PAPER

Use of Computed Tomography in Anterior Abdominal Stab Wounds

Results of a Prospective Study

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Hypothesis: Computed tomography (CT) can be used to evaluate patients with anterior abdominal stab wounds (AASWs).

Design: Prospective observational study.

Setting: Academic level I trauma center.

Patients and Methods: All of the patients sustaining AASWs, excluding those with hemodynamic instability, peritonitis, or omental evisceration, were admitted for serial abdominal examinations with or without CT depending on attending preference. Patients with associated left thoracoabdominal stab wounds underwent diagnostic laparoscopy.

Main Outcome Measures: Change in patient management as a direct result of the CT scan findings, as well as sensitivity, specificity, positive predictive value, and negative predictive value of CT scanning calculated against clinical outcome (the need for laparotomy, uneventful discharge without laparotomy, or return to the hospital for adverse events).

Results: One hundred fifty-six consecutive patients with AASWs were included over 24 months. Computed tomography was performed for 67 patients (CT group) whereas 89 patients were admitted for serial examination only (no-CT group). Nineteen of the 67 patients in the CT group had positive CT results, leading to laparotomy in 10 patients. Of the 48 patients with negative CT results, 3 underwent diagnostic laparoscopy for an associated thoracoabdominal stab wound and 2 eventually underwent laparotomy for clinical deterioration with negative results. Excluding patients with associated thoracoabdominal stab wounds, the negative predictive value of CT was 100%.

Conclusions: In patients with AASWs, CT can be used to identify visceral injuries. It is a promising tool that may identify patients who can be discharged after a shorter period of observation. Further evaluation of its use in patients with AASWs is warranted.

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Selective conservatism of anterior abdominal stab wounds (AASWs) has been the standard of care since its introduction in the 1960s.[1-3] By this approach, laparotomy is reserved for patients with peritonitis, hypotension, or any factor that would preclude adequate physical examination. All of the other patients are admitted for observation and either are discharged after a period of observation or undergo delayed laparotomy if signs of intra-abdominal injury develop. In addition to physical examination, several adjuncts are used by some centers to help avoid missed injuries and unnecessary laparotomies. These adjuncts include local wound exploration, diagnostic peritoneal lavage, laparoscopy, and more recently, ultrasonography. Since no single modality has proven to be adequate for all of the patients with AASWs, no uniform standard regarding the most appropriate management exists.

Helical computed tomography (CT), already the standard of care for evaluating hemodynamically stable patients with blunt abdominal trauma, is emerging as a useful tool in the evaluation of penetrating trauma. Triple-contrast CT (oral, intravenous, and rectal) has been used with excellent results to evaluate the retroperitoneum after flank and back stab wounds.[4-6] Computed tomography has also been used to determine bullet trajectory after abdominal gunshot wounds with encouraging results.[7-10] The role of CT in evaluating patients with AASWs remains unknown.

The purpose of the study was to evaluate the role of single-contrast CT (intravenous only) as an adjunct to physical examination in patients with AASWs selected for nonoperative management.

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Table 1. Demographics and Admission Characteristics

Characteristic	All Patients (N = 156)	CT Group (n = 67)	No-CT Group (n = 89)	P Value*
Age, mean ± SD, y	31 ± 12	31 ± 12	31 ± 12	.83
Male, No. (%)	140 (90)	62 (93)	78 (88)	.32
Vital signs				
SBP, mean ± SD, mm Hg	129 ± 16	130 ± 16	128 ± 17	.52
Heart rate, mean ± SD, beats/min	93 ± 20	92 ± 20	94 ± 21	.68
GCS score, mean ± SD	15 ± 1	15 ± 1	15 ± 1	.91
Initial hemoglobin level, mean ± SD, g/dL	14.0 ± 1.8	14.2 ± 1.7	13.8 ± 1.8	.15
Alcohol intoxication at admission, No. (%)	34 (22)	20 (30)	14 (16)	.03
Associated injury, No. (%)	74 (47)	27 (40)	47 (53)	.12
Head	14 (9)	5 (8)	9 (10)	.57
Neck	9 (6)	3 (5)	6 (7)	.55
Chest	47 (30)	19 (28)	28 (32)	.68
Extremity	36 (23)	11 (16)	25 (28)	.09
ISS, mean ± SD	5 ± 5	5 ± 5	4 ± 4	.23
Laparotomy, No. (%)	20 (13)	12 (18)	8 (9)	.10
Nontherapeutic laparotomy, No. (%)	8 (40)	4 (33)	4 (50)	.65
Time to laparotomy, mean ± SD, h	6.2 ± 5.7	6.6 ± 5.4	5.6 ± 6.7	.38

Abbreviations: CT, computed tomography; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; SBP, systolic blood pressure.

