Performance of Abdominal Ultrasonography in Blunt Trauma Patients With Out-of-Hospital or Emergency Department Hypotension

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Study objectives: We determine the test performance of abdominal ultrasonography for detecting hemoperitoneum in blunt trauma patients with out-of-hospital or emergency department (ED) hypotension.

Methods: We reviewed the medical records of all blunt trauma patients hospitalized at a Level I trauma center. Patients were included if they were older than 6 years and had out-of-hospital or ED hypotension (systolic blood pressure ≤90 mm Hg) and underwent ED ultrasonography. The initial interpretation of the abdominal ultrasonography was recorded, including the presence or absence of intraperitoneal fluid and the specific location of such fluid. Presence or absence of intra-abdominal injury was determined by abdominal computed tomography scan, laparotomy, or clinical follow-up.

Results: Four hundred forty-seven patients with a mean age of 36.0±17.5 years were enrolled. One hundred forty-eight (33%) patients had intra-abdominal injuries, and 116 (78%) of these patients had hemoperitoneum. Abdominal ultrasonography had the following test performance for detecting patients with intra-abdominal injury and hemoperitoneum: sensitivity 92/116 (79%; 95% confidence interval [CI] 71% to 86%), specificity 316/331 (95%; 95% CI 93% to 97%), positive predictive value 92/107 (86%; 95% CI 78% to 92%), and negative predictive value 316/340 (93%; 95% CI 90% to 95%). The positive likelihood ratio was 15.8, and the negative likelihood ratio was 0.22. One hundred five (91%) of the 116 patients with intra-abdominal injuries and hemoperitoneum underwent a therapeutic laparotomy. Abdominal ultrasonography demonstrated intraperitoneal fluid in 87 (sensitivity 83%; 95% CI 74% to 90%) of these 105 patients.

Conclusion: Of patients with out-of-hospital or ED hypotension, abdominal ultrasonography identifies most patients with hemoperitoneum and intra-abdominal injuries. Hypotensive patients with negative abdominal ultrasonography results, however, must be further evaluated for sources of their hypotension, including additional abdominal evaluation, once they are hemodynamically stabilized.

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Capsule Summary

What is already known on this topic

Emergency bedside ultrasonography is frequently used in trauma patients, but its sensitivity for detecting hemoperitoneum has not been clarified.

What question this study addressed

This work tests the hypothesis that emergency bedside ultrasonography will be sensitive enough to detect the presence of hemoperitoneum in all blunt trauma patients who have been hypotensive either in the out-of-hospital setting or emergency department.

What this study adds to our knowledge

Emergency bedside ultrasonography detected hemoperitoneum in only 92 (sensitivity 79%; 95% CI 71% to 86%) of 116 patients with the condition present; however, it correctly ruled out the presence of hemoperitoneum in 316 (specificity 95%; 95% CI 93% to 97%) other patients who did not have hemoperitoneum.

How this might change clinical practice

The authors conclude that emergency ultrasonography cannot be relied on alone to detect the presence of hemoperitoneum in all blunt trauma patients.

INTRODUCTION

Background

Patients with hypotension after a blunt traumatic event require rapid evaluation to identify and treat the source or sources of hypotension. Immediate identification of hemorrhagic sources of hypotension is a priority during the initial resuscitation because hypotension caused by hemorrhage requires urgent volume replacement and specific therapy to cease further hemorrhage. External sources of hemorrhage are readily identified on physical examination, and hemorrhage from pelvic fractures or into the thoracic cavity may be initially assessed with pelvic and chest radiography. Because of the unreliability of the abdominal examination and limitations of acceptable diagnostic testing in the hemodynamically unstable patient, intra-abdominal hemorrhage has traditionally been a challenge for the clinician to identify.

