Clinical Policy: Critical Issues in the Evaluation of Adult Patients Presenting to the Emergency Department With Acute Blunt Abdominal Trauma

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This clinical policy was developed by the ACEP Clinical Policies Committee and the Clinical Policies Subcommittee on Acute Blunt Abdominal Trauma. For a complete listing of subcommittee and committee members, please see page 283.

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INTRODUCTION

Blunt abdominal trauma is a leading cause of morbidity and mortality among adult and pediatric trauma victims. Blunt trauma is also a leading cause of intra-abdominal injuries. However, the clinical evaluation of these patients remains somewhat controversial.

Physical examination is inaccurate in evaluating blunt abdominal trauma patients with altered mental status.[1] In a large prospective study, Livingston et al[2] found that abdominal tenderness was absent in 19% of blunt abdominal trauma patients with intra-abdominal injuries. In 1965, Root et al[3] initially described diagnostic peritoneal lavage. Since that time, diagnostic peritoneal lavage has been used to evaluate blunt abdominal trauma victims for hemoperitoneum. Diagnostic peritoneal lavage is an invasive procedure, however, and it is relatively ineffective in identifying retroperitoneal and solid organ injuries not associated with hemoperitoneum. Abdominal computed tomography (CT) became an adjunct in evaluating blunt abdominal trauma patients during the early 1980s.[4] Although abdominal CT effectively identifies hemoperitoneum, retroperitoneal trauma, and solid organ injuries, CT is less effective in diagnosing diaphragmatic, pancreatic, and hollow viscus injuries.[5-7] Focused abdominal sonography for trauma (FAST) effectively identifies hemoperitoneum and may be performed serially. However, FAST is not as accurate as CT in identifying solid organ injuries.[8-10]

This clinical policy focuses on selected diagnostic studies in blunt abdominal trauma. Specifically, we present evidence-based recommendations to questions regarding the accuracies of CT, diagnostic peritoneal lavage, and FAST in identifying various intra-abdominal injuries.

Recommendations offered in this policy are not intended to represent the only diagnostic and management options that the emergency physician should consider. The American College of Emergency Physicians (ACEP) clearly recognizes the importance of the individual physician's judgment. Rather, this guideline defines for the physician those strategies for which medical literature exists to provide support for answers to the crucial questions addressed in this policy.

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METHODOLOGY

This clinical policy was created after careful review and critical analysis of the peer-reviewed literature. All articles were graded by at least 2 subcommittee members for strength of evidence. A MEDLINE search for articles published between January 1966 and June 2002 was performed using the terms "abdominal injuries" and "abdominal trauma" in combination with the following: diagnosis, ultrasonography, peritoneal lavage, diagnostic peritoneal lavage, lavage, laboratory testing, and trauma panel. Other MEDLINE searches for articles published during the same time interval were performed using the following key words: tomography (x-ray computed); wounds (nonpenetrating); and injuries in combination with the following key words: kidney, pelvis, ureter, and bladder. Searches were limited to English-language sources. Additional articles were reviewed from the bibliography of articles cited. Recent journals and standard texts were also examined for additional sources.

The reasons for developing clinical policies in emergency medicine and the approaches used in their development have been enumerated.[11] This policy is a product of the ACEP clinical policy development process, including expert review, and is based on the existing literature; where literature was not available, consensus of emergency physicians was used. Expert review comments were received from emergency physicians, members of ACEP's Trauma Care and Injury Control Committee, leaders of ACEP's Section of Trauma and Injury Prevention, leaders of ACEP's Section of Emergency Ultrasound, and physicians from specialty societies, including individual members of the American College of Surgeons Committee on Trauma and the American Academy of Family Physicians. Their responses were used to further refine and enhance this policy. Clinical policies are scheduled for revision every 3 years; however, interim reviews are conducted when technology or the practice environment changes significantly.

During the review process, all articles used in the formulation of this policy were classified by the subcommittee members into 3 classes on the basis of design of study, with design 1 representing strongest evidence and design 3 representing weakest evidence for therapeutic, diagnostic, and prognostic clinical reports, respectively (Appendix A). Reports were then graded on 6 dimensions thought to be most relevant to the development of a clinical guideline: blinded versus nonblinded outcome assessment, blinded or randomized allocation, direct or indirect outcome measures, biases (eg, selection, detection, transfer), external validity (generalizability), and sufficient sample size. Articles received a final grade (I, II, III) on the basis of a predetermined formula taking into account design and grade of study (Appendix B). Articles with fatal flaws were given an "X" grade and not used in the creation of this policy. An Evidentiary Table was constructed and is included at the end of this policy.

Clinical findings and strength of recommendations regarding patient management were then made according to the following criteria:

Level A recommendations. Generally accepted principles for patient management that reflect a high degree of clinical certainty (ie, based on "strength of evidence class I" or overwhelming evidence from "strength of evidence class II" studies that directly address all the issues).

Level B recommendations. Recommendations for patient management that may identify a particular strategy or range of management strategies that reflect moderate clinical certainty (ie, based on "strength of evidence class II" studies that directly address the issue, decision analysis that directly addresses the issue, or strong consensus of "strength of evidence class III" studies).