*Equality in proportions was tested by χ^2 test or Fisher exact test as appropriate. Paired differences in age, SBP, heart rate, GCS score, initial hemoglobin level, ISS, and time to laparotomy were tested by 2-tailed *t* test or Wilcoxon signed rank test as appropriate.

METHODS

The prospective observational study was performed at the Los Angeles County and University of Southern California Medical Center, Los Angeles, a large academic level I trauma center, during a 24-month period from January 15, 2004, through January 15, 2006. All of the patients with AASWs, defined by the nipple line superiorly, pubic symphysis inferiorly, and midaxillary lines bilaterally, were considered for inclusion in the study. Patients with hemodynamic instability, peritonitis, gastrointestinal bleeding, or omental evisceration were excluded. All of the patients were admitted for serial abdominal examinations with or without helical CT scans depending on the preference of the attending trauma surgeon on call. Patients with left thoracoabdominal wounds underwent diagnostic laparoscopy after a period of observation to evaluate for diaphragmatic injury. Data regarding patient demographics, physical examination findings, alcohol intoxication status, Glasgow Coma Scale score on emergency department admission, laboratory data, CT findings, changes in management based on these findings, major operative procedures, operative findings, Injury Severity Score, and hospital course were recorded prospectively.

Computed tomographic examinations were performed by certified technologists with a helical single-detector scanner (model 2000; Picker, Cleveland, Ohio) with 10-mm collimation, pitch of 1.5, 28- to 36-second exposure at 1 revolution per second, 200-mA current, and 120 kV from the nipple line to the pubic symphysis, and the examinations were supervised by radiology residents, fellows, and staff. Intravenous contrast (150 mL of Omnipaque [Amersham-Health, Cork, Ireland]) was injected by a power injector at a rate of 3 mL/s with a scanning delay of 60 seconds. Oral contrast was not administered. Paper clips were placed directly on the stab wound site to facilitate visualization of the wound tract. All of the images were then reviewed and directly communicated to a member of the trauma team caring for the patients. The official radiologic report as signed by the attending radiologist was used to determine whether the scan showed any traumatic abnormality and what injuries, if any, were present. Computed tomographic results were compared with findings at laparotomy and/or laparoscopy when performed.

Table 2. Results of Computed Tomographic Scans

Result	Cases, No. (%)
Clear trajectory	47 (70)
Isolated free fluid	11 (16)
Liver injury	7 (10)
Pneumoperitoneum	6 (9)
Spleen injury	1 (1)

Descriptive analyses were performed initially to provide summaries of demographic information, baseline clinical status, frequencies of the findings on physical examination, laboratory examination results, abnormalities in the CT findings, major operative procedures, and hospital course. Data between the patients who were admitted for serial abdominal examinations with CT (CT group) and without CT (no-CT group) were compared for equality using a Fisher exact test or χ^2 test. Paired differences in age, Glasgow Coma Scale score, vital signs, and Injury Severity Score were tested using a 2-tailed *t* test or Wilcoxon signed rank test as appropriate. Statistical significance was considered at the level of $P<.05$ for all of the comparisons.

For patients who were admitted for nonoperative management with CT (CT group), the sensitivity, specificity, positive predictive value, and negative predictive value of CT were calculated against the clinical outcome of nonoperative management rather than peritoneal violation, which other studies[11,12] have used. The clinical outcome was classified as the need for laparotomy, uneventful discharge without laparotomy, or return to the hospital for adverse events related to nonoperative management. Computed tomographic results were defined as true positive if, on surgical exploration, injuries suspected on CT were found and repaired. They were defined as false positive if surgical exploration performed on the basis of CT findings was nontherapeutic (no injuries or injuries not requiring repair). Computed tomographic results were true negative if there was no intra-abdominal traumatic abnormality on the CT scan and the patient was discharged without undergoing surgical exploration or underwent laparotomy that was nontherapeutic. They were false negative if CT failed to identify an intra-abdominal abnormality in a patient who later required operative intervention and repair of an injury.

The effect of CT in management was recorded by asking the attending surgeon prospectively about the management plan that he or she had formulated before CT scanning and then after CT scanning. Patient management changes were defined as alterations in the normal treatment plan as a direct result of the CT findings. These changes included early discharge, performance of additional diagnostic studies or interventions (eg, angiography, diagnostic peritoneal aspiration or lavage), and immediate operative intervention. The study was approved by the institutional review board, and the need for informed consent was waived.