Abdominal computed tomography (CT), although excellent for the diagnosis of intra-abdominal injuries and intraperitoneal fluid, is contraindicated in hemodynamically unstable patients. Diagnostic peritoneal lavage requires time, is invasive, and may not be appropriate in alert patients. The development of abdominal ultrasonography has provided clinicians with a diagnostic technique for abdominal evaluation that is theoretically useful in the unstable patient. Abdominal ultrasonography allows physicians a rapid method for evaluating the abdomen for intraperitoneal fluid. Most clinically significant intra-abdominal injuries, including those resulting in patient hypotension, are associated with hemoperitoneum.[1,2] The focused abdominal sonography for trauma examination may be performed rapidly in the emergency department (ED) during the patient's initial evaluation. It has a high sensitivity for detecting intraperitoneal fluid and a high negative predictive value for predicting laparotomy.[3-14] These qualities make ultrasonography a useful diagnostic modality for evaluating patients with hypotension caused by intra-abdominal hemorrhage. Limited previous evidence suggests that ultrasonography has an excellent test performance in this cohort of patients.[15-17]

Goals of This Investigation

The objective of this study was to determine the performance of abdominal ultrasonography for detecting hemoperitoneum in blunt trauma patients with out-of-hospital or ED hypotension. We hypothesize that ultrasonography will have excellent test characteristics (sensitivity and specificity) in blunt trauma patients with out-of-hospital or ED hypotension.

MATERIALS AND METHODS

Study Design

This study was a retrospective review of the medical records of all hospitalized blunt trauma patients from July 1, 1996, to January 31, 2001. The study was approved by the Human Subjects Research Committee at our institution.

Setting and Selection of Participants

The study was conducted at an urban Level I trauma center. The ED has an annual census of 65,000 patient visits, of which 12% of visits are after traumatic events.

Hospitalized blunt trauma patients were included if they were older than 6 years and had out-of-hospital or ED hypotension. All patients were identified from the study site's trauma registry. Hypotension was defined as a systolic blood pressure less than or equal to 90 mm Hg. This systolic blood pressure cutoff is accepted for adult patients and is considered by many experts to be a low blood pressure for children older than 6 years.[18] ED hypotension was determined from the initial systolic blood pressure on arrival to the ED. Patients with a sys-

tolic blood pressure of less than or equal to 90 mm Hg during any portion of their out-of-hospital care were considered to have out-of-hospital hypotension. Patients with penetrating trauma and patients transferred from outside facilities were excluded.

Interventions

Abdominal ultrasonography was performed in the ED during initial evaluation and resuscitation. Ultrasonography was performed by sonographers who were trained in trauma ultrasonography and were registered diagnostic medical sonographers. The sonographers used either an Acuson XP 10-128 (Acuson, Mountain View, CA) or Acoustic Imaging 5200S (Acoustic Imaging, Phoenix, AZ) ultrasound with 3.5-MHz and 5.0-MHz probes. The trauma abdominal ultrasonography protocol at the study site included views of the right upper quadrant (Morison's pouch), left upper quadrant (splenorenal fossa), bilateral paracolic gutters, and the pelvis. The protocol did not include dedicated imaging of the abdominal organs. Initial abdominal ultrasonography interpretations as determined by the sonographers and the bedside clinicians were used for study purposes. Ultrasonographic examinations were considered positive if intraperitoneal fluid was identified in any location. Examinations considered probable for intraperitoneal fluid were also considered positive for study purposes. The location of intraperitoneal fluid was identified, but no attempt was made to grade the amount of intraperitoneal fluid in positive cases. Ultrasonographic examinations were considered negative if intraperitoneal fluid was not identified. Examinations documented as "questionable" or "possible" for intraperitoneal fluid, or listed as "equivocal" were considered negative.

Data Collection and Processing

The medical records of all patients were reviewed by 2 abstractors (DH, JFH) in a structured format. Definitions for abstraction were agreed on by the abstractors before review of the medical records. Demographic and historical data, physical examination, and surgical and radiographic findings were abstracted from each record and recorded into a central database in a structured pattern. Abstractors determined the abdominal ultrasonography results before determination of the presence or absence of intra-abdominal injury and laparotomy results. Discrepancies between the 2 abstractors were reviewed for a third time and resolved on the basis of this third review.

Outcome Measures

Intra-abdominal injuries were defined as any injury to the spleen, liver, pancreas, gastrointestinal tract (from stomach to sigmoid colon), gallbladder, adrenal glands, or urinary tract. A patient was considered to have an intra-abdominal injury if it was visualized on abdominal CT scan or identified at exploratory laparotomy. Hemoperitoneum was considered present if intraperitoneal fluid was identified on abdominal CT scan in a patient with intra-abdominal injury or if blood was identified in the intraperitoneal cavity at laparotomy.