Level C recommendations. Other strategies for patient management based on preliminary, inconclusive, or conflicting evidence or, in the absence of any published literature, based on panel consensus.

There are certain circumstances in which the recommendations stemming from a body of evidence should not be rated as highly as the individual studies on which they are based. Factors such as heterogeneity of results, uncertainty about effect magnitude and consequences, strength of prior beliefs, and publication bias, among others, might lead to such a downgrading of recommendations.

Scope of Application. This guideline is intended for physicians working in hospital-based emergency departments (EDs).

Inclusion Criteria. This clinical policy is intended for nonpregnant adults with blunt force injuries to the abdomen (eg, falls, direct abdominal blows, motor vehicle collisions).

Exclusion Criteria. Excluded from this policy are: (1) children, (2) pregnant women, and (3) victims of penetrating abdominal injuries.

CRITICAL QUESTIONS

I. What is the diagnostic performance of CT in diagnosing significant intra-abdominal injuries requiring intervention in blunt abdominal trauma?

Background: CT has been used to evaluate the injured abdomen since the early 1980s. Although CT is widely accepted as a primary modality to evaluate blunt abdominal trauma, its overall accuracy in specific situations is a subject of ongoing study. The difficulty in studying CT is compounded by the fact that technology is improving quickly, as are the criteria for determining when to operate in the setting of a positive result. Whereas the liver and spleen are relatively easy to evaluate by CT, the bowel, pancreas, and diaphragm are more difficult. It also is well recognized that CT interpretation is, to an extent, reader dependent. This element of subjectivity places a premium on interpreter experience. The vast majority of CT studies are retrospective reviews at individual trauma centers. Given the acceptance of CT as nearly a criterion standard for evaluating the abdomen, future prospective randomized studies may be very difficult to perform.

Findings: Liu et al[8] completed a prospective, comparative study of CT, diagnostic peritoneal lavage, and ultrasonography. Each of 55 stable patients suspected of blunt abdominal injuries underwent all 3 studies. If the results of any study were positive, the patients underwent laparotomies. Thirty-nine of these patients underwent laparotomies, a relatively high positive test rate for trauma. Results were as follows: CT sensitivity 97% and specificity 95%, diagnostic peritoneal lavage sensitivity 100% and specificity 84%, ultrasonography sensitivity 92% and specificity 95%. The only false negative CT was a case of intestinal perforation. Although it is difficult to draw conclusions from a study of this size published more than a decade ago, it bears inclusion as the only study of its kind available for review. In a separate study, Stafford et al[9] studied 394 trauma patients prospectively and reported that for solid organ injuries, CT with oral contrast was 84.2% sensitive and 94% specific.

Specific intra-abdominal injuries that are difficult to diagnose have been the subjects of specific retrospective case reviews. These injuries include those to the bowel, diaphragm, and pancreas. Sherck et al[5] studied 26 patients in their institution (3% of the 883 receiving CT scans) who had proven small bowel injuries. These authors found that, for small bowel perforation, CT scan had a sensitivity of 92% and a specificity of 94%. Butela et al[12] retrospectively reviewed 50 cases of proven small bowel injuries in which CT was available for review. Sixty-two patients were chosen randomly as a comparison group to create a case-control study. On the basis of the original CT interpretation, the study revealed a sensitivity of 64% and a specificity of 97%.

Killeen et al[13] performed a retrospective study of 150 patients with either CT or surgical diagnoses of blunt abdominal trauma or of bowel or mesenteric injuries. CT had a sensitivity of 94% in detecting bowel injury and 96% in detecting mesenteric injury. The lack of a control group and lack of surgical confirmation of bowel injury in 44% of patients were recognized weaknesses of the study. The authors noted that many of these patients had evidence of bowel wall contusions that resolved on follow-up CT. Janzen et al[14] retrospectively examined 19 patients with surgically proven bowel or mesenteric injuries and compared them with 12 patients with no bowel or mesenteric injuries at surgery and calculated a sensitivity of 83% and specificity of 84% for CT in surgically proven bowel or mesenteric injuries. The positive predictive value was 77%, and the negative predictive value was 89%, although the control group size was relatively small. In a large, retrospective, case-controlled study of hollow viscus injury associated with blunt abdominal trauma, Fakhry et al[15] found that CT was fair at identifying hollow viscus injury and even worse at identifying perforated hollow viscus injury. Although 84.2% of patients with free fluid and no solid organ injury had small bowel injury, only 30.5% of these patients suffered small bowel perforation. Hollow viscus injury was present in 91.5% of patients with pneumoperitoneum. Other radiologic findings on CT (eg, bowel wall thickening, stranding, contrast extravasation, retroperitoneal blood) were less effective in identifying hollow viscus injury.

