

Abdominal Seat Belt Marks in the Era of Focused Abdominal Sonography for Trauma

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Hypothesis: Focused abdominal sonography for trauma (FAST) is an unreliable method for assessing intra-abdominal injury in patients with seat belt marks.

Design: Retrospective review of trauma patients with intestinal injury and seat belt marks during a 3-year period. Records were reviewed for patient demographics, FAST results, computed tomographic (CT) scan results, and operative findings. The CT scan results were considered positive if bowel wall thickening, extraluminal air, or free fluid without solid organ injury were present.

Setting: University hospital designated as a level I trauma center.

Patients: Twenty-three patients who required operation for intestinal or mesenteric injury and who had an abdominal seat belt mark.

Main Outcome Measure: Sensitivity of FAST in these patients.

Results: All patients were evaluated using both FAST and CT scan of the abdomen and pelvis. Eighteen patients (78%) had either negative or equivocal FAST results when significant intestinal injury was present. All 23 patients had CT scan findings suggestive of bowel or mesenteric injury. Moderate-to-large free intraperitoneal fluid without solid organ injury was the most common finding (n=21, 91%). Operative findings included small-bowel perforation (n=18, 78%), colonic perforation (n=7, 30%), bowel deserosalization (n=8, 35%), and isolated mesenteric injury (n=5, 22%). Sixteen patients (70%) had multiple intra-abdominal injuries. All patients were taken directly from the emergency department to the operating room. Seventeen percent of operative explorations (4/23) were non-therapeutic (no repairs required).

Conclusion: This study confirms that FAST cannot reliably exclude intestinal injury in patients with seat belt marks.

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PROPERLY WORN seat restraints have effectively reduced motor vehicle crash fatalities and injury severity.¹ Before the widespread use of seat belts, most crash fatalities were secondary to severe head injury.² Unfortunately, seat belts themselves are associated with certain injury patterns. The classically described *seat belt syndrome* results from a lap belt restraint and consists of visceral organ and musculoskeletal injuries, including mesenteric injury, bowel injury, lumbar spine fractures, and abdominal wall ecchymosis. The mechanism of injury is thought to be compression of the abdominal wall and viscera between the seat belt and the spine, leading to a sudden increase in intraluminal pressure and shearing and deceleration forces against the mesentery and peritoneal attachments.

Hollow viscous injury is seen in approximately 1% of all blunt trauma pa-

tients. When patients have a seat belt mark, hollow viscous injury incidence increases to 10%.³ Although the incidence of bowel injury is low, there is significant morbidity and mortality associated with a delay in diagnosis.⁴ The diagnosis of bowel and mesenteric injuries has been notoriously difficult to establish rapidly in blunt trauma patients because their presentation is often occult.⁵ There are several options for the initial abdominal evaluation, including physical examination, immediate operation, diagnostic peritoneal lavage (DPL), focused abdominal sonography for trauma (FAST), and computed tomography (CT) of the abdomen and pelvis. A recent survey of American Association for the Surgery of Trauma members revealed wide variation in the diagnostic evaluations performed to identify blunt small-bowel injury.⁶

In many trauma centers, FAST is becoming the primary diagnostic test for patients with blunt abdominal trauma. FAST

PATIENTS AND METHODS

All hemodynamically stable patients admitted to the University of Louisville Hospitals, Louisville, Ky, who sustained a bowel or mesenteric injury secondary to a car crash from June 1998 to June 2001 were identified using the University of Louisville Trauma Registry. The University of Louisville Hospitals is a designated level I trauma center that serves the western part of the commonwealth of Kentucky and Southern Indiana. Patients without seat belt marks and those who met criteria for immediate operative exploration (peritonitis, hemodynamic instability) were excluded. Medical records were reviewed for patient demographics, FAST results, CT scan results, complications, and operative findings.

Trained surgical staff used a Siemens Prima ultrasound machine (Siemens Medical Systems, Inc, Issaquah, Wash) with a 3.5-MHz convex transducer to perform FAST during the secondary survey. Five areas consisting of a transthoracic view of the pericardium, a subxiphoid view of the pericardium, a hepatorenal window, a splenorenal window, and suprapubic window were examined. The FAST result was considered positive if fluid was found in any window. If the windows were not able to be clearly visualized, the FAST result was considered equivocal.