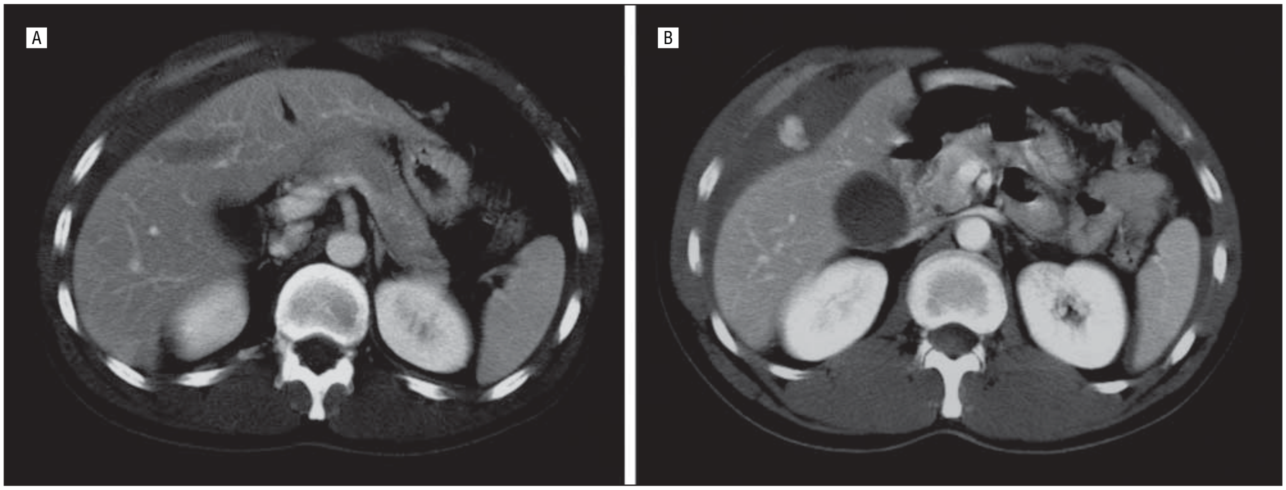

Figure 1. Computed tomography of a patient with a stab wound to the abdomen shows liver injury (A) as well as contrast blush and hemoperitoneum (B). The patient was taken to the operating room for hepatorrhaphy directly based on computed tomographic findings.

RESULTS

During the 24-month study period, there were 290 patients admitted to our trauma center with AASWs. After excluding patients who were taken to the operating room for obvious signs of intra-abdominal injury, 156 patients (54%) met the study inclusion criteria. Eighty-nine patients were admitted for serial examination only whereas CT was performed in the remaining 67 patients. **Table 1** summarizes the demographic and admission characteristics of the study population.

Among the 67 patients who underwent CT, the stab wound tract was defined with certainty in 47 patients (70%). Eight patients (12%) had solid organ injury, 6 (9%) had pneumoperitoneum, and 11 (16%) had isolated free fluid. **Table 2** summarizes the CT results of the 67 patients who underwent CT.

Of those 19 patients (28%) with intra-abdominal traumatic abnormalities on CT, 5 patients (26%) underwent a therapeutic laparotomy as a direct result of the CT findings. **Figure 1** and **Figure 2** show CT findings that resulted in laparotomy. For the remaining 14 patients (74%) with intra-abdominal traumatic abnormalities on CT, 8 (57%) were discharged uneventfully after a period of serial abdominal examination, 1 (7%) underwent diagnostic laparoscopy for an associated thoracoabdominal stab wound with no intra-abdominal organ injury, and 5 (36%) required a delayed laparotomy during the period of observation for a change in physical examination. Of the 5 cases that required a delayed laparotomy, 3 were from hollow viscous injuries that were classified as true positives, 1 was from a nonbleeding liver injury, and 1 was from a nonbleeding mesenteric injury. The latter 2 cases were included in the false-positive group since no therapeutic measures were performed. **Table 3** summarizes the effect of positive CT results on individual patient management.

Regarding the 48 patients (72%) with no intra-abdominal traumatic abnormalities on CT, 7 (15%) were discharged directly based on the negative scan results whereas 36 (75%) were discharged after a period of uneventful observation. Two patients (4%) underwent delayed laparotomy within 8 hours of admission, one for worsening abdominal signs and the other for an episode of hypotension. Both laparotomies were nontherapeutic. One of the 3 patients was found to have a nonbleeding mesenteric injury whereas the second patient who underwent laparotomy had completely negative results. Three patients (6%) underwent diagnostic laparoscopy for an associated thoracoabdominal stab wound. One patient was found to have a diaphragm injury whereas the other 2 had negative laparoscopy examination results. **Table 4** summarizes the effect of negative CT results on individual patient management.

