Focused Abdominal US in Patients with Trauma[1]

Sattam S. Lingawi, MD, FRCPC
Anne R. Buckley, MB, FRCPC

Index terms:
Abdomen, injuries, 70.411, 70.412
Abdomen, US, 70.12981
Ultrasound (US), focused, 70.12981

Radiology 2000; 217:426–429

Abbreviation:
DPL = diagnostic peritoneal lavage

[1] From the Department of Radiology, Vancouver Hospital and Health Science Center, Vancouver, BC, Canada V5Z IM9. Received August 18, 1999; revision requested October 7; final revision received March 28, 2000; accepted April 4. **Address correspondence to** S.S.L. (Department of Radiology, the University Hospital, King Abdulaziz University, PO Box 7363, Jeddah 21462, Saudi Arabia (e-mail: *tersam2@yahoo.com*).

Author contributions:
Guarantor of integrity of entire study, S.S.L.; study concepts, S.S.L.; study design, S.S.L.; definition of intellectual content, A.R.B.; literature research, S.S.L.; clinical studies, S.S.L.; data acquisition, S.S.L.; data analysis, S.S.L.; manuscript preparation, S.S.L.; manuscript editing, A.R.B.; manuscript review, A.R.B.

PURPOSE: To evaluate the accuracy of focused abdominal ultrasonography (US) in detecting abdominal injuries that require in-hospital patient treatment in the setting of blunt abdominal trauma.

MATERIALS AND METHODS: One thousand ninety patients with blunt abdominal trauma were assessed with focused abdominal US within 30 minutes of arrival at the hospital. Focused abdominal US results were positive if intra- or retroperitoneal fluid was detected. Patients with negative US results and no other major injuries were observed in the emergency department for 12 hours before discharge. Patients who deteriorated clinically after negative initial US underwent repeat US and/or emergency abdominopelvic computed tomography (CT). Patients with positive or indeterminate US results underwent emergency abdominopelvic CT.

RESULTS: Nine hundred seventy-four (89%) patients had negative focused abdominal US results; eight of these underwent CT. Sixty-six (6%) had positive US results. Four (0.4%) had false-negative and 19 (1.7%) had false-positive US results. Twenty-seven (2.5%) had indeterminate US results; of these, five (18.5%) had positive CT results. One hundred twenty-four (11.4%) required emergency CT. After indeterminate cases were excluded, focused abdominal US had 94% sensitivity, 98% specificity, 78% positive predictive value, 100% negative predictive value, and 95% accuracy.

CONCLUSION: Focused abdominal US has a high negative predictive value for major abdominal injury in patients with blunt abdominal trauma.

Assessment of the abdomen for possible sustained intraabdominal injury due to blunt abdominal trauma is a common clinical challenge for surgeons and emergency medicine physicians. Physical findings may be unreliable because of decreased patient consciousness, neurologic deficit, medication, or other associated injuries (1). Although diagnostic peritoneal lavage (DPL) is thought to be superior to clinical examination in assessing abdominal injuries, it is an invasive procedure. DPL carries a risk of organ injury and decreases the specificity of subsequent ultrasonography (US) and/or computed tomography (CT) because of the introduction of intraperitoneal fluid and air (2–4).

CT remains the radiologic standard for investigating the injured abdomen but requires patient transfer and inevitable delay (bowel preparation) and is unsuitable for patients who are clinically unstable.

US is an accessible, portable, noninvasive, and reliable diagnostic tool for assessment of the presence of abdominal fluid (5–8).

The purpose of our study was to evaluate the accuracy of focused abdominal US in detecting abdominal injuries that require in-hospital patient treatment in the setting of blunt abdominal trauma.

MATERIALS AND METHODS

One thousand ninety consecutive patients with blunt abdominal trauma were enrolled in the study between July 1996 and June 1998. These included 836 (77%) male and 254 (23%) female patients (age range, 16–85 years; mean age, 36 years). On arrival at the emergency department, all patients were assessed by the trauma team. Most injuries were due to high-speed motor vehicle accidents (>50 km/h), pedestrian and motor-vehicle collisions (>35 km/h), falls from a height (>6 m), and skiing accidents. Patients who were hemo-

TABLE 1
Injuries Detected at CT in Patients with True-Positive Focused Abdominal US Results