A dynamic abdomen and pelvis CT scan with 10-mm cuts was performed using a high-speed scanner (General Electric CTI; General Electric Medical Systems, Milwaukee, Wis) following administration of 500 mL of oral contrast (Gastroview; Mallinckrodt Chemicals, St Louis, Mo) and 100 mL of intravenous contrast (Conray; Mallinckrodt Chemicals) with a 60-second scanning delay. The CT scan results were considered positive if bowel wall thickening, extraluminal air, or free fluid without solid organ injury was present. Radiology and surgical attending staff reviewed the CT scans. The amount of free fluid present was graded as trace (1-3 CT scan cuts with fluid), moderate (4-5 CT segments with fluid or 2 separate areas of trace fluid), or large (more than 5 CT segments with fluid or a combination of trace and moderate fluid) based on the grading scale previously described by Brasel et al.⁹ Their CT scan protocol also used 10-mm cuts with both intravenous and oral contrast.

relies on the detection of free intraperitoneal fluid to identify patients with potential intra-abdominal injury. It must be remembered, however, that 29% to 44% of patients with intra-abdominal injuries can present without serious hemoperitoneum.^{7,8} In particular, the sensitivity of FAST in detecting hollow viscous injuries is poor, with only 40% to 50% of such injuries identified.⁸ In our trauma center, blunt trauma patients are evaluated with FAST during their secondary survey. If the FAST examination result is negative and there is not a suspicion of hollow viscous injury, no further abdominal diagnostic workup is performed. With a positive FAST examination result in a stable patient, CT is performed to evaluate the potential source for the intraperitoneal fluid. If a hollow vis-

cous injury is suspected because a seat belt mark is present, CT is performed regardless of the FAST result.

The utility of CT in identifying bowel and mesenteric injuries is mixed because CT findings associated with bowel and mesenteric injuries are nonspecific and subtle. Free fluid without solid organ injury, bowel wall thickening, and mesenteric streaking are considered to be CT findings suspicious for bowel or mesenteric injury, whereas extravasation of oral contrast and free intraperitoneal air are considered diagnostic findings.⁹ Misinterpretation of a true-positive CT scan result is more common than truly false-negative scans as seen in a study by Chandler et al¹⁰ in which two thirds of supposedly negative CT scan results had been incorrectly interpreted. A recent comprehensive study by Killeen et al¹¹ showed the negative predictive value of CT to be 96%. The purpose of this study was to evaluate whether FAST is an accurate noninvasive screening test for bowel or mesenteric injury in patients with abdominal seat belt marks.

RESULTS

Twenty-three patients, ranging in age from 14 to 57 years (average, 32 years), with a seat belt mark and associated intestinal or mesenteric injury were identified. All patients were evaluated using both FAST and CT scan findings of the abdomen and pelvis. Twenty patients (87%) had mild-to-moderate abdominal tenderness. No patients had peritonitis.

Eighteen patients (78%) had either negative or equivocal FAST results when significant intestinal injury was present (**Table**). All 23 patients had CT scan findings suggestive of bowel or mesenteric injury (**Figure 1**). Moderate-to-large free intraperitoneal fluid without solid organ injury was the most common CT finding (n=21, 91%). Four patients (18%) had a combination of findings. One patient had free air. No patient had oral contrast extravasation.

Operative findings included small-bowel perforation (n=18, 78%), colonic perforation (n=7, 30%), bowel deserosalization (n=8, 35%), and isolated mesenteric injury (n=5, 22%) (Figure 1). Most patients (n=16, 70%) had multiple intra-abdominal injuries. All patients were taken directly from the emergency department to the operating room. Four (17%) of 23 operative explorations were nontherapeutic (no repairs required). Of the 4 patients with nontherapeutic explorations, 1 (25%) had positive FAST results. Three patients had lumbar spine fractures. Average length of stay was 13 days (range, 5-73 days). Longer lengths of stay were associated with spine fracture patients. There were no deaths.

COMMENT

Patients with abdominal seat belt marks have an increased incidence of bowel and mesenteric injury when compared with patients without seat belt marks.¹² There are multiple choices for initial abdominal evaluation, including physical examination, DPL, FAST, and helical CT scan of the abdomen and pelvis.