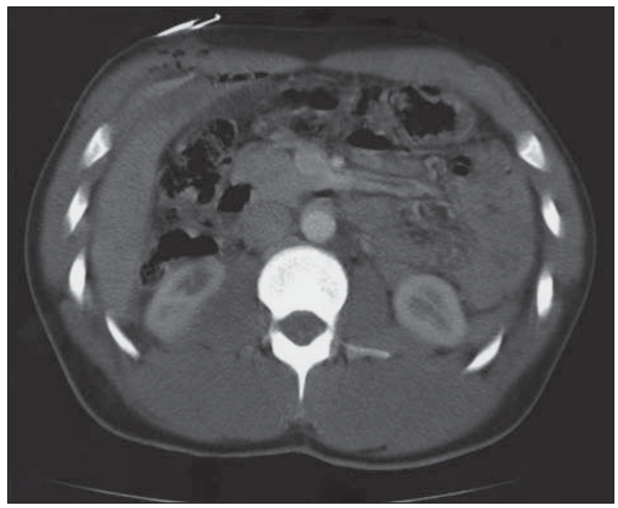

Figure 2. Isolated free fluid with pneumoperitoneum on computed tomography. The patient was taken to the operating room directly based on computed tomographic findings and was found to have small-bowel, colon, and diaphragm injury.

With 8 true-positive examinations and 48 true-negative examinations, the positive predictive value of CT was 42% and the negative predictive value was 100%. The sensitivity of CT was 100% and the specificity was 81% based on 11 false-positive and no false-negative examinations. The CT findings resulted in a change in management in 12 patients (18%). In 5 patients, laparotomy

Table 3. Effects of Traumatic Abnormalities on Computed Tomographic Scans of Individual Patients

Patient No.	CT Scan Findings	Effect	Outcome
1	Liver injury, contrast extravasation, free fluid	Direct to surgery	Hepatorrhaphy for liver injury
2	Isolated free fluid, free air	Direct to surgery	Primary repair of small-bowel, colon, and diaphragm injury
3	Isolated free fluid	Direct to surgery	Primary repair of small-bowel injury
4	Isolated free fluid	Direct to surgery	Primary repair of colon and diaphragm injury
5	Liver injury, free fluid, free air	Direct to surgery	Hepatorrhaphy for liver injury
6	Isolated free fluid	Serial abdominal examination	Laparotomy for a change in physical examination, hepatorrhaphy, and gastric laceration repaired
7	Isolated free fluid	Serial abdominal examination	Laparotomy for a change in examination, gastric and diaphragm injury found and repaired
8	Isolated free fluid	Serial abdominal examination	Laparotomy for a change in examination, colon injury repaired
9	Isolated free fluid	Serial abdominal examination	Laparotomy for a change in examination, nonbleeding mesenteric injury not requiring repair
10	Liver injury, free fluid	Serial abdominal examination	Laparotomy for a change in examination, nonbleeding liver injury not requiring repair
11	Spleen injury	Laparoscopy for an associated TASW	No intra-abdominal injury
12	Liver injury, free fluid	Serial abdominal examination	Uneventful discharge
13	Liver injury, free fluid	Serial abdominal examination	Uneventful discharge
14	Liver injury, free fluid	Serial abdominal examination	Uneventful discharge
15	Liver injury, free fluid	Serial abdominal examination	Uneventful discharge
16	Isolated free fluid, free gas	Serial abdominal examination	Uneventful discharge
17	Isolated free fluid, free gas	Serial abdominal examination	Uneventful discharge
18	Isolated free fluid	Serial abdominal examination	Uneventful discharge
19	Isolated free fluid	Serial abdominal examination	Uneventful discharge

Abbreviations: CT, computed tomography; TASW, thoracoabdominal stab wound.

Table 4. Effects of Normal Findings of Computed Tomography on Management and Outcome

Effect	Outcome
Discharge directly	Uneventful (n = 7)
Admission for serial examination	Discharge uneventful (n = 36)
	Delayed laparotomy (n = 2; both nontherapeutic)
	Diagnostic laparoscopy for associated thoracoabdominal stab wound (n = 3; 1 patient was found to have diaphragm injury)

was performed as a direct result of the CT findings. Seven patients were discharged from the hospital as a direct result of the negative CT findings. Excluding 2 patients with associated extra-abdominal injuries, the 5 patients who were discharged based on normal CT results stayed in the hospital for a mean±SD of 24±1 hour (median hospital stay, 24 hours; range, 23-25 hours) compared with a mean±SD of 28±11 hours (median hospital stay, 24 hours; range, 24-72 hours) for the patients who were discharged without laparotomy after a period of observation without CT (P=.63). No complications directly related to CT were observed. All of the patients in the study survived to discharge.