Injury Location	No. of Patients	No. of Patients Treated Conservatively	No. of Patients Requiring Surgery	Surgical Procedure
Spleen	41	34	7	Splenorrhaphy (n = 6) and splenectomy (n = 1)
Liver	4	3	1	Hepatorrhaphy
Spleen and liver	10	8	2	Splenorrhaphy
Kidney	5	5	0	NA
Bowel	2	0	2	Resection and primary anastomosis (n = 2)
Spleen and diaphragm	1	0	1	Splenectomy and diaphragm repair
Liver and diaphragm	1	0	1	Hepatorrhaphy and diaphragm repair
Bowel and pancreas	1	0	1	Partial pancreatectomy and bowel repair
Urinary bladder	1	0	1	Repair

Note.—NA = not applicable.

dynamically unstable, had a penetrating abdominal injury or other injuries requiring immediate surgical intervention, or had undergone DPL or abdominal CT at another institution prior to arrival in our emergency department were not enrolled in the study.

All focused abdominal US scans were obtained by using a portable US machine (140 SC; Toshiba, Norcross, Ga); the senior radiology residents and/or fellows interpreted the results in the emergency department within 30 minutes of the patient's arrival at the hospital. The US scans were obtained in conjunction with the patients' triage and resuscitation. Each US examination was completed within 10 minutes. Hard-copy images were reviewed and reported by a staff radiologist the next morning. The residents' and fellows' reports were compared with the staff radiologist's interpretation; the latter was used for the study.

Focused abdominal US is an examination of the abdomen for free fluid (blood) in the perihepatic area (which includes the Morrison pouch), perisplenic region (which includes the splenorenal recess), paracolic gutters, and cul-de-sac. The urinary bladder was filled with saline before or during scanning to allow visualization of the cul-de-sac. Solid organs (the liver and spleen) were not specifically evaluated for evidence of injury.

The study protocol was approved by the hospital's ethics review board, and written or verbal informed consent was obtained from all patients who were clinically stable and conscious. The absence of abdominal fluid was considered evidence of a negative scan, and no further radiologic investigation was warranted unless the patients' clinical presentation changed and/or their hemoglobin level decreased substantially. In such a situation, abdominopelvic CT was performed. Patients with negative focused abdominal US results who sustained no other injuries that required hospital admission were observed in the emergency department for 12 hours prior to discharge. The patient and his or her family were instructed to return to the emergency department if the patient's condition deteriorated. The presence of abdominal fluid was considered evidence of a positive scan regardless of the fluid's volume or location, and contrast material–enhanced spiral CT of the abdomen and pelvis was performed to further evaluate the extent of solid organ and/or bowel injury.

Abdominopelvic CT extended from the lower chest to the symphysis pubis. Spiral CT (CT/i High Speed; GE Medical Systems, Milwaukee, Wis) was performed with 10-mm collimation and a table speed of 10 mm/sec (pitch of 1). Intravenous contrast material (iohexol, Omnipaque 240; Nycomed Amersham, Princeton, NJ) was administered routinely as a 150-mL bolus at 3 mL/sec by using a power injector. All patients received orally administered contrast material that consisted of 5 g diatrizoate meglumine powder (Hypaque; Nycomed Amersham) in 400 mL of water approximately 45 minutes prior to scanning. A second dose of oral contrast material was given immediately prior to scanning.

Although the amount and location of hemoperitoneum at CT were not compared with focused abdominal US findings, the injuries noted at CT, the treatment, and its outcome were all tabulated. Patients who had positive US findings who were found to have true-positive CT findings of fluid were admitted for further treatment. All patients with indeterminate US findings due to patient size, subcutaneous emphysema, or limited US windows were treated in our protocol as having positive findings and were assessed by using emergency CT. All CT scans were initially interpreted by the same resident or fellow who performed US. All CT scans were formally reviewed and reported by a staff radiologist the next morning. The resident's or fellow's reports were compared with the staff radiologist's interpretation, and the latter was used for the study.

The sensitivity, specificity, accuracy, negative predictive value, and positive predictive value of focused abdominal US were calculated.