Relying solely on physical examination is problematic, because the initial presentation of bowel injury can

Patient Findings*

Patient No.	FAST Result	CT Findings	Operative Findings
1	Negative	Trace-free fluid without solid organ injury, free air	Multiple duodenal lacerations, transverse colon laceration
2	Negative	Moderate free fluid without solid organ injury	Jejunal perforation
3	Negative	Large free fluid without solid organ injury	Terminal ileal mesenteric rent, jejunal perforation
4	Negative	Moderate free fluid without solid organ injury	Jejunal perforation
5	Negative	Moderate free fluid without solid organ injury	Cecal perforation, ileal mesenteric rent
6	Negative	Moderate free fluid without solid organ injury	Ileal mesenteric rent
7	Negative	Moderate free fluid without solid organ injury	Multiple small-bowel deserosalizations
8	Negative	Moderate free fluid without solid organ injury	Jejunal and sigmoid deserosalizations
9	Negative	Moderate free fluid without solid organ injury	Multiple ileal perforations, sigmoid colon deserosalization
10	Negative	Trace-free fluid without solid organ injury, bowel wall thickening	Jejunal deserosalization, jejunal mesenteric rent
11	Negative	Moderate free fluid without solid organ injury	Ileal mesenteric rent
12	Negative	Large free fluid without solid organ injury	Multiple jejunal and ileal perforations
13	Negative	Moderate free fluid without solid organ injury	Cecal deserosalization, ileal perforation
14	Negative	Moderate free fluid without solid organ injury, mesenteric stranding	Left colon laceration, small-bowel mesenteric rent
15	Negative	Moderate free fluid without solid organ injury	Jejunal laceration, small-bowel mesenteric rent
16	Equivocal	Large free fluid without solid organ injury	Actively bleeding small-bowel mesenteric rent
17	Equivocal	Large free fluid without solid organ injury	Jejunal perforation, right colon perforation
18	Equivocal	Moderate free fluid without solid organ injury	Small-bowel mesenteric rent

*FAST indicates focused abdominal sonography for trauma; CT, computed tomography.