COMMENT

Selective nonoperative management has been widely accepted as the standard treatment for AASWs in most trauma centers. Physical examination has proven to be an extremely reliable method of identifying patients who need surgery while also helping to avoid unnecessary and nontherapeutic laparotomies.[2,3,13-16] Adjuncts to the physical examination, such as local wound exploration, diagnostic peritoneal lavage, laparoscopy, and ultrasonography, have been used to minimize missed injury and to decrease hospital length of stay. Since all of the adjuncts have advantages and disadvantages, there is no universally accepted management protocol for patients with AASWs.

Local wound exploration was introduced as a method to evaluate the integrity of the fascia in patients with penetrating abdominal wounds.[17,18] Without fascial penetration, patients could be reliably discharged from the emergency department. Local wound exploration is not universally accepted because it is an invasive, often misleading tool that can be extremely difficult to perform in certain groups of patients such as those with morbid obesity. In addition, since nearly 30% of patients with fascial penetration will not have a significant injury requiring repair, it is no longer an indication for laparotomy.[13]

Diagnostic peritoneal lavage has also been used to identify patients with intra-abdominal injury. However, there is no consensus as to the exact red blood cell count that constitutes a positive finding in penetrating trauma.[19] In addition, with the increasing success of nonoperative management of penetrating solid organ injury, hemoperitoneum is no longer an indication for laparotomy.[11,12,20,21]

Diagnostic laparoscopy has also been proposed as a useful adjunct in penetrating trauma. It can be used to identify peritoneal penetration, hemoperitoneum, and solid organ injury. Laparoscopy remains the gold standard in evaluating the diaphragm in penetrating thoracoabdominal injuries[22]; however, it has yet to catch on in the evaluation of AASWs because of its poor sensitivity and inability to adequately diagnose hollow viscous and retroperitoneal injuries.[23,24]

With the emergence of ultrasonography as an invaluable tool in the evaluation of blunt abdominal trauma, several studies have examined its applicability in penetrating trauma. Most studies[25-28] have come to the same conclusion: although it may be helpful, it does not exclude injury and may be no better than clinical judgment.

Computed tomography has emerged as a useful adjunct in the nonoperative management of patients with abdominal gunshot wounds.[7-12] It has also been used with excellent results to evaluate the retroperitoneum in patients with flank and back stab wounds.[4,5] The experience with AASWs is much more limited. In a study of 50 patients with stab wounds to the back, flank, and lower anterior chest, Rehm et al[29] found that CT with oral and intravenous contrast was useful in identifying peritoneal penetration, solid organ injury, and retroperitoneal injury but was unreliable with respect to hollow viscous injury. They concluded that CT was a valuable adjunct in the preoperative assessment, which may help to reduce the rate of unnecessary laparotomy. Soto et al[30] evaluated 32 patients with AASWs and proven peritoneal penetration with triple-contrast CT and serial ultrasonographic examination. The CT scans were useful in identifying solid organ injuries; however, no patient had a hollow viscous injury. Soto and colleagues suggested that the use of CT and ultrasonography may play a role in reducing the period of observation. In one of the largest series evaluating CT in penetrating trauma, Shanmuganathan et al[12] prospectively collected information on 111 stab wounds (200 patients in total). Using triple-contrast CT, they found that CT had a sensitivity of 97%, a specificity of 98%, and a negative predictive value of 98%. They included all torso wounds and could not comment specifically on AASWs.

Using intravenous contrast only, our study demonstrated that CT had a high sensitivity (100%), with a moderately high specificity (81%) in patients with AASWs. More importantly, it showed a negative predictive value of 100%. As a result, nearly 18% of patients had their management directly altered by the CT findings. Five patients were taken to the operating room whereas 7 patients were immediately discharged as a result of the CT findings. Computed tomography offers a noninvasive alternative to local wound exploration, diagnostic peritoneal lavage, and laparoscopy and is a more sensitive tool than ultrasonography.

Despite the obvious advantages of using CT, there appears to be reluctance for its use in evaluating patients with AASWs. The concern regarding the accuracy of CT in diagnosing hollow viscous injuries is the most likely reason. The false-negative rates of CT with respect to hollow viscous injury have been notoriously high, ranging from 13% to 15% in blunt trauma.[31,32] Even in penetrating trauma, CT has lacked accuracy with respect to bowel injury in the past.[29] With advances in CT technology, this may be changing. In the study by Shanmuganathan et al,[12] CT reliably identified bowel injury with no false-negative scans. Similarly, CT correctly identified the 6 patients with bowel injury with no false-negative scans in our study. Most patients with bowel injury after penetrating trauma either present with peritonitis or develop it soon after arrival at the hospital. They are often taken directly to the operating room without any type of evaluation. The CT scans are therefore obtained from patients with a low likelihood of having bowel injury, which probably explains the low false-negative rates.