Patients were considered to have repeat episodes of hypotension if a second measured systolic blood pressure in the ED was less than or equal to 90 mm Hg. Abdominal tenderness was considered present only if tenderness was documented in alert (Glasgow Coma Scale score >13) patients in the ED records by the ED/surgical house staff or the emergency/surgical faculty physician.

Laparotomy was categorized by the abstractors as either therapeutic or nontherapeutic. A therapeutic laparotomy was defined as any laparotomy resulting in a specific intervention to an injured organ (eg, placement of avitene on a liver laceration would be considered a therapeutic laparotomy). A laparotomy providing no intervention would not be considered therapeutic (eg, identification of an intra-abdominal injury that was observed only at laparotomy would be considered nontherapeutic). All patients with negative ultrasonographic examination results and who underwent laparotomy and a random sample of patients with positive ultrasonographic examination results and who underwent laparotomy were additionally reviewed by a faculty trauma surgeon to determine whether the laparotomy was therapeutic or nontherapeutic. The faculty surgeon was masked to the patients' clinical findings and results of the ultrasonographic examination at this review. Any disagreements between the faculty surgeon and the abstractors were resolved on the basis of a third review.

Timing of the laparotomy was categorized as urgent or delayed. Patients undergoing laparotomy within 6 hours of ED arrival were considered to undergo urgent laparotomy, and patients undergoing laparotomy more than 6 hours after the time of ED presentation were considered to have undergone delayed laparotomy.

The medical records of eligible patients who did not undergo ED ultrasonography were reviewed to evaluate for selection bias. We compared the frequency of intra-abdominal injury and death among those eligible

patients who underwent abdominal ultrasonography and those who did not.

Primary Data Analysis

The sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios for abdominal ultrasonography were calculated for the primary outcome (patients with intra-abdominal injuries and hemoperitoneum). Patients with intra-abdominal injuries but without hemoperitoneum were not included as a positive outcome when the test performance of abdominal ultrasonography was calculated. We chose this strategy because the abdominal ultrasonographic examination was designed and is used solely to detect the presence or absence of intraperitoneal fluid. Abdominal ultrasonography would not be expected to identify patients without hemoperitoneum. The sensitivity of abdominal ultrasonography was also calculated for the secondary outcome (patients with intra-abdominal injuries and hemoperitoneum who underwent a therapeutic laparotomy).

Continuous data were described as the mean±1 SD. Where appropriate, 95% confidence intervals (CIs) were displayed by using the calculation by Cornfield. Relative risk ratios were calculated to determine risk for categorical variables. To assess interrater reliability, the results of the 2 investigators' abstractions were measured with the κ statistic. Data analysis was performed with STATA 5.0 for Windows statistical software (release 5.0; Stata Corporation, College Station, TX).

RESULTS

Characteristics of Study Subjects

A total of 12,119 admitted patients' records were reviewed, and 717 (5.9%) patients had out-of-hospital or ED hypotension (Figure). The 447 (62%) patients who underwent abdominal ultrasonography compose the study population. The mean age of the 447 patient study population was 36.0±17.5 years, and 254 (57%) were men. Two hundred sixty-two (59%) patients were identified with ED hypotension. Two hundred seventy-five (61%) patients had out-of-hospital hypotension. Ninety (20%) patients had ED and out-of-hospital hypotension.

Four hundred six patients underwent abdominal CT, diagnostic peritoneal lavage, or laparotomy. The remaining 41 patients had clinical follow-up to evaluate the presence or absence of intra-abdominal injury. Intra-abdominal injuries were identified in 148 (33%; 95% CI 29% to 38%) patients. Types of intra-abdominal injuries are shown in Table 1. One-hundred sixteen (78%; 95% CI 71% to 85%) of the 148 patients with intra-abdominal injuries had hemoperitoneum and represent the primary outcome measure.

Main Results

We calculated the test performance for abdominal ultrasonography against these 116 patients with intra-abdominal injuries and hemoperitoneum (Table 2). In this cohort of patients, the likelihood ratio for an ultrasonographic examination demonstrating intraperitoneal fluid was 15.8, and the likelihood ratio for an ultrasonographic examination negative for intraperitoneal fluid was 0.22.