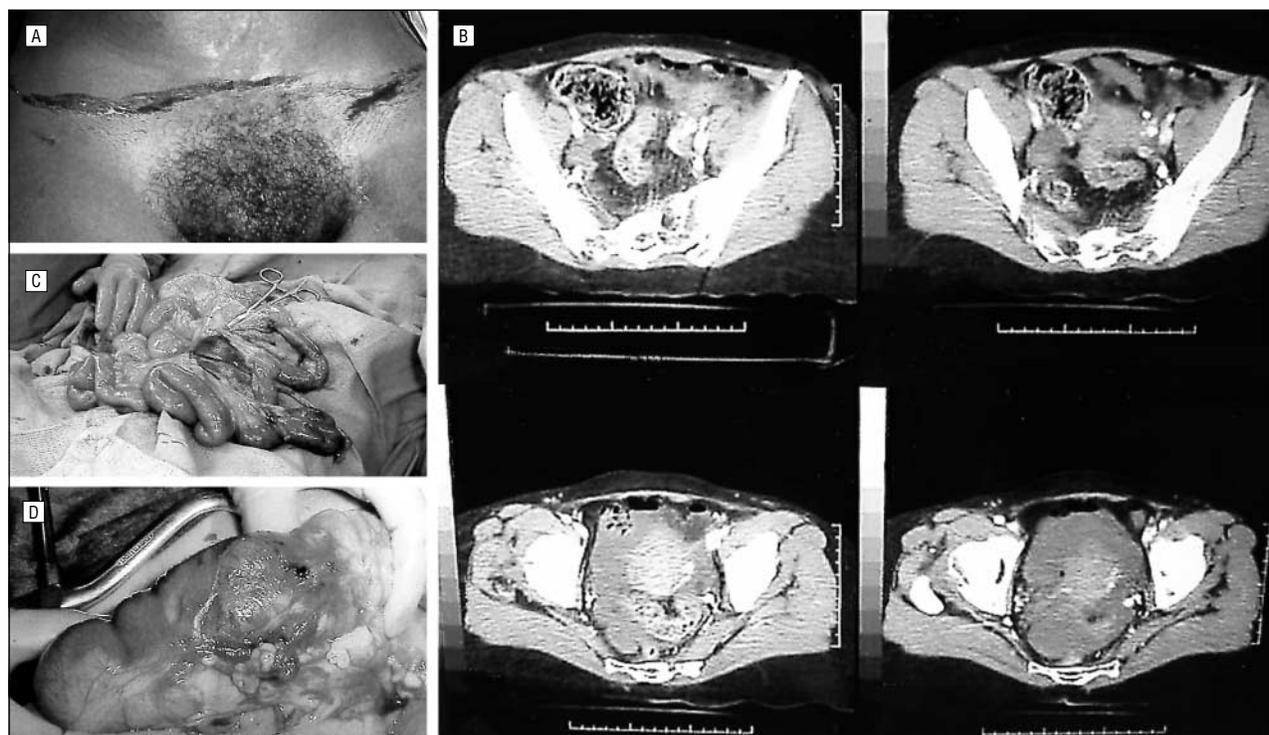


Figure 1. Patient with negative focused abdominal sonography for trauma scan result. A, Abdominal seat belt mark; B, computed tomographic findings—large free fluid without solid organ injury; C, operative findings—small-bowel mesenteric injury, compromised small bowel and ileal perforation; and D, operative findings—cecal deserosalization.

be subtle. Associated injuries and decreased mental status in many blunt trauma patients further decrease the reliability of clinical examination. Initial or delayed abdominal tenderness has not been shown to correlate with laparotomy results.¹³ The operative findings of patients in our study did not correlate with their initial physical examination results.

Isolated use of DPL to identify bowel and mesenteric injuries was not addressed in this study. Like ultrasound, DPL relies on its ability to detect blood in the

peritoneal cavity. It does not provide specific information on the cause of the hemoperitoneum. Fluid amylase measurement, white blood cell count, and alkaline phosphatase levels are used to help provide evidence for and against bowel and mesenteric injury.¹⁴ The drawback is that these are invasive investigations that often result in nontherapeutic operative exploration.¹⁵

The CT findings associated with bowel and mesenteric injuries are nonspecific and often subtle. Our study shows free fluid without solid organ injury to be the most

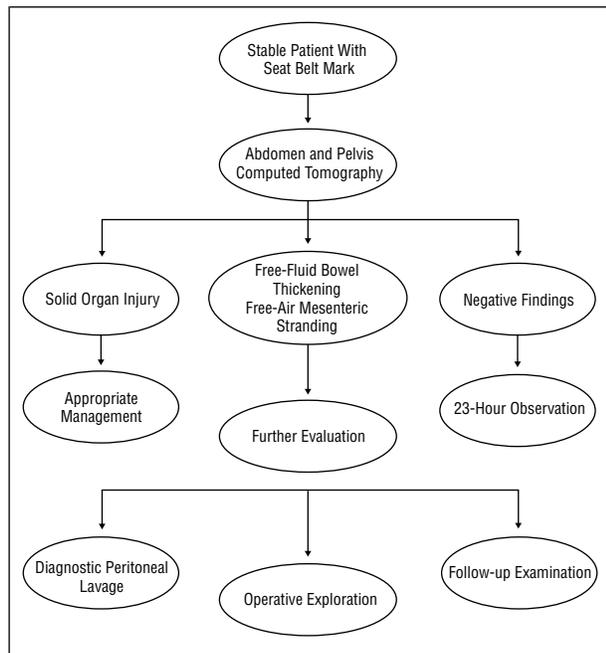


Figure 2. Algorithm for patients with abdominal seat belt marks.