It seems that the most appropriate role of CT is to augment the physical examination in patients with AASWs. The goals of selective management are to minimize missed injuries, minimize nontherapeutic and negative laparotomies, and minimize health care costs. Performing serial physical examination alone accomplishes all of these goals. However, a positive CT scan may lead to earlier operative intervention whereas a negative scan may lead to earlier hospital discharge. In our study, 5 patients were taken directly to the operating room without serial examination. Clearly, all of the 5 patients would have developed signs and symptoms of intra-abdominal injury and would have eventually undergone laparotomy even without a CT scan. Theoretically, avoiding these operative delays should decrease operative morbidity and could even decrease hospital stay. Probably the biggest benefit of CT is the potential to discharge patients after a negative scan. Seven patients were discharged after a negative CT scan in our series. Discharging patients from the emergency department or after a shorter-than-normal period of observation would presumably offer a cost benefit. There may be reluctance in discharging patients on the basis of a negative CT scan for fear of missing an injury. Even in our study, there were 2 patients with negative scans who underwent delayed laparotomy within 8 hours of admission. Although the operations were nontherapeutic, the patients' clinical deterioration is still concerning.

Although this is a prospective study, there are several limitations that need to be pointed out. The decision to obtain a CT scan was at the discretion of the attending surgeon. Therefore, CT scans were obtained from only 43% of the patients. If we had obtained CT scans from all of the 156 patients, our conclusions and recommendations would have been much stronger. Since our general protocol for AASWs prior to the study initiation included hospital admission for serial examinations regardless of the CT results, many patients who could have been discharged were still admitted. Without a comparison group, we could not perform a cost analysis or compare outcomes such as length of stay. Our study used single-contrast CT only rather than the triple-contrast CT that other studies have used.[11,12,30] We believe that triple-contrast CT is time consuming, resource consuming, and uncomfortable for the patient, and we are not convinced that it is necessary. We used a single-row-detector CT scanner, which provides image quality that is inferior to the newer generation of multidetector CT scanners. These newer CT scanners will be more accurate for identifying the wound tract and any associated injury. Finally, our CT outcome did not show peritoneal penetration, as other studies have done.[11,12] Since peritoneal penetration has long been abandoned as an indication for laparotomy, we were not concerned about identifying it. However, identifying the wound tract was helpful, especially when it extended toward a segment of bowel.

In summary, CT is a useful tool when used in conjunction with physical examination in patients with AASWs. It can help to identify injuries early and to potentially select patients who can be discharged from the emergency department with minimal observation. Further evaluation is needed to establish the most appropriate role of CT in these patients.

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DISCUSSION

Steven C. Stain, MD, Albany, NY: The group from LA County/USC [Los Angeles County and University of Southern California] has made seminal contributions to how we care for trauma patients. Their scientific study of selecting which trauma patients are best served by operative intervention has been buttressed by the superb prospective data collection, a committed team of trauma surgeons and house staff, and careful analysis of their results. With that tradition, however, comes some responsibility for how the recommendations will be taken by the broader trauma community. In that regard, I would caution the authors who suggest that CT scan is a useful tool for evaluation of anterior abdominal stab wounds, albeit in conjunction with the physical examination, that this needs to be couched in an appreciation of the methodologic shortcomings of this study and the selective interpretation of their results.

First of all, it is described as a prospective observational study with prior IRB [institutional review board] approval, and the need for informed consent was waived by the IRB. Although the data were collected prospectively, the key outcome measure (did the CT scan change the management plan?) was recorded by asking the attending surgeon after the management had already been completed. So, in my mind, this is retrospective collection on the most important outcome measure—did the CT scan really make a difference.

In that regard, the attending surgeon's decision was retrospectively recorded, sometimes as long as 24 hours after treatment was concluded. Furthermore, the manuscript states that the official radiologic report as signed by the attending radiologist was used to determine whether the CT scan exhibited any abnormality. This was also reviewed retrospectively, and although the attending radiologists were available (from home, I might add), the real decisions were made by the attending surgeons, albeit experienced trauma surgeons, interpreting their own scans.

It should be acknowledged that the USC group has a dedicated surgical admitting area where trauma patients receive regular serial examinations by experienced surgeons, and only 7 patients were discharged to home directly, I assume from the emergency department, based on these negative CT scans. Most of those with a negative scan (36 patients) had a period of uneventful observation. The last thing that needs to be noted is that this was not a randomized study, and the decision to get a CT scan at all was based on the attending surgeon's whim. It is likely that the surgeon's commitment to the study and clinical experience and judging the likelihood of serious injury provided significant bias in the interpretation of their results.