One hundred twenty-four (84%) of the 148 patients with intra-abdominal injuries underwent laparotomy (urgent cases 114; delayed cases 10). Laparotomies were considered therapeutic in 114 cases (urgent cases 107; delayed cases 7). Of the 114 patients who underwent a therapeutic laparotomy, 105 patients had intra-abdominal injuries and hemoperitoneum (9 had intra-abdominal injuries without hemoperitoneum). Abdominal ultrasonography identified 87 of these 105 patients (sensitivity 83%; 95% CI 74% to 90%). Types of injuries among patients with intra-abdominal injuries and hemoperitoneum and normal abdominal ultrasonographic examinations are shown in Table 3.

Abdominal ultrasonography was positive for intraperitoneal fluid in 15 patients without intra-abdominal injury and hemoperitoneum. Seven of these patients with false-positive ultrasonographic examinations underwent laparotomy, and the remaining 8 were evaluated with abdominal CT scan or diagnostic peritoneal lavage. Of the 7 patients undergoing laparotomy, 2 patients were found to have ascites, 2 patients had large retroperitoneal hematomas, and 1 patient had hemoperitoneum from a ruptured ectopic pregnancy. One patient with a false-positive ultrasonographic examination result experienced an iatrogenic liver injury during laparotomy.

We compared patients who were hypotensive and underwent abdominal ultrasonography (n=447) with those who were eligible for the study but did not undergo abdominal ultrasonography during initial ED evaluation (n=270). Patients not undergoing abdominal ultrasonography had a mean age of 32.1±16.2 years. Fifty (19%) patients not undergoing ultrasonography were determined to have intra-abdominal injuries, and

40 (80%) of these patients were taken within 30 minutes of ED arrival for laparotomy because of obvious indications for laparotomy. Fifty-five (20%) patients died. Patients not undergoing ultrasonography were less likely to have an intra-abdominal injury (50/270 versus 148/447; relative risk 0.56; 95% CI 0.42 to 0.74) but were more likely to die (55/270 versus 54/447; relative risk 1.7; 95% CI 1.2 to 2.4).

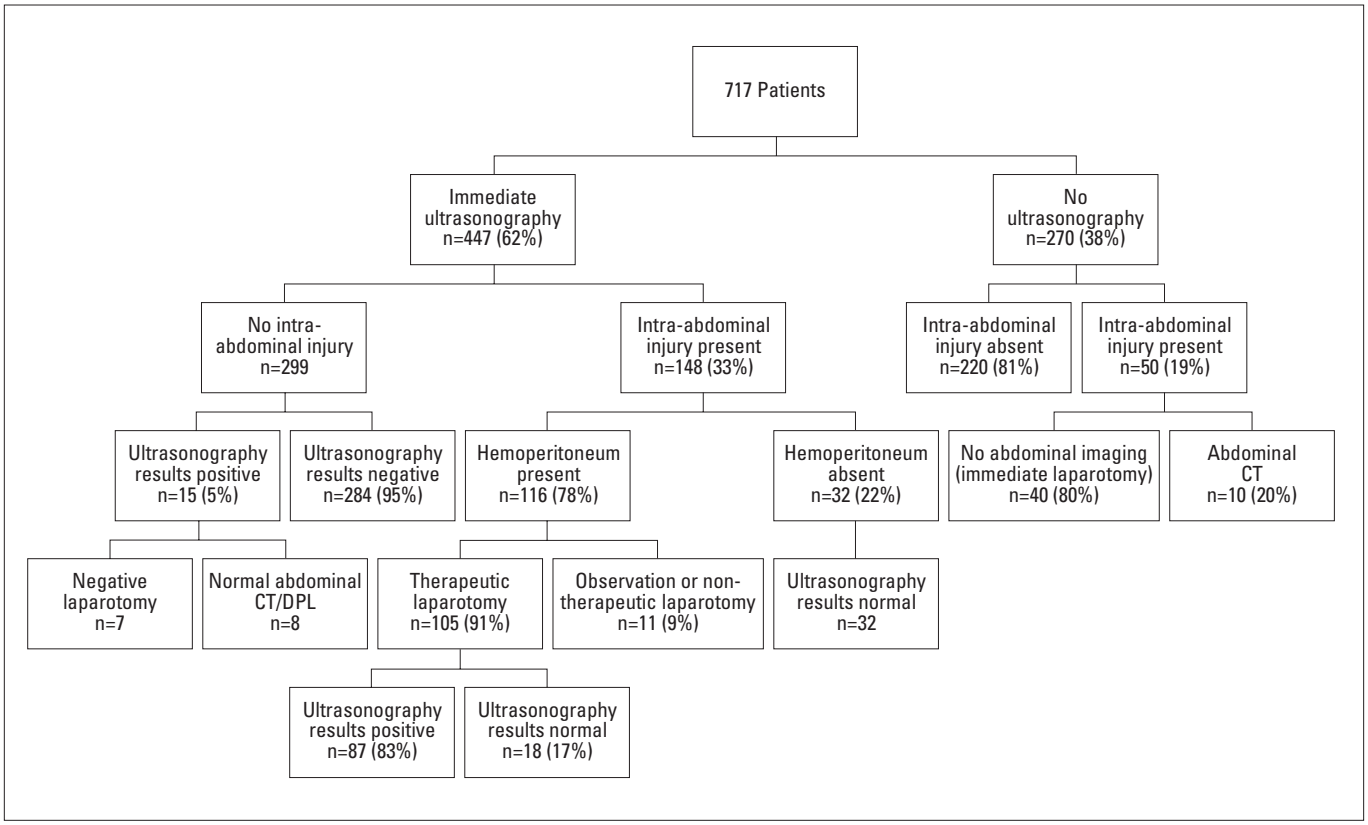
Interrater reliability was excellent for the abstractors detecting the presence or absence of intraperitoneal fluid on abdominal ultrasonography, with a κ score of 0.90. Agreement for therapeutic laparotomy was also excellent, with a κ score of 0.89.