The meaningful study of pancreatic and diaphragmatic injuries is difficult because these injuries occur in small numbers. Akhrass et al[6] examined 72 patients with pancreatic injuries, only 10 of whom had CT scans for blunt mechanisms. Of these 10, only 3 had initially positive results on CT scan for pancreatic injuries (sensitivity 30%). Murray et al[7] identified 11 patients with diaphragmatic rupture proven at surgery and reviewed their CT scans retrospectively using 3 radiologists. The investigators chose a control group of 21 patients who also had surgery but did not have injured diaphragms. The authors reported a sensitivity of 61% (95% confidence interval [CI] 41% to 81%) and a specificity of

87% (95% CI 76% to 99%) for the CT diagnosis of diaphragmatic rupture. Similar studies with smaller numbers yielded conflicting results.

Patient Evaluation Recommendations: What is the diagnostic performance of CT in diagnosing significant intra-abdominal injuries requiring intervention in blunt abdominal trauma?

Level A recommendations. None specified.

Level B recommendations. When either liver or spleen injury is suspected, CT can reliably exclude injuries that require emergent operative intervention. CT alone cannot be used to exclude either bowel, diaphragm, or pancreas injury.

Abdominal CT accurately identifies hemoperitoneum among patients with blunt abdominal trauma.

Level C recommendations. None specified.

II. Does oral contrast improve the diagnostic performance of CT in blunt abdominal trauma?

Background: Trauma centers frequently administer oral contrast before each CT scan. Patients either drink contrast or have it administered through nasogastric tubes. Authors report contrast volumes in the range of 450 to 1,000 mL. Multiple authors have written that oral contrast improves the diagnostic accuracy of abdominal CT by identifying extravasation of bowel contents, delineating mesentery, and setting opacified bowel apart from hematomas and pancreatic injuries.[16] Some authors have become concerned, however, about the possible risks of oral contrast administration: vomiting, aspiration, and delayed diagnosis related to bowel transit time of the contrast.[17]

Findings: Few studies examine the utility of using oral contrast during abdominal CT when evaluating blunt abdominal trauma. Stafford et al[9] performed the only prospective randomized study of this technique currently in the literature. The authors randomized 394 injured patients to receive either oral contrast through a nasogastric tube or no contrast before CT evaluation of the abdomen. When analyzing only small bowel injuries, the authors reported a sensitivity of 86% (6 out of 7 injuries discovered) for CT with oral contrast and a sensitivity of 100% (3 out of 3 injuries discovered) for CT without oral contrast. The authors reported that for solid organ injuries, the oral contrast and no contrast groups demonstrated sensitivities of 84.2% and 88.9%, respectively, and specificities of 94% and 57.1%, respectively. The average time from nasogastric tube placement to CT scan was 39±18 minutes for the no contrast group and 46±24 minutes for the contrast group. These time intervals suggested that contrast was not allowed to transit for an optimal amount of time before scanning, although the authors did not assess the adequacy of contrast administration. The authors concluded that oral contrast did not provide additional benefit in CT scanning of the abdomen after blunt abdominal trauma. However, the authors also admitted that the small numbers of bowel injuries in their study suggested the need for additional studies with larger sample sizes.

Fakhry et al[15] performed a retrospective, case-control study of 275,557 trauma center admissions from 95 participating institutions. This study included 408 patients with perforated small bowel injuries identified at laparotomy who also received abdominal CT with oral contrast; 2.9% exhibited extravasation of oral contrast. Tsang et al[17] performed a retrospective review of contrast CT scans between 1988 and 1993 to determine whether oral contrast was essential to these scans in the opinion of a radiologist blinded to the clinical outcomes. Thirty-one liver and spleen injury cases were chosen randomly for review, and contrast was not judged to be essential in any of these cases. Contrast was not helpful among 20 randomly chosen patients who had no injuries. Contrast was not essential to the diagnosis of 22 intestinal injuries, but was essential in the diagnosis of 2 of 6 pancreatic injuries. Among the 22 intestinal injuries, the initial CT scan diagnosed only 1. The authors pointed out that multiple intestinal injuries were diagnosed in their institution by laparotomy without CT scan. The authors concluded that contrast was not helpful in the diagnosis of most solid organ injuries and did not improve sensitivity for intestinal injuries, but may help improve the sensitivity of CT for pancreatic injuries. The authors also acknowledged the significant weaknesses of their study. The study was retrospective, relied on subjective reviews of CT for contrast utility, and contained few intestinal and pancreatic injuries.

Clancy et al[18] reviewed 492 patients who underwent CT scan over a period of 4 years, only 8 of whom received oral contrast. They reported an overall sensitivity of 98.4% and a specificity of 99.8% for intra-abdominal injuries. The 1 missed injury in this series was cecal ischemia with intestinal perforation. The 2 false positive CT scans were a suspected bowel injury and a suspected splenic rupture. The authors concluded that contrast was not necessary, but may prove helpful on follow-up CT scans for patients with findings suggestive of bowel injury on the first CT.

Federle et al[19] retrospectively reviewed the records of 510 patients who received contrast and found that no patients had evidence of aspiration pneumonitis. The authors concluded that oral contrast was safe for this population.

Patient Evaluation Recommendations: Does oral contrast improve the diagnostic performance of CT in blunt abdominal trauma?

Level A recommendations. None specified.

Level B recommendations. Oral contrast is not essential to the evaluation of blunt abdominal trauma.