Enough about the methodology, now to the results. Only 19 of the 67 CT group patients had a positive CT, again, interpreted by the attending surgeon. Of these 19, 5 went directly to surgery, 2 for liver injuries and 3 for repair of enteric injury. Presumably, the 2 patients with liver injuries requiring repair would have demonstrated other signs of ongoing hemorrhage that would have become manifest, and perhaps the CT scan prompted earlier intervention. Likewise, the 3 patients with enteric injuries may have been picked up sooner. Interestingly, the USC group has extensively published on the selective management of stab wounds previously and has argued in the literature that the potential delay of relying upon serial examinations, assuming appropriate protocols are followed, does not increase morbidity.

Five of the 19 CT-positive patients had celiotomy after a change in physical examination. Again, 2 of these had nontherapeutic operations for nonbleeding liver or mesenteric injuries, and 3 had delayed recognition of their enteric injuries in which, presumably, there was no long-term adverse results, although this is not mentioned specifically in the manuscript.

It should be noted that only 2 of the patients with normal CT scans who were observed required delayed celiotomy, and both were nontherapeutic although clearly indicated because of hypotension and increasing tenderness.

I remind the audience that the primary outcome measure, change in patient management, occurred in 12 patients (17.9% based on the CT scans). If I add the numbers up, at least 4 of these 12 were nontherapeutic operations.

I have 5 questions for the authors. What exactly were the CT scan results that the attending surgeons correctly interpreted as being positive? The manuscript lists most of them as being free fluid, most often associated with a liver injury. I should point out that these are the same findings in the manuscript for the patients who were discharged uneventfully after serial examinations.

What was the outcome, length of stay, and postoperative morbidity in the 3 patients with positive CT scans who had delayed recognition of enteric injury after change in their physical examination?

Before this paper, I understood the standard measurement of a patient with interior stab wounds at USC to be serial examinations. During this study, 89 patients, more than the study group, were treated by only serial examinations. Their outcome was not presented at all in this manuscript. While you may not have that data on hand, it is an important comparison group. In fact, there was no intermediate or long-term morbidity listed for either group. What were the morbidity and mortality of the CT scan group and the serial examination control patients?

The manuscript discounts the results of previous studies of abdominal ultrasound for these patients. Some centers have considered the FAST [focused abdominal sonography for trauma] scan as an extension of the physical examination for blunt trauma patients. The most common finding in your positive CT scan group was free fluid. Do you believe that there is any role for ultrasound to determine the presence of free fluid, perhaps to identify patients who require more extensive serial examination?

Finally, only 7 patients were able to be discharged directly from the emergency department. Are the authors ready to describe a group of patients who can be safely discharged from the ED [emergency department] based only on CT scans?

Again, I would like to applaud the USC group for challenging us to consider the different diagnostic algorithms for patients with anterior abdominal stab wounds. It does set the stage for a more rigorously designed study that would better determine the use of CT scan for anterior abdominal stab wounds. I would caution the readers of this paper to consider the setting in which it was done: a dedicated trauma unit with surgeons experienced in serial physical examinations and using their own interpretation of CT scans. In my opinion, this diagnostic paradigm is not ready for adoption by the broader trauma community who cares for trauma patients.

A. Brent Eastman, MD, Rancho Santa Fe, Calif: I, too, would like to congratulate Dr Demetriades and his colleagues, who continue to provoke us and cause us to think about the management of anterior abdominal stab wounds. As I sit here with Dr Blaisdell, I'm curious about what he is thinking about this nonoperative management of abdominal stab wounds and remembering his admonitions during our training at the San Francisco General Hospital in the late 1960s and early 1970s. I also remembered a case when Dr Olcott and I were on call and an intern called in to tell us that a patient had been stabbed. When I asked how he had been stabbed, he said, "up, down, and repeatedly." So, I think 1 question is, what about multiple stab wounds that border the anterior abdominal area and the flank?

Second, Col John Holcomb, who we all know as doing tremendous work on studying the injuries and improving care for our soldiers in Iraq, recently told me that the average number of penetrating wounds in a soldier hit by a fragmentation weapon is 18.5. The reason to mention that is that they, too, are using CT scans now because there is no way that they can explore and operate on all of these patients, and he will be presenting those results. The question is, what were the CT findings on the 4 nontherapeutic laparotomies? What CT scan findings caused you to operate, and were they nontherapeutic? Finally, did you look at the cost of CT vs the observation group?

