acute blunt abdominal trauma. *Ann Emerg Med* 2004; 43:278–290
7. McGahan JP, Richards J, Gillen M. The focused abdominal sonography for trauma scan: pearls and pitfalls. *J Ultrasound Med* 2002; 21:789–800
8. McGahan JP, Rose J, Coates TL, Wisner DH, Newberry P. Use of sonography in the patient with acute abdominal trauma. *J Ultrasound Med* 1997; 16:653–662
9. Brown MA, Sirlin CB, Hoyt DB, Casola G. Screening ultrasound in blunt abdominal trauma. *J Intensive Care Med* 2003; 18:253–260
10. Miller MT, Pasquale MD, Bromberg WJ, Wasser TE, Cox J. Not so FAST. *J Trauma* 2003; 54:52–60
11. McKenney KL. Ultrasound of blunt abdominal trauma. *Radiol Clin North Am* 1999; 37:879–893
12. Ng AK, Simons RK, Torreggiani WC, Ho SG, Kirkpatrick AW, Brown DR. Intra-abdominal free fluid without solid organ injury in blunt abdominal trauma: an indication for laparotomy. *J Trauma* 2002; 52:1134–1140
13. Holmes JF, Harris D, Battistella FD. Performance of abdominal sonography in blunt trauma patients with out-of-hospital or emergency department hypotension. *Ann Emerg Med* 2004; 43:354–361
14. Brown MA, Casola G, Sirlin CB, Patel NY, Hoyt DB. Blunt abdominal trauma: screening US in 2,693 patients. *Radiology* 2001; 218:352–358
15. Sirlin CB, Brown MA, Andrade-Barreto OA, et al. Blunt abdominal trauma: clinical value of negative screening US scans. *Radiology* 2004; 230:661–668
16. Sirlin CB, Brown MA, Deutsch R, et al. Screening US for blunt abdominal trauma: objective predictors of false-negative findings and missed injuries. *Radiology* 2003; 229:766–774
17. McGahan JP, Wang L, Richards JR. From the RSNA refresher courses: focused abdominal US for trauma. *RadioGraphics* 2001; 21 spec no:S191–S199
18. Farahmand N, Sirlin CB, Brown MA, et al. Hypotensive patients with blunt abdominal trauma: performance of screening US. *Radiology* 2005; 235:436–443
19. McKenney KL, McKenney MG, Cohn SM, et al. Hemoperitoneum score helps determine need for therapeutic laparotomy. *J Trauma* 2001; 50:650–656
20. Rhea JT, Garza DH, Novelline RA. Controversies in emergency radiology: CT versus ultrasound in the evaluation of blunt abdominal trauma. *Emerg Radiol* 2004; 10:289–295
21. Poletti PA, Wintermark M, Schnyder P, Becker CD. Traumatic injuries: role of imaging in the management of the polytrauma victim (conservative expectation). *Eur Radiol* 2002; 12:969–978
22. Bakker J, Genders R, Mali W, Leenen L. Sonography as the primary screening method in evaluating blunt abdominal trauma. *J Clin Ultrasound* 2005; 33:155–163
23. Poletti PA, Kinkel K, Vermeulen B, Irmay F, Unger PF, Terrier F. Blunt abdominal trauma: should US be used to detect both free fluid and organ injuries. *Radiology* 2003; 227:95–103
24. Richards JR, McGahan JP, Simpson JL, Tabar P. Bowel and mesenteric injury: evaluation with emergency abdominal US. *Radiology* 1999; 211:399–403