Level C recommendations. None specified.

III. What is the diagnostic performance of FAST in diagnosing hemoperitoneum in blunt abdominal trauma?

Background: Rapidly identifying hemoperitoneum among unstable blunt trauma victims is a linchpin of early intervention and effective management. Emergency physicians and surgeons have used diagnostic peritoneal lavage in this role, but diagnostic peritoneal lavage is invasive and associated with procedural complications.[8,20] Many trauma centers now use abdominal ultrasonography instead of diagnostic peritoneal lavage for the rapid identification of hemoperitoneum.

FAST is an ultrasonographic technique used to visualize, at a minimum, Morrison's pouch (ie, the right upper quadrant), the splenorenal recess (ie, the left upper quadrant), and the pouch of Douglas in the pelvis. The presence of intra-peritoneal fluid (ie, blood) in the setting of blunt abdominal trauma facilitates decisions regarding laparotomy and further diagnostic studies.

Findings: The performance of FAST in identifying hemoperitoneum in blunt abdominal trauma victims is summarized in the Table.

FAST detects intra-peritoneal fluid with 68% to 91% sensitivity and excellent specificity.[22] In a prospective study of 1,540 blunt abdominal trauma victims, FAST was 100% sensitive and 100% specific in identifying hemoperitoneum among hypotensive patients.[22]

Tso et al[10] calculated a sensitivity of 69% for FAST in identifying all intra-abdominal injuries (combined), including solid organ injuries, viscus trauma, and hemoperitoneum. Similarly, Richards et al[25] found that, among 30 patients with false negative FAST examinations, 16 had either bowel or mesenteric injuries.

Patient Evaluation Recommendations: What is the diagnostic performance of FAST in diagnosing hemoperitoneum in blunt abdominal trauma?

Level A recommendations. None specified.

Level B recommendations. FAST is useful as an initial screening examination to detect hemoperitoneum in blunt abdominal trauma patients.

Level C recommendations. None specified.

IV. What is the diagnostic performance of diagnostic peritoneal lavage in diagnosing significant intra-abdominal injuries requiring intervention in blunt abdominal trauma?

Background: Clinical examination alone does not identify all intra-abdominal injuries, especially in blunt trauma patients with multiple injuries.[26] Diagnostic peritoneal lavage was introduced in 1965 as a rapid method to identify hemoperitoneum.[3] Multiple studies documented that diagnostic peritoneal lavage is a sensitive test for intra-peritoneal blood.[20,27-29] Since 1965, diagnostic peritoneal lavage decreased the number of trauma deaths and nontherapeutic laparotomies in severely injured patients.[30]

Diagnostic peritoneal lavage is performed using either an open or closed (ie, percutaneous over a guide wire) technique. Sensitivity, specificity, and complica-

Table.
The performance of FAST in identifying hemoperitoneum in blunt abdominal trauma victims.

Study	Study Class	Study Size	No. of Patients With Hemoperitoneum	Sensitivity, %	Specificity, %	Positive Likelihood Ratio	Negative Likelihood Ratio
Ma et al [21]	I	245 patients	64	90	99	90	0.1
Rozycki et al[22]	II	1,227 patients	96	83.3	99.7	278	0.17
Shackford et al[23]	I	241 patients	51	68	98	34	0.33
Smith et al[24]	III	841 patients	45	73	98	36.5	0.28
Tso et al[10]	II	163 patients	11	91			

tion rates of the 2 techniques are similar.[31-34] The closed technique, however, is completed more quickly.[31-33]

Results of diagnostic peritoneal lavage are positive for hemoperitoneum in blunt abdominal trauma in the presence of the following: (1) the aspiration of 5 to 10 mL of frank blood, (2) an RBC count of 100,000/mL in the effluent after lavaging the abdomen with 1 L of isotonic fluid, or (3) a WBC count greater than 500/mL in the effluent.[35] Lavage fluid Gram's stain and biochemical markers such as alkaline phosphatase and amylase are nonspecific and insensitive for intra-abdominal injury.[29,36,37]

Findings: The sensitivity of diagnostic peritoneal lavage for hemoperitoneum approaches 98%.[8,20,28,38,39] A mean sensitivity of 95% for diagnostic peritoneal lavage was determined in a review of 58 studies in a decision analysis of optimal modalities evaluating blunt trauma in hemodynamically stable adults.[40] Diagnostic peritoneal lavage can detect as little as 20 mL of intraperitoneal blood.[35]

Diagnostic peritoneal lavage has practical limitations in identifying retroperitoneal, diaphragmatic, and enteric injuries because intra-abdominal bleeding usually is limited.[30,41] For example, in 1 study where diagnostic peritoneal lavage was performed early after blunt abdominal trauma, the authors found that lavage was falsely negative in 18% of patients with bowel injuries.[42]

Several prospective studies compared diagnostic peritoneal lavage to ultrasonography and abdominal CT in blunt abdominal trauma. Diagnostic peritoneal lavage was at least as sensitive (ie, 83% to 100%) as CT and ultrasonography in detecting hemoperitoneum.[8,27,39,43]