LIMITATIONS

This study was limited by its retrospective design. Incomplete documentation may exist in the patients' medical records. Most important, this methodology limits the ability to determine the effect of ultrasonography on clinical decisionmaking at patient resuscitation. Future prospective studies could best answer this question. We were unable to truly assess the presence or absence of intraperitoneal fluid at initial abdominal ultrasonography. The determination of intraperitoneal fluid was made by abdominal CT scanning or at laparotomy, both of which occurred after initial ultrasonography. We cannot exclude the presence of an injury that resulted in minimal or no hemoperitoneum at ultrasonography, but subsequent hemorrhage occurred and was later identified by abdominal CT scan or at laparotomy.

Not all the hypotensive patients presenting during the study period underwent abdominal ultrasonography. This selection bias potentially lowered the sensitivity of ultrasonography. Forty of the 50 patients with intra-abdominal injuries were taken immediately from the ED for laparotomy. These patients had obvious indications for laparotomy and were profoundly unstable because of massive intra-abdominal hemorrhage. It is unlikely that ultrasonography would have aided in the clinical decisionmaking for these patients, but had

Figure.
Patients with out-of-hospital or ED hypotension. ***DPL,*** *Diagnostic peritoneal lavage.*



these patients undergone ultrasonography, the majority would likely have had positive ultrasonographic examination results because of their degree of injury. Finally, the study was conducted at a single center, which limits the generalizability of the study's results.

DISCUSSION

We found that abdominal ultrasonography identified the majority of hypotensive patients with hemoperitoneum caused by intra-abdominal injuries, as well as most patients who underwent therapeutic laparotomy for these injuries. However, ultrasonography failed to identify intraperitoneal fluid in an important percentage of patients with hemoperitoneum, including several patients who required urgent laparotomy. The effect of abdominal ultrasonography in the hypotensive trauma patient is best demonstrated in its likelihood ratios. A positive ultrasonographic examination result has a substantial effect on the probability of intra-abdominal injury (positive likelihood ratio 15.8), whereas a negative ultrasonographic examination result has a limited effect on posttest probability of disease (likelihood ratio 0.22).