common presentation. Free air, bowel wall thickening, and mesenteric stranding were less frequent findings. This correlates with previous studies that also found free fluid without solid organ injury to be common with bowel and mesenteric injuries.^{3,9,11} The significance of isolated free intraperitoneal fluid depends on the amount present, and the risk of a missed injury must be weighed against that of a negative laparotomy result.^{9,11,16,17} Patients with only trace amounts of free fluid as the only finding on CT scan can sometimes be treated expectantly because this finding is less likely to be associated with serious injury.^{9,11,16} In contrast, the demonstration of moderate-to-large amounts of free fluid on CT findings has an incidence of associated bowel or mesenteric injury of 50% to 94% according to previous studies.^{9,11,18} Our study had a therapeutic laparotomy rate of 83% (19/23) for patients with moderate-to-large amounts of free fluid without solid organ injury. If free fluid is found in concert with oral contrast extravasation, free air, or mesenteric stranding, operative intervention is warranted regardless of the amount of fluid present. We realize that the CT scan is not completely accurate in diagnosing intra-abdominal injury; nonetheless, FAST was far less sensitive, with a false-negative rate of 78%. This is slightly higher than what has been previously reported.^{7,8} Positive FAST results did not correlate with the probability of patients undergoing therapeutic laparotomy.

Based on these results, our current institutional algorithm now includes seat belt mark as a contraindication to FAST (**Figure 2**). A CT scan is used preferentially as the initial screening modality. If the CT result is negative, the patients are still observed for 23 hours and discharged as able. Patients are not discharged from the emergency department after negative CT findings because CT is not completely reliable for ruling out a small bowel injury, as was confirmed by the results of a recently presented multi-institutional trial.¹⁹ Solid organ

injury identified by CT is managed conservatively. Expedient operative intervention is undertaken in any patients with oral contrast extravasation, free air, or moderate-to-large amounts of free intraperitoneal fluid without solid organ injury, accepting the potential risk of a negative laparotomy result. If an isolated finding of trace fluid is present, the patient is closely monitored, and follow-up diagnostic evaluations are performed as indicated.

In conclusion, patients with abdominal seat belt marks have an increased incidence of bowel and mesenteric injuries. This study confirms that FAST cannot reliably exclude intestinal injury in these patients. Patients with abdominal seat belt marks should be evaluated with CT scan (Figure 2) and treated accordingly. The weakness of this study is that it is relatively small. Furthermore, no comment can be made on specificity because not all patients with seat belt marks were included.

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DISCUSSION

Frederick A. Moore, MD, Houston, Tex: The FAST exam has become a standard of care in trauma centers worldwide. It is clearly an invaluable triage tool for a hemodynamically unstable victim of blunt trauma. In this setting, the traditional ABCs become the ABC-S, that is airway, breathing, circulation—sonography. With this approach, FAST results are available within minutes of arrival. If the FAST is positive and instability persists, immediate transport to the operating room is the prudent triage decision. However, the use of the FAST exam has been extended into other clinical scenarios, where its usefulness is not so clear. In their presentation today, Dr Stassen and associates nicely demonstrated that in the hemodynamically stable patient with a seat belt mark injury, the FAST is probably no better than physical exam. Of note, 15 of 23 exams were negative, despite significant hollow viscous injuries and mesenteric rents.

I have three questions. (1) In the “Methods” section, you state that the FAST exam is done in the secondary survey but list no indications. In hemodynamically stable patients, what are your specific indications to obtain a FAST exam? Does the FAST exam substantially reduce the subsequent need for CT scanning or do the patients, as in this series, simply get both tests?

(2) You conclude that patients with seat belt mark injuries should be evaluated by CT scanning. In the “Methods,” you describe the use of oral contrast. This fits my bias. However, recent publications make a strong argument against the use of oral contrast. Would you please comment on this controversy?

(3) My mentors, Ben Eiseman and Gene Moore, would expend a lot of red ink on your management algorithm. Specifically, you have a box that contains 4 potential signs of hollow viscous injury—not all of which would prompt the same decision. In the abstract, all of your patients with these CT scan findings go to the operating room while your manuscript lists 3 potential options: DPL, OR, or serial exams. Unfortunately, you do not tell us how to make these choices. Tell us what you would do. It is the middle of the night, Dr Richardson. You get an equivocal CT scan. Examples may include mild-to-moderate unexplained fluid or bowel wall thickening with mesenteric streaking. Are you going to operate or are you going to go back to bed? Another way of asking this question is do you believe that delayed treatment of hollow viscous injury substantially increases morbidity and mortality which outweigh the cumulative risks of nontherapeutic laparotomies?