Although diagnostic peritoneal lavage efficiently identifies hemoperitoneum resulting from intra-abdominal injuries, many injuries are self-limited and do not require laparotomy. The false-positive rate for diagnostic peritoneal lavage is between 13% and 54%.[28,38,39,43-45] Nontherapeutic laparotomies can have significant complications; 1 prospective study had a complication rate of up to 20%.[46] Excluding nontherapeutic laparotomies, the major complication rate for diagnostic peritoneal lavage is 1% to 2%.[8,20]

Mele et al[47] used diagnostic peritoneal lavage as a screening test. These authors followed each diagnostic peritoneal lavage with a positive result with an abdominal CT to identify those patients requiring laparotomies for surgical repair. The authors experienced no nontherapeutic laparotomies, no missed injuries, and an overall decreased utilization of CT in this small series. Besides having a small sample size, this study was not randomized and suffered from selection bias.

Patient Evaluation Recommendations: What is the diagnostic performance of diagnostic peritoneal lavage in diagnosing significant intra-abdominal injuries requiring intervention in blunt abdominal trauma?

Level A recommendations. None specified.

Level B recommendations. Diagnostic peritoneal lavage can be used to exclude hemoperitoneum in blunt abdominal trauma patients. Diagnostic peritoneal lavage does not define the extent of injury, has a 1% to 2% complication rate, and may lead to nontherapeutic laparotomies.

Level C recommendations. On the basis of consensus and current practice patterns, the initial choices for the evaluation of blunt abdominal trauma are CT and FAST, depending on the patient's hemodynamic stability.

This clinical policy was developed by the ACEP Clinical Policies Committee and the Clinical Policies Subcommittee on Acute Blunt Abdominal Trauma.

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Evidentiary Table.

Study	Design	Findings	Limitations	Grade
Livingston et al[2]	Prospective cohort	A total of 2,299 trauma patients prospectively enrolled into a protocol of initial physical examination, abdominal CT with oral contrast, and admission for observation; 19% of patients without abdominal tenderness had intra-abdominal injuries	Excluded patients with head injuries, GCS score <14, focal neurologic deficit, open or basilar skull fracture, seen >12 h after injury, bleeding diathesis, severe heart disease, and cirrhosis	II
Sherck et al[5]	Retrospective review of 883 consecutive stable patients who had CT after blunt abdominal trauma	Purpose is to evaluate the accuracy of CT for small bowel injuries; total of 26 small bowel perforations; CT is 92% sensitive and 94% specific for small bowel perforation; negative predictive value is 100%; positive predictive value is 30%	Small number of bowel perforations	III
Akhrass et al[6]	Case series of patients with pancreatic injury	10 of the blunt trauma patients had surgery and CT, allowing comparison of CT and operative findings; CT was accurate in 2 of the cases, undergraded 1 injury, and missed 7 injuries	Very small case series	III
Murray et al[7]	Retrospective review	Review of presurgery CT scans of 11 patients with diaphragm rupture and 21 patients with intact diaphragms by 3 blinded radiologists; 61% sensitivity, 87% specificity of CT for acute diaphragmatic rupture after blunt trauma	Very specific—looked at diaphragm injuries only; blinded radiologists were aware they were looking at the diaphragm	III
Liu et al[8]	Prospective comparative study of the accuracy of CT, ultrasonography, and DPL in the evaluation of blunt abdominal trauma	Sensitivity of CT 97%, specificity 95%	Small sample size; study could not be replicated	II
Stafford et al[9]	Prospective randomized trial	Patients requiring CT of the abdomen received oral contrast or no oral contrast; 394 patients in study received nasogastric tube with oral contrast or no oral contrast; no significant difference in sensitivity for small bowel injury with oral contrast, 9 total bowel injuries, only 1 missed (with oral contrast); sensitivity for solid organ injury 84% with oral contrast, 89% without; specificity 94% with oral contrast, 57% without	Small sample size for bowel injuries; average time from placement of nasogastric tube to CT was 39 minutes without oral contrast, 46 minutes with oral contrast, perhaps limiting ability of contrast to transit bowel	II
Tso et al[10]	Prospective criterion standard study	Sensitivity 91% for hemoperitoneum, 69% in overall diagnostic accuracy, including visceral injuries; specificity 99% overall	This study was performed at the Maryland Institute for Emergency Medical Services Systems (MIEMSS); DPL and CT used as criterion standards; ultrasonography was done at the trauma attending physicians' discretion	II
Butela et al[12]	Retrospective case-control study	CT scans of 50 patients with proven bowel injury, 62 patients with no bowel injury; prospective CT sensitivity for bowel injury is 64%, specificity is 97%; in retrospective review, CT showed good to excellent interobserver reliability	Blinded radiologists aware they were studying bowel injuries	III
Killeen et al[13]	Retrospective review	150 patients during a 4-y period with either CT or surgical diagnosis of blunt abdominal trauma, or bowel or mesenteric injuries; CT had a sensitivity of 94% in detecting bowel injury and 96% in detecting mesenteric injury	No surgical confirmation of findings in 44% of patients; no control group	III
Janzen et al[14]	Retrospective review	Review of helical CT and surgery findings in 31 patients, 19 with surgically proven bowel or mesenteric injuries, 12 without; consensus CT readings of 3 radiologists compared with surgical findings; CT is 83% sensitive and 84% specific for surgically proven bowel or mesenteric injuries; positive predictive value is 77%; negative predictive value is 89%	Small sample size; 19 total surgically proven bowel or mesenteric injuries; agreement between observers not measured	III

Evidentiary Table (continued).