Abdominal ultrasonography has several attractive qualities as a potential screening examination in hypotensive trauma patients. It may be performed in the ED during the initial resuscitation and thus does not require transportation of the patient. The procedure may be performed rapidly, taking from 1 to 5 minutes to complete.[7,9] The examination may be performed by surgeons, emergency physicians, radiologists, and radiology technicians.[4,5,19,20] The primary drawback of ultrasonography is its inability to reliably identify injured organs, a limitation it shares with diagnostic peritoneal lavage.[21,22]

The test performance of abdominal ultrasonography for detecting intraperitoneal fluid has been widely studied. In large studies, the sensitivity of ultrasonography for detecting intraperitoneal fluid ranges from 75% to 90%.[4,5,7,8,10,12,19,20,23,24] These studies, however, have not focused on the performance of ultrasonography in the clinically important subgroup of patients who are hypotensive. Most clinicians believe that abdominal ultrasonography would perform better in this cohort because intra-abdominal hemorrhage capable of producing hypotension should result in a positive ultrasonographic examination result. A previous study has suggested from 500 to 1,000 mL of blood are required for a positive abdominal ultrasonographic examination.[25] Hemorrhage to a lesser degree is less likely to be the sole cause of hemodynamic instability.

Although there is limited evidence on the performance of abdominal ultrasonography in hypotensive blunt trauma patients, these studies suggest that the sensitivity of abdominal ultrasonography in this cohort approaches 100%. One prospective study performed a subanalysis of patients with ED hypotension and reported a sensitivity of 85% for patients with intra-abdominal injuries (regardless of the presence of hemoperitoneum), including the identification of all patients requiring urgent laparotomy.[17] The average time to determine a positive ultrasonographic examination result in this cohort was a remarkable 19 seconds.[17] Only 1 patient in this study required laparotomy despite a negative ultrasonographic examination result. The authors did not consider the failure of ultrasonography to be important, although the patient underwent delayed repair of a jejunal perforation. This study was limited by its sample size because only 69 patients with hypotension were enrolled, and only 20 of these patients had intra-abdominal injuries. Additionally, the study did not include patients with out-of-hospital hypotension.

Table 1.
Types of injuries among the 148 patients with intra-abdominal injuries.

Injury Type	No. (%)
Liver	70 (47)
Spleen	59 (40)
Gastrointestinal	47 (32)
Kidney	25 (17)
Gallbladder	8 (5)
Pancreas	4 (3)

Table 2.
Performance of ultrasonography in the study population (116 patients with intra-abdominal injury and hemoperitoneum).

Test Characteristics	No.	Percent (95% CI)
Sensitivity	92/116	79 (71–86)
Specificity	316/331	95 (93–97)
Positive predictive value	92/107	86 (78–92)
Negative predictive value	316/340	93 (90–95)

A second adult study also suggested that abdominal ultrasonography had excellent test performance in the cohort of patients who were hemodynamically unstable.[15] Although that study also was limited by a small sample size, all 8 of the 30 hypotensive patients with intra-abdominal injuries were identified by ultrasonography. Finally, a pediatric study has suggested similar results because ultrasonography identified all 7 hypotensive children with hemoperitoneum.[16] None of the 6 hypotensive children without hemoperitoneum had a positive ultrasonographic examination result. As with the previous studies, the small sample size limits the conclusions of the pediatric study.

In the current study, the types of intra-abdominal injuries among the 18 patients with hemoperitoneum who underwent laparotomy despite normal ultrasonographic examination results were variable (Table 3). Gastrointestinal injuries were the most frequent, but liver and splenic injuries were also common. The presence of such injuries highlights the potential failure of ultrasonography in this group of high-risk patients. The group of patients undergoing urgent laparotomy despite normal abdominal ultrasonographic examinations stresses the importance of further abdominal evaluation in patients with out-of-hospital or ED hypotension.

Abdominal ultrasonography had an excellent specificity in the study, which is important because patients without intra-abdominal injury and hemoperitoneum are unlikely to test positive. The risk of a negative laparotomy in a patient with a positive ultrasonographic examination is minimal, although several patients in this study had negative laparotomy results after positive ultrasonographic examination results. A surgeon can therefore confidently proceed to the operating suite for the majority of hypotensive patients with a positive ultrasonographic examination result. Future research should attempt to further delineate patients with posi-

Table 3.
Findings in the 18 patients with hemoperitoneum who underwent therapeutic laparotomy and had normal ultrasonographic examination results.