In conclusion, I would like to congratulate Nicole on an excellent presentation and the authors for providing a straightforward study with an irrefutable conclusion that the FAST exam will frequently miss hollow viscous injuries.

Jerry M. Shuck, MD, Cleveland, Ohio: The more we wrestle with the value of the FAST exam and the other appropriate studies of blunt trauma to the abdomen, the more we are going to learn. I have a question that relates somewhat to Dr Moore’s final query that has to do with the timeline. There was no timeline that I could tell from the presentation. It may be in the manuscript. How long after injury were the diagnos-

tic studies done? When you say you see some secondary or soft signs of bowel injury on CT scan, you say you follow them or else you operate on them. How long was it between injury and operation when there is bowel that has been disrupted?

I bring that up because of 2 lawsuits that I know of in our own area. I have recently been asked to defend one where the patient had blunt trauma with seat belt marks and the patient was not operated on for close to 24 hours. The doctor was being sued because of that delay. If one reviews the literature on blunt trauma to bowel, one finds that the average time of diagnosis is between 18 and 24 hours. This case was dismissed only because of data that was provided by our literature. Tell us when you do your studies and when you operate on these people.

Gregory J. Jurkovich, MD, Seattle, Wash: The first point is to better define the utility of FAST scan in the abdominal trauma patient. The second one, and the one I will ask a question on, is regarding the role of free fluid on the abdominal CT scan in patients with no solid organ injury. You demonstrated a remarkable 78% to 80% therapeutic laparotomy in patients with free fluid on CT scan with no solid organ injury. Others have reported as low as 5% or 10% therapeutic laparotomy with free fluid on CT scan. It leads me to question that this population is a very select one.

Indeed, this was just patients who had a seat belt sign and underwent an operation. It was not all patients with a seat belt sign. It was not all patients with free fluid. It was not all patients who had ultrasound. So to really put this in some perspective, we do need an understanding of the total number of patients with free fluid on CT scan who were or were not operated on, as well as the total number of patients with seat belt signs and what their findings were. I know these are hard numbers to come up with and it is a semirhetorical question because it is difficult to document all of those patients with seat belt signs, but I think it is important to note that this is a fairly select population.

Lawrence Danto, MD, Stockton, Calif: At the University of California, Davis, a while back, we reported a small series of patients with seat belt injuries and other forms of linear abdominal trauma requiring celiotomy. We were struck by the finding, and this question is about incisions, that visceral and abdominal wall injuries invariably lay directly beneath the bruise and could most easily be managed via a transverse incision that followed the course of this linear contusion. Further, for this reason, a vertical midline incision was not only unnecessary but it unnecessarily complicated the repair of the abdominal wall. Would you please comment about this little bit of heresy in recommending a transverse celiotomy in these trauma patients?

Also, have you used ultrasound in these patients to evaluate the extent of the abdominal wall injury as a separate indicator for celiotomy? In other words, in an otherwise stable patient with a negative FAST or CT scan, would the finding of an abdominal wall defect on ultrasound or CT be enough to cause you to operate?

James G. Tyburski, MD, Detroit, Mich: I want to congratulate the authors on again trying to define the use of ultrasound in the trauma room. I have a question about the CT scans. If I understood the presentation, there were basically no false-negative CT scans for small-bowel injury. That is, the CT was 100% sensitive. Would you discharge somebody from the ED with a negative CT scan whether they had a seat belt injury or not? In other words, do you use that for a screening tool for 23-hour observations or admission?

R. Stephen Smith, MD, Wichita, Kan: I also want to congratulate the Louisville group on a very nice paper. You have appropriately pointed out that the Achilles heel of trauma ultrasound is that the serious intra-abdominal injuries, which produce little or minimal intra-abdominal fluid, may be missed. I have a few questions.

First of all, were serial ultrasound examinations performed in the trauma bay? This has been shown by some groups to improve accuracy.

Secondly, what was the timing of the CT scan in relation to the ultrasound examination? Often, the intra-abdominal findings are in evolution, and fluid is much easier to detect by CT or by ultrasound after a few hours have passed. I have personally seen several patients within the last year who presented initially with a negative ultrasound examination followed immediately by a negative CT scan. CT scan was repeated between 6 and 12 hours, and findings of free air or fluid were then present, which led to laparotomy.