Study	Design	Findings	Limitations	Grade
Fakhry et al[15]	Retrospective case control	275,557 trauma center admissions; 2,249 patients with small bowel injuries; oral contrast extravasation during CT occurred in 2.9% of 408 patients with perforated small bowel injuries; 13% of patients with documented perforating small bowel injuries had normal abdominal CT scans	Retrospective study	II
Novelline et al[16]	Review	A comprehensive review of the use of helical CT in abdominal trauma, parsed by type of organ injury	None	III
Tsang et al[17]	Retrospective review of CT scans with oral contrast for abdominal trauma	Authors included scans of patients with liver and spleen injuries (n=31), pancreas injuries (n=22), and no injury (n=20); blinded radiologists reviewed CT scans for evidence of injury and whether the diagnosis could have been made without oral contrast; all liver and spleen injuries were correctly diagnosed by CT; only 1 of the intestinal injuries was diagnosed by CT; 3 of 6 pancreas injuries were diagnosed by CT; all of the no-injury cases were thought to have been accurate readings; oral contrast thought to be essential to only 2 of the pancreas injury cases and none of the others	Data using CT scans from 1988-1993; no noncontrast scans were available	III
Clancy et al[18]	Retrospective review	Review of 492 patients undergoing CT scan, of whom 8 received oral contrast; outcome measure is diagnostic error in nonoral contrast scans; 98% sensitivity, 99% specificity for intra-abdominal injury; 5 bowel injuries in study	Small sample size for bowel injuries	II
Federle et al[19]	Retrospective review	Review of 510 consecutive patients who received oral contrast after blunt abdominal trauma; outcome variable was evidence of aspiration pneumonitis; no patients had aspiration attributable to the oral contrast	Retrospective chart review for outcomes related to a diagnosis that may not be specifically documented	II
Nagy et al[20]	Retrospective observational	2,501 DPLs done, with 41% due to blunt trauma; sensitivity of open technique 90%, closed technique 95%; >2,400 done with closed technique; 21 complications total (0.8%); no difference between open and closed; specificities open 100%, closed 99.8%; DPL remains an accurate test for intra-abdominal bleeding	Not randomized; do not differentiate between positive results for laparotomy and a nontherapeutic laparotomy; use 200 mL effluent as adequate; exclusions not accounted for	III
Ma et al[21]	Prospective criterion standard study	Sensitivity of FAST for hemoperitoneum 90%, specificity 99%	10 h of instruction for emergency physicians; good "gold standard"; examinations performed by emergency medicine faculty and residents	I
Rozycki et al[22]	Prospective criterion standard study	Reported sensitivity of 83% and specificity of 99.7% for FAST in identifying hemoperitoneum; sensitivity and specificity were 100% for hypotensive patients	Excluded patients in extremis with an unobtainable blood pressure and indications for immediate laparotomy	II
Shackford et al[23]	Prospective criterion standard study	241 patients; FAST sensitivity 68%, specificity 98% for identifying hemoperitoneum; initial error rate decreased from 17% to 5% after 10 examinations	No major flaws; criterion standards were DPL, CT, and laparotomy	I
Smith et al[24]	Retrospective observational	Senior-level surgical residents were able to perform FAST with limited training; there was no significant learning curve, and diagnostic accuracy was not different than what would be expected on the basis of the literature	Studied program year 4 and 5 surgery residents with 8 to 11.5 h of training; no mention of criterion standard	III
Richards et al[25]	Prospective criterion standard study	Sensitivity of FAST for bowel and mesenteric injury was 58%	1,686 patients received FAST; criterion standard: CT, DPL, laparotomy	II

Evidentiary Table (continued).