RESULTS

Of the 1,090 patients who underwent focused abdominal US, 974 had true-negative findings, 66 had true-positive findings, four had false-negative findings, 19 had false-positive findings, and 27 had indeterminate findings. Overall, 124 patients underwent CT evaluation. Sixty-six (6%) patients had a positive US result that was confirmed at CT (true-positive). Of these, 41 (62%) had splenic injuries, four (6%) had hepatic injuries, 10 (15%) had splenic and hepatic injuries, five (8%) had renal injuries, and two (3%) had bowel injuries. Four (6%) patients had other visceral injuries (Table 1). Only 16 (24%) patients required surgery.

Nine hundred seventy-four (89%) patients had a negative focused abdominal US result; these patients remained stable during the emergency observation period and hospitalization (true-negative). Eight patients underwent abdominopelvic CT despite a negative US result; all CT scans were normal. These eight patients' CT scans were obtained at the beginning of the study to gain the trauma team's acceptance of focused abdominal US as a screening tool for blunt abdominal injury. Review of hospital and trauma registry records did not reveal any patients with clinical deterioration or readmission

TABLE 2
Injuries Detected at CT in Patients with False-Negative Focused Abdominal US Results

Location of Injury	No. of Patients Sustaining the Injury	Reason for CT	No. of Patients Requiring Surgery	Surgical Procedure
Kidney (subcapsular hematoma)	1	Persistence of abdominal pain	0	NA
Spleen	2	Persistence of abdominal pain	0	NA
	1	Hemodynamic instability during observation period	1	Splenectomy

Note.—NA = not applicable.

to the emergency department after discharge.

There were no discrepancies between the real-time interpretations by the radiology resident or fellow and the final hard-copy readouts by the staff radiologist for both focused abdominal US and CT scans.

Four (0.4%) patients had false-negative focused abdominal US findings on the basis of follow-up CT that was performed because of clinical deterioration. Three of the four patients sustained splenic injury; only one needed surgery. The fourth patient had a subcapsular renal hematoma (Table 2).

Nineteen (1.7%) patients had a false-positive focused abdominal US finding for which the CT scan was normal. Twenty-seven (2.5%) patients had indeterminate US findings; five of these patients (18.5%) had positive CT findings (Table 3). None of the five patients required surgery.

Emergency CT was performed in 124 patients. Three patients in the group with true-positive findings died. Two of those three had severe closed-head injuries. Similarly, 36 patients in the group with true-negative findings died of associated severe extraabdominal injuries. The rest of the groups with true-positive and negative findings and all patients with false-positive (n = 19), false-negative (n = 4), or indeterminate (n = 27) findings survived and were discharged within 30 days of admission.

On the basis of these results and with the exclusion of the indeterminate focused abdominal US findings, focused abdominal US had 94% (66 of 70) sensitivity, 98% (974 of 993) specificity, 95% (1,040 of 1,090) accuracy, 78% (66 of 85) positive predictive value, and 100% (974 of 978) negative predictive value.

TABLE 3
Injuries Detected at CT in Patients with Indeterminate Focused Abdominal US Results

Location of Injury	No. of Patients Sustaining the Injury	No. of Patients with Hemoperitoneum	No. of Patients Requiring Surgery
Kidney (contusion)	1	0	0
Spleen	4	3	0

DISCUSSION

The accuracy of the clinical diagnosis of blunt abdominal injury varies between 47% and 87% (9,10). Physical findings may be unreliable because of decreased patient consciousness, neurologic deficits, medications, or other associated injuries (1).

DPL has been used as a surgical tool for the diagnosis of hemoperitoneum since 1965 (11). Despite the substantial improvement in DPL technique and equipment, it remains an invasive procedure that carries a 1.0%–9.5% complication rate (12,13). These complications include bowel perforation, bladder penetration, vascular laceration, and wound complications. Also, the interpretation of DPL results is not standardized. The general acceptance of a red blood cell count of more than 100×10^9/L or a white blood cell count of more than $.5 \times 10^9$/L in the lavage effluent as being positive is not accurate, since there is up to a 59% chance of finding a major injury in a patient with a red blood cell count of less than 100×10^9/L (9).

False-positive DPL results can also occur from iatrogenic injuries during the placement of the DPL catheter and by peritoneal contamination with blood from the DPL incision site (14,15). Although Liu et al (16) reported comparable sensitivities, specificities, and accuracies of DPL and US, the latter, in our opinion, remains the examination of choice because of the previously mentioned limitations of DPL.