Age, y	Mechanism	Abdominal Injury	Therapy	Additional Injuries
13	MVC	Splenic laceration	Splenectomy	Severe head injury, facial fractures, femur fracture, forearm fractures
19	MVC	Serosal tear: colon, mesenteric laceration, renal hematoma*	Repair, none, none	Severe head injury, multiple bony fractures
22	MVC	Splenic laceration	Splenectomy	Pelvic fracture
23	MVC	Serosal tear: colon, mesenteric laceration	None, repair	Tibia/fibula fracture
27	MVC	Liver laceration, diaphragm rupture	Avitene placement, diaphragm repair	Hemothorax, pelvic fracture
28	MVC	Splenic laceration	Splenectomy	SDH, hemopneumothorax, pelvic fracture, died
29	MVC	Mesenteric laceration	Repair	Cerebral edema/shear hemorrhages, brachial plexus injury
30	Motorcycle	Devascularized bowel	Bowel resection	Pelvic fracture, femur fracture, died
31	MVC	Splenic laceration, liver capsule tear, serosal tear: stomach	Splenectomy, none, repair	Closed head injury
34	Assault	Liver laceration, gallbladder avulsion	Liver packing, cholecystectomy	Concussion, facial fractures
45	MVC	Liver laceration, gallbladder avulsion, serosal tear: colon	Liver packing, cholecystectomy, none	Concussion, multiple rib fractures
45	MVC	Splenic laceration, liver laceration, diaphragm rupture	Splenectomy, none, repair	EDH, aortic injury, cervical spine injury, pelvic fracture
46	MVC	Liver laceration, gallbladder avulsion, splenic laceration, serosal tear: colon	None, cholecystectomy, splenectomy, repair	Multiple rib fractures
65	MVC	Splenic laceration, liver laceration*	Splenectomy, none	Multiple rib fractures, concussion
67	Auto vs pedestrian	Splenic laceration	Splenectomy	SAH, SDH, hemothoraces, femur fracture, spinal fractures, died
73	MVC	Serosal tear: colon, mesenteric laceration	Repair, repair	Pelvic fracture, multiple bony fractures
79	MVC	Splenic laceration, liver laceration, mesenteric laceration	Splenectomy, none, repair	Severe head injury, flail chest, died
80	MVC	Liver laceration, sigmoid perforation	Packing, sigmoid colectomy	Pelvic fracture, spinal fracture, tibia/fibula fracture, died

MVC, Motor vehicle collision; **SDH,** subdural hematoma; **EDH,** epidural hematoma; **SAH,** subarachnoid hemorrhage.
*Laparotomy delayed (occurred >6 h from ED presentation).

tive ultrasonographic examination results who require laparotomy so that the rate of negative laparotomy results can be reduced.

In summary, the qualities of being portable, rapidly performed, and conducted while additional resuscitation procedures are ongoing make abdominal ultrasonography an ideal screening examination for blunt trauma patients who are hypotensive. Abdominal ultrasonography identifies most of these patients who are hypotensive from intra-abdominal hemorrhage. However, a subgroup of patients with out-of-hospital or initial ED hypotension will have hemoperitoneum despite normal ultrasonographic examination results. Hypotensive patients with normal ultrasonographic examination results should continue to be evaluated for sources of hypotension, including intra-abdominal hemorrhage.

Author contributions: JFH and DH conceived the study. JFH developed its design. JFH, DH, and FDB acquired the data; DH managed the data; and JFH analyzed and interpreted the data. JFH and FDB drafted the manuscript. All authors take responsibility for the paper as a whole.