Study	Design	Findings	Limitations	Grade
Schurink et al[26]	Retrospective observational; consecutive trauma patients with possible blunt abdominal trauma	Utility of reliable physical examination in detecting intra-abdominal injury compared among 4 groups; isolated abdominal injury, lower rib fractures, multiple trauma, and isolated head injury; isolated abdominal injury: sensitivity 95%, specificity 71%; multiple injury: sensitivity 57%, specificity 92% but about one half had unreliable abdominal examination; isolated head injury patients had a reliable examination in 16%; 3 of 4 intestinal perforations not detected by imaging modalities but had abnormal abdominal PE	No criterion standard examination; not blinded; small sample size in each group	III
Blow et al[27]	Retrospective cohort	Compared a liberalized policy for doing DPL with a prior group in which CT was the primary diagnostic modality for blunt trauma patients; time in ED was decreased considerably in the DPL group, with no missed injuries and the same number of nontherapeutic laparotomies as in the CT group; costs were considerably less in the DPL group	No randomization; few CT images from before 1994; small numbers; selection bias	III
Henneman et al[28]	Retrospective observational	608 patients with blunt trauma; DPL 87% sensitive; 122 laparotomies done, 19 nontherapeutic; of 12 false negative DPLs, 3 had bowel injuries	Lavage amylase did not add any information above that provided by cell counts	III
Day et al[29]	Retrospective observational	200 patients had DPL on the basis of established indications; 47 had positive DPL; 83% sensitive for positive laparotomy	No criterion standard; decision to operate based on unknown criteria, not necessarily positive results of DPL; small series; 2 patients with positive results of DPL not operated on	III
Hughes[30]	Review article	Most accurate method of identifying intestinal injuries in unstable patient is immediate laparotomy and DPL; stable patients benefit best from CT	Good review of methods used in detecting intestinal injuries from blunt trauma; 116 references	III
Velmahos et al[31]	Prospective series; retrospective review	55 DPL closed technique; 75 DPL open technique; equal accuracy; closed technique faster 7 minutes versus 11 minutes; 10 technical failures: 8 in open group; 27% nontherapeutic laparotomies	Not randomized; technique left to physician; DPL done by residents	III
Hodgson et al[32]	Analysis of randomized controlled trials comparing closed and open technique for DPL	7 trials identified with a total of 1,126 patients; no difference in major complications between closed or open technique; technical failures higher in closed group; accuracy of closed and open were comparable; procedure time consistently lower in the closed technique	Overall quality of studies reviewed was thought to be poor	II
Troop et al[33]	Randomized prospective series	220 patients; 1 trauma team used closed technique, 1 used open then switched for the second month of the study; no difference in complication rate noted; significant difference in time to catheter insertion; 3.6 versus 6.9 minutes; material costs in favor of closed lavage by 23%; lavage effluent time also equal between groups	Patients with previous abdominal surgery excluded; DPL indications not specified; training in procedure not specified	II
Moore et al[34]	Retrospective observational	372 DPLs with closed techniques completed, 40 of which were in patients with previous abdominal surgery; no difference in percentage with positive DPL results, misclassification rate, or complication rate; accuracy of closed DPL in patients with previous abdominal surgery is similar to those without previous abdominal surgery	57 patients excluded from the data analysis suggests possible selection bias; previous abdominal surgery may not have been accurately documented, thereby changing the patient's group; multiple operators doing DPL	III
Otomo et al[35]	Prospective series	Validation of new criteria for positive DPL results in intestinal injury; the authors used the standard quantitative WBC criterion for detection of intestinal injury supplemented by a positive-negative borderline adjusted to WBC ≥RBC/150, where RBC $\geq 10\times10^4/mm^3$; 250 patients had DPL done; new WBC criteria 82% sensitive, 99% specific for detecting intestinal injury; 6 of 7 false negative DPL done within 3 h of injury and became positive on subsequent DPL	Delay in doing DPL needed to increase accuracy of new criteria; nontherapeutic laparotomies were not differentiated; diagnostic modality left to individual surgeon; some patients required repeated DPLs to make diagnosis	II

Evidentiary Table (continued).