The capabilities and limitations of US in the evaluation of blunt abdominal injury have been discussed in a number of publications (10,17–21). Despite the widespread use of US for assessing blunt abdominal injury in Europe and Japan, its similar application in North America has been limited (4,12). The method of investigation for such clinical scenarios has been contrast-enhanced CT of the abdomen and pelvis. A rapid, portable, and reliable method of screening these patients is desired. Results of the current study demonstrate that focused abdominal US is sensitive (94%), specific (98%), and accurate (95%) for detecting hemoperitoneum. Our results are comparable with the published data (10,16,18–24). McKenney et al (18) and Bode et al (19) advocate solid organ screening as part of the primary screening examination. Focused abdominal US is dedicated to the detection of abdominopelvic hemoperitoneum and is not intended to evaluate the degree of parenchymal injury in solid organs.

Although Chiu et al (25) reported major blunt abdominal injuries without hemoperitoneum in 5% of all blunt abdominal injuries, which represent a potential limitation of focused abdominal US, only four of the 15 patients in that study with a false-negative focused abdominal US result needed surgery. Of these four patients, two deteriorated clinically after an initial negative focused abdominal US result and could have received a diagnosis at repeat focused abdominal US or CT.

The results of our study show that in the absence of hemoperitoneum it is unlikely that the patient would require surgical intervention. Although this does not eliminate the exceptional case of high-grade abdominal injury without hemoperitoneum, it is unlikely that such patients would remain stable during the 12-hour observation in the emergency department. The 12-hour limit was cho-

sen according to the emergency department's policy, which specifies 12 hours as the maximum time allowed for patient observation without hospital admission.

Since US is more sensitive than CT for depicting small intraabdominal and pelvic fluid collections, some investigators do not perform CT to confirm the presence of a minimal amount of fluid (4, 12,24).

It is important to emphasize the need to fill the urinary bladder prior to or during the examination to displace bowel gas and decrease the likelihood of missing a pelvic hemoperitoneum. In comparing US with CT, McGahan et al (26) reported 14 of 500 false-negative US results. Almost 50% of their false-negative results were due to the identification of free fluid in the pelvis at CT but not at US, owing to lack of a full bladder. We adopted a strict policy of filling the bladder (unless contraindicated) to avoid such misses.

Of the 66 patients with true-positive focused abdominal US results, only 16 (24%) required surgery, while the remaining 50 were treated conservatively. Although we agree that from the patient treatment perspective, the patients with true-positive focused abdominal US findings should be the only patients who require surgery, we do not believe that US is accurate in categorizing visceral injuries; hence, it cannot be the basis on which surgery is contemplated. We believe that focused abdominal US is an accurate screening modality for detection of major injuries in patients with blunt abdominal trauma. However, we do not advocate the use of focused abdominal US to decide whether the patient should be treated surgically or conservatively. In our opinion, this decision should be made on a clinical basis.

In a recent study by Shanmuganathan et al (27), 34% of patients with blunt abdominal trauma revealed no evidence of hemoperitoneum at CT. Of those, 17% required surgery. They also reported that 40%–50% of hemoperitoneum-negative hepatic and/or splenic injuries were of a high grade, in accordance with the American Association for the Surgery of Trauma's hepatic and splenic injury scales. Our results do not support these figures. Nevertheless, these figures are concerning when US is used as the screening modality. This emphasizes the importance of the 12-hour patient observation period in the emergency department and urges trauma and emergency physicians to maintain a low threshold in requesting abdominopelvic CT whenever the patient's clinical findings change or are inconsistent with the focused abdominal US result.

In conclusion, we think that focused abdominal US is an efficient and accurate method for evaluating blunt abdominal trauma. A negative focused abdominal US result has a high negative predictive value for major intraabdominal injury in patients with blunt abdominal trauma, given the constraints of a 12-hour observation period. It can be used to reduce and probably eliminate the need for diagnostic peritoneal lavage and allows a substantial reduction in the number of emergency abdominopelvic CT examinations performed.