Would the authors comment on intentional delay of the CT scan to improve the diagnostic accuracy of the CT study?

Finally, if you are in the trauma room and you have a positive ultrasound examination and the presence of a seat belt sign on physical exam, would you proceed directly to laparotomy or would you perform other diagnostic studies?

Ernest E. Moore, MD, Denver, Colo: I submit as we critically analyze the role of ultrasound in the evaluation of blunt abdominal trauma, it is important that we define what a true ultrasound study should constitute. We have a problem embracing the terminology of FAST exam because it implies that someone quickly obtains their 5 views, staples the hard copy on the encounter sheet, and assumes that it is a definitive ultrasound study.

We have suggested instead the acronym SLOH, that is, systemic look for occult hemorrhage. Because in many patients with small collections of intraperitoneal fluid, it is on the repeat exam that fluid is identified by ultrasound. Indeed in our institution, like many others, we have a protocol that ultrasound is redone not only in the secondary survey but also the tertiary. When our radiology colleagues accept that surgeons should have ultrasound available, I predict we will find ultrasound useful in our intensive care units to identify delayed fluid collections.

What do you do with this patient who has suggestive CT findings? As you have nicely outlined, these CT findings—short of extravasation—have simply identified the high-risk patient, which was already known by seeing the seat belt mark. Who should undergo diagnostic peritoneal lavage and what do you analyze? As you know, a number of groups have found enzymes, eg, bilirubin, alkaline phosphatase, and amylase, as well as ratios of white cells to red cells as useful. With your new algorithm, can you enlighten us as to what hard criteria you would use to select the patient for either laparotomy or laparoscopy?

Dr Richardson: There are multiple questions to answer. Dr Moore asked about a negative ultrasound. If there is a negative ultrasound, about 30% have a CT scan. In terms of second exams on ultrasound, we generally do that by protocol about

30 minutes apart. Do patients with CT scans get contrast? The answer is yes, because that is the way our radiologists want to do that. We have argued that for a variety of reasons, including the difficulty of getting the contrast administered, that the contrast is not necessary. On the other hand, our radiologists insist on contrast.

We have a very low threshold to operate on patients with potential for small bowel injury. If somebody has a seat belt sign and has significant free fluid, their chance of getting an operation is fairly high. With trace fluid, we generally would recommend DPL. We do not do enzyme determinations in DPL fluid. We have occasionally found an elevated white blood cell count of above 500 cells/mm³ level to be useful. Most of these patients actually had a copious amount of fluid on CT scan, which made the decision to operate easier. CT alone should not be a hard and fast arbiter of who needs to be operated on. CT will surely miss some injuries so we would not try to make the case that CT is going to be 100% effective. It just happened to be in the patients in this report.

Generally, with patients who have thickened mesentery as their only finding on CT, if they are patients that are evaluable on physical examination, we recommend serial exams.

Dr Shuck asked about timing of scans and operations. None of these patients had delayed operation. All were scanned early and were operated on early. The strategy of delaying scans to allow minor bleeding to become more apparent was not practiced.

Dr Jurkovich questioned the free fluid without solid organ injury. We perform DPL with small amounts to help sort that out. Dr Jurkovich mentioned a selection bias and he is likely correct.

Dr Danto, we really have no experience with transverse incisions. On occasion our abdominal wall reconstruction with major abdominal wall defects is a problem. We likewise have no experience in terms of using ultrasound to diagnose the extent of abdominal wall injuries. We have noted major abdominal wall injuries on CT on occasion.

Dr Tyburski, we have had no false-negative CT scans, but I think that is just a matter of luck more than anything else, and we are not at all implying that CT is 100% perfect by any means. We have a policy of evaluating almost anybody that could be hurt for 23 hours in-house. Missed small-bowel injury or its delayed diagnosis is still a problem. Dr Shuck neatly made the point that it is a major issue and if you miss this, you can really create tremendous long-term problems for a patient.

Dr Smith, we often use serial ultrasound but, as I say, it is twice by protocol, about 30 minutes apart.

We really don't do laparoscopy much at all for blunt trauma. I'm not saying that we don't occasionally use it, but it's certainly not a part of any kind of protocol in large part just because of logistical issues, particularly in the middle of the night.