Study	Design	Findings	Limitations	Grade
Fang et al[36]	Retrospective observational	212 patients with positive DPL results by classic criteria; cell count ratio; WBC/RBC in lavage fluid divided by ratio in peripheral blood; if ratio is >1.0, it is 97% sensitive for hollow viscus injury and 100% specific; other parameters: Gram stain, amylase, alkaline phosphatase, are approximately 35% sensitive for hollow viscus injury and <3% sensitive for nonhollow viscus perforation	Laparotomy is not done in all cases with positive DPL results by classic criteria; >65% of DPLs done >3 h after injury; exclusion criteria not mentioned; patients with negative DPL results excluded from study and further data collection	III
Allen et al[37]	Retrospective observational	35 patients with duodenal injury from blunt trauma; in 20%, diagnosis delayed >6 h and subsequent increased complication rate; 80% diagnosed <6 h; lavage fluid WBC or enteric contents not helpful for diagnosis in either group	Reasons for diagnostic delay not clear; small numbers in each group; no consistent protocol for diagnosis; not randomized; variety of physicians doing examinations over a 10-y period	III
Fryer et al[38]	Retrospective observational	200 DPLs completed over 5-y period before extensive CT utilization; 117 of 125 DPLs with positive results had laparotomies completed; approximately 35% nontherapeutic laparotomy rate just on the basis of positive DPL results	8 laparotomies not completed; residents primarily responsible for tests; classic criteria for positive results of DPL usually not used; visual analysis of effluent used to determine positive results of DPL	III
Bain et al[39]	Retrospective observational; trauma admissions receiving DPL or abdominal ultrasonography over a 3-y period reviewed	52 patients had DPL done; sensitivity 83%, specificity 97%, and 36% nontherapeutic laparotomies based on DPL results; ultrasonography in 220 patients; 83% sensitivity, 99% specificity, and 13% nontherapeutic laparotomies resulting from abdominal ultrasonographic examination; repeat scanning increased ultrasonographic sensitivity to 89%; abdominal ultrasonography is first-line investigation rather than DPL	Not controlled or randomized; patient allocation unequal; intervention left to individual trauma chiefs; positive DPL results determined by visual means	III
Brown et al[40]	Decision analysis model based on hypothetical patient with blunt abdominal trauma	Review of the existing literature reveals a mean sensitivity for DPL of 95%, CT 72%, ultrasonography 89%; expected utility of each modality was calculated in hypothetical case; ultrasonography was generally the best test with best utility; institutional experience and prevalence of injury will alter utility of each modality	Review; many assumptions used to produce model; preference survey may have introduced bias	III
Neugebauer et al[41]	Retrospective observational	70 patients with small intestinal hollow viscus injuries; diagnosis by ultrasonography in 30; sensitivity 100%, specificity 75%; 5 of 70 patients had clinically unremarkable PE; 6 patients underwent DPL, all results were positive and all were hemodynamically unstable; 14% had elevated serum or urine amylase; timeliness of diagnosis depended on general condition of patient; stable patients had delay in diagnosis; free air on radiographs unusual	Small number of patients; multiple modalities used to diagnose hollow viscus; many different physicians involved; study was of lengthy duration	III
Kemmeter et al[42]	Retrospective observational; 6-y review of all trauma patients	709 patients with documented blunt abdominal trauma; 69 patients with enteric injuries identified; 10% of those required operative repair and constituted study group; 18% of injuries missed with initial DPL; 38% missed by initial CT scan; delayed DPL identified 4 patients missed by CT	Retrospective chart review; no protocol for deciding initial diagnostic modality	III
Meredith et al[43]	Retrospective observational	116 patients with unreliable abdominal examinations; CT done and decision about laparotomy recorded; DPL then completed and final decision for laparotomy made; 54% of cases with positive DPL results did not require therapeutic laparotomy	No defined inclusion criteria; recommendation for surgery at discretion of trauma surgeon; laparotomy not done in many patients; complications of DPL not listed	III
Drost et al[44]	Case series	Case series of 85 consecutive patients with positive DPL results who also underwent celiotomy; 37% of blunt trauma patients had nontherapeutic laparotomy	Not randomized or blinded; decision for DPL based on the surgeon's experience, no criteria mentioned; criteria determining nontherapeutic laparotomy not specified	III
Sozuer et al[45]	Retrospective observational	2,010 DPLs completed over 18-y period; 719 (35.8%) had positive DPL results; 1.5% complication rate; all patients with positive DPL results had laparotomies; DPL 96% sensitive, 87% specific; 24% nontherapeutic (or negative) laparotomy rate	Not randomized; training of those performing procedures not mentioned; those with typical results not included	II

Evidentiary Table (continued).

Study	Design	Findings	Limitations	Grade
Renz and Feliciano[46]	Prospective cohort	254 patients with negative or nontherapeutic laparotomy were followed up; 41% complication rate of nontherapeutic laparotomies in patients with associated injury; 20% complication rate in those without associated injuries; unnecessary laparotomies for trauma result in a significant morbidity; mortality (0.8%) thought to be unrelated to any unnecessary laparotomies	Surgeon's choice when to do laparotomy; length of and extent of follow-up not specified; no randomization	II
Mele et al[47]	Prospective cohort; hemodynamically stable patients	167 patients; screening DPL then CT (n=71) or CT alone (n=96); positive results of DPL in 20 patients (28%); 10 patients underwent laparotomy, 10 further evaluated by CT; 3 had laparotomies; CT identified those with positive DPL results needing laparotomy; CT after a screening positive DPL result is an efficient method to reduce nontherapeutic laparotomies and missed injuries, and to decrease CT utilization	Small numbers; no criteria mentioned for which patients went to surgery after CT; DPL can screen those patients needing CT to define injury, whereas CT alone missed 7% of injuries; no nontherapeutic laparotomies reported; possible selection bias because surgeon on call determined diagnostic modality	III

GCS, Glasgow Coma Scale; **DPL,** diagnostic peritoneal lavage; **PE,** pulmonary embolism; **ED,** emergency department.

APPENDIX A.

Literature classification schema.[*]

Design/Class	Therapy[†]	Diagnosis[‡]	Prognosis[§]
1	Randomized, controlled trial or meta-analyses of randomized trials	Prospective cohort using a criterion standard	Population prospective cohort
2	Nonrandomized trial	Retrospective observational	Retrospective cohort Case control
3	Case series Case report Other (eg, consensus, review)	Case series Case report Other (eg, consensus, review)	Case series Case report Other (eg, consensus, review)

[*]Some designs (eg, surveys) will not fit this schema and should be assessed individually.
[†]Objective is to measure therapeutic efficacy comparing ≥2 interventions.
[‡]Objective is to determine the sensitivity and specificity of diagnostic tests.
[§]Objective is to predict outcome including mortality and morbidity.

APPENDIX B.

Approach to downgrading strength of evidence.

	Design/Class		
Downgrading	1	2	3
None	I	II	III
1 level	II	III	X
2 levels	III	X	X
Fatally flawed	X	X	X