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REFERENCES

1. Hahn DD, Offerman SR, Holmes JF. Clinical importance of intraperitoneal fluid in patients with blunt intra-abdominal injury. *Am J Emerg Med.* 2002;20:595-600.
2. Ochsner MG, Knudson MM, Pachter HL, et al. Significance of minimal or no intraperitoneal fluid visible on computed tomography scan associated with blunt liver and splenic injuries: a multicenter analysis. *J Trauma.* 2000;49:505-510.
3. Porter RS, Nester BA, Dalsey WC. Use of ultrasound to determine need for laparotomy in trauma patients. *Ann Emerg Med.* 1997;29:323-330.
4. Rozycki GS, Ochsner MG, Jaffin JH, et al. Prospective evaluation of surgeons' use of ultrasound in the evaluation of trauma patients. *J Trauma.* 1993;34:516-526.
5. Rozycki GS, Ochsner MG, Schmidt JA, et al. A prospective study of surgeon-performed ultrasound as the primary adjuvant modality for injured patient assessment. *J Trauma.* 1995;39:492-498.
6. Ma OJ, Mateer JR, Ogata M, et al. Prospective analysis of a rapid trauma ultrasound examination performed by emergency physicians. *J Trauma.* 1995;38:879-885.
7. Boulanger BR, McLellan BA, Brenneman FD, et al. Emergent abdominal sonography as a screening test in a new diagnostic algorithm for blunt trauma. *J Trauma.* 1996;40:867-874.
8. Brown MA, Casola G, Sirlin CB, et al. Blunt abdominal trauma: screening us in 2,693 patients. *Radiology.* 2001;218:352-358.
9. Jehle D, Guarino J, Karamanoukian H. Emergency department ultrasound in the evaluation of blunt abdominal trauma. *Am J Emerg Med.* 1993;11:342-346.
10. McKenney MG, Martin L, Lentz K, et al. 1,000 consecutive ultrasounds for blunt abdominal trauma. *J Trauma.* 1996;40:607-610.
11. Ingeman JE, Plewa MC, Okasinki RE, et al. Emergency physician use of ultrasonography in blunt abdominal trauma. *Acad Emerg Med.* 1996;3:931-937.
12. Dolich MO, McKenney MG, Varela JE, et al. 2,576 ultrasounds for blunt abdominal trauma. *J Trauma.* 2001;50:108-112.
13. McKenney KL, Nunez DB Jr, McKenney MG, et al. Sonography as the primary screening technique for blunt abdominal trauma: experience with 899 patients. *Am J Roentgenol.* 1998;170:979-985.
14. Stengel D, Bauwens K, Sehouli J, et al. Systematic review and meta-analysis of emergency ultrasonography for blunt abdominal trauma. *Br J Surg.* 2001;88:901-912.
15. Rozycki GS, Newman PG. Surgeon-performed ultrasound for the assessment of abdominal injuries. *Adv Surg.* 1999;33:243-259.
16. Holmes JF, Brant WE, Bond WF, et al. Emergency department ultrasonography in the evaluation of hypotensive and normotensive children with blunt abdominal trauma. *J Pediatr Surg.* 2001;36:968-973.
17. Wherrett LJ, Boulanger BR, McLellan BA, et al. Hypotension after blunt abdominal trauma: the role of emergent abdominal sonography in surgical triage. *J Trauma.* 1996;41:815-820.
18. Report of the Second Task Force on Blood Pressure Control in Children—1987. Task Force on Blood Pressure Control in Children. National Heart, Lung, and Blood Institute, Bethesda, Maryland. *Pediatrics.* 1987;79:1-25.
19. Ingeman JE, Plewa MC, Okasinski RE, et al. Emergency physician use of ultrasonography in blunt abdominal trauma. *Acad Emerg Med.* 1996;3:931-937.
20. Ma OJ, Kefer MP, Mateer JR, et al. Evaluation of hemoperitoneum using a single- vs multiple-view ultrasonographic examination. *Acad Emerg Med.* 1995;2:581-586.
21. Richards JR, Schleper NH, Woo BD, et al. Sonographic assessment of blunt abdominal trauma: a 4-year prospective study. *J Clin Ultrasound.* 2002;30:59-67.
22. Yoshii H, Sato M, Yamamoto S, et al. Usefulness and limitations of ultrasonography in the initial evaluation of blunt abdominal trauma. *J Trauma.* 1998;45:45-50.
23. Bode PJ, Edwards MJ, Kruit MC, et al. Sonography in a clinical algorithm for early evaluation of 1671 patients with blunt abdominal trauma. *Am J Roentgenol.* 1999;172:905-911.
24. Boulanger BR, McLellan BA, Brenneman FD, et al. Prospective evidence of the superiority of a sonography-based algorithm in the assessment of blunt abdominal injury. *J Trauma.* 1999;47:632-637.
25. Branney SW, Wolfe RE, Moore EE, et al. Quantitative sensitivity of ultrasound in detecting free intraperitoneal fluid. *J Trauma.* 1995;39:375-380.