References

1. Perry JF Jr. A five-year survey of 152 acute abdominal injuries. J Trauma 1965; 5:53–56.
2. Powell DC, Bivins BA, Bell RM. Diagnostic peritoneal lavage. Surg Gynecol Obstet 1982; 155:257–269.
3. Soderstrom CA, DuPriest RW Jr, Cowley RA. Pitfalls of peritoneal lavage in blunt abdominal trauma. Surg Gynecol Obstet 1980; 151:513–518.
4. Healey MA, Simons RK, Winchell RJ, et al. A prospective evaluation of abdominal ultrasound in blunt trauma: is it useful? J Trauma 1996; 40:875–883.
5. Boulanger BR, Brenneman FD, McLellan BA, et al. A prospective study of emergent abdominal sonography after blunt trauma. J Trauma 1995; 39:325–330.
6. Tso P, Rodriguez A, Cooper C, et al. Sonography in blunt abdominal trauma: a preliminary progress report. J Trauma 1992; 33:39–43.
7. McKenney M, Lentz K, Nunez D, et al. Can ultrasound replace diagnostic peritoneal lavage in the assessment of blunt trauma? J Trauma 1994; 37:439–441.
8. 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.
9. Goletti O, Ghiselli G, Lippolis PV, et al. The role of ultrasonography in blunt abdominal trauma: results in 290 consecutive cases. J Trauma 1994; 36:178–181.
10. Sarkisian AE, Khondkarian RA, Amirbekian NM, et al. Sonographic screening of mass casualties for abdominal and renal injuries following the 1988 Armenian earthquake. J Trauma 1991; 31:247–250.
11. Root HD, Hauser CW, McKinley CR, Laufaue JW, Mendola RD Jr. Diagnostic peritoneal lavage. Surgery 1965; 57:633–637.
12. Rothlin MA, Naf R, Amggerd M, et al. Ultrasound in blunt abdominal and thoracic trauma. J Trauma 1993; 34:488–495.
13. Powell DL, Bivens BA, Bell RM. Diagnostic peritoneal lavage. Surg Gynecol Obstet 1982; 155:257–264.
14. 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.
15. Glaser K, Tschmelitsch J, Klingler P, et al. Ultrasonography in the management of blunt abdominal and thoracic trauma. Arch Surg 1994; 129:743–747.
16. Liu M, Lee CH, P'eng FK. Prospective comparison of diagnostic peritoneal lavage, computed tomographic scanning, and ultrasonography for the diagnosis of blunt abdominal trauma. J Trauma 1993; 35:267–270.
17. Goletti O, Ghiselli G, Lippolis PV, et al. The role of ultrasonography in blunt abdominal trauma: results in 290 consecutive cases. J Trauma 1994; 36:178–181.
18. McKenney KL, Nunez DB, McKenney MG, Asher J, Zelnick K, Shipshak D. Sonography as the primary screening technique for blunt abdominal trauma: experience with 899 patients. AJR Am J Roentgenol 1998; 170:979–985.
19. Bode PJ, Edwards MJR, Kruit MC, van Vugt AB. Sonography in a clinical algorithm for early evaluation of 1,671 patients with blunt abdominal trauma. AJR Am J Roentgenol 1999; 172:905–911.
20. Richards J, McGahan JP. Blunt abdominal trauma: the role of emergent sonography and a review of the literature. AJR Am J Roentgenol 1999; 172:897–903.
21. McKenney MG, Martin L, Lopez C, et al. 1000 consecutive ultrasounds for blunt abdominal trauma. J Trauma 1996; 40: 607–612.
22. 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.
23. Hoffmann R, Nerlich M, Muggia-Sullam M, et al. Blunt abdominal trauma in cases of multiple trauma evaluated by ultrasonography: a prospective analysis of 291 patients. J Trauma 1992; 34:452–458.
24. Glaser K, Tschmelitsch J, Klingler P, et al. Ultrasonography in the management of blunt abdominal and thoracic trauma. Arch Surg 1994; 129:743–747.
25. Chiu WC, Cushing BM, Rodriguez A, et al. Abdominal injuries without hemoperitoneum: a potential limitation of focused abdominal sonography for trauma (FAST). J Trauma 1997; 42:617–623.
26. McGahan JP, Rose J, Coates TL, Wisner DH, Newberry P. Use of ultrasonography in the patient with acute abdominal trauma. J Ultrasound Med 1997; 16:653–662.
27. Shanmuganathan K, Mirvis SE, Sherbourne CD, Chiu WC, Rodriguez A. Hemoperitoneum as the sole indicator of abdominal visceral injuries: a potential limitation for screening abdominal US for trauma. Radiology 1999; 212:423–430.