Edward E. Cornwell III, MD, Baltimore, Md: Take us back, if you would please, to the genesis of the study. Twenty years ago, Dr Berne published from your institution on 1776 stab wounds about the torso, including those to the back and to the flank, where very few patients had CT scans, and he described a very efficient management algorithm. Ten years ago, when you, Ali, were a resident, Dr Demetriades published a paper on the selective management of gunshot wounds to the anterior abdomen, 309 patients, and only 19 of those patients had CT scans in a very well-managed group. So, what prompted the new enthusiasm for CT scans described in this study?

Amplifying on Dr Eastman's question, of the 17 abnormal CTs, 4 patients had nontherapeutic laparotomies. That is greater than 20%, so while you had a change in your management across the board by CT scan of 18%, a similar percentage of patients had an unnecessary operation that they otherwise might not have had without the CT scan. So, can you give us a revised algorithm of how you would weigh the impact of physical examination vs CT scan in the patients who presumably had a negative examination?

David H. Wisner, MD, Sacramento, Calif: I would appreciate a bit more information about who got scanned and why and who didn't get scanned and why. This really doesn't sound a whole lot different to me than your previously published work where some patients got operated on and some were watched. I wonder if the key decision was right at the very beginning. Would you go so far as to say now that if somebody comes in and has a negative CT scan after having been included in the scanning group by whatever criteria you are using to decide who gets scanned, would you now send that patient home from the emergency department?

I guess a variation on that same question is with respect to the 2 patients with negative CT scans who ultimately underwent exploration. Would you now, after the results of this paper, say, well, those 2 people had a negative CT scan so no matter what happens to them down the line, the CT scan is 100% helpful and I am therefore not going to operate on them? That is really the acid test for this study. Are you going to go so far as to say, anterior abdominal stab wound, negative CT scan, nothing wrong with the patient, they can go home, and even if they do stay, we're not going to operate on them no matter what happens to them down the line?

And finally, a technical question: can you tell us a little bit about the CT scanners used, and have you found a difference between older-generation scanners and newer-generation scanners in terms of sensitivity or specificity?

Thomas V. Berne, MD, Los Angeles, Calif: My colleagues are the authors on this paper; I am standing in for Dr Demetriades.

Dr Stain, I thank you. You did a great job of reviewing this, and I think that you did a great job of pointing out some of the weaknesses of the paper. However, this is not the end of the line for this information. It really was a way of getting started to look at the problem, and it probably will take some kind of randomized study to make it so we can have hard statements about the management of these patients, particularly the question that Dr Wisner asked at the end. Are you willing to do a CT scan and then send the patient home immediately? I will get to the answer to that in a minute.

Just a little something about the CT scan readings. Our trauma surgeons do read a lot of CT scans, maybe 4 or 5 abdominal trauma CT scans a day, day after day after day. They are pretty good at figuring out most of these. Many if not most of the CT scans, even in the middle of the night, are seen by teleradiology and read by radiologists, and presumably, the report is representative of that reading.

To answer some of your specific questions, the question about what exactly were the CT scan results in patients who were correctly interpreted as having positive CT scan: fluid was one of them, in particular, isolated free fluid. Pneumoperitoneum was another finding. Solid organ injuries, particularly with evidence of bleeding, was the last finding.

What happened to the 3 patients with a positive CT scan who had delayed recognition of enteric injury after they demonstrated changes in their physical findings? We know that there was no postoperative morbidity, and these patients were discharged after uneventful postoperative courses.

In regard to your question about the standard measurement of abdominal stab wounds being physical examination, we were pretty content that all you had to do was serial examinations on those patients. We occasionally perform an IVP [intravenous pyelogram] or something, but we believed that your hands told you what was going wrong with those patients. But, the modern world of CT scanning and particularly the experience of CT scanning in penetrating trauma teased us into the idea of looking at CT scanning in stab wounds to see if we could get patients out of the hospital faster or get them to the operating room faster than they otherwise would have gotten there just based on our hands. In that regard, you asked a question about what was the morbidity and the mortality in the serial examination–only control group. There was no mortality, but we don't know about morbidity, and we can try and get that.

You also asked if we believe that there is any role for ultrasound. We haven't been terribly happy with ultrasound. We think that a positive ultrasound, which usually takes a fair amount of blood to get, is reliable most of the time. However, a negative ultrasound is not helpful in making a decision.

Dr Stain's last question asked if we are ready to come up with a statement about a group of patients who can be discharged from the emergency department based on a negative CT scan. I think the answer is not yet, but we do think that CT scanning can shorten the observation periods in patients with no physical or laboratory findings of peritonitis or blood loss. We have usually kept those patients 12 to 24 hours for routine serial examinations, and that probably could be shortened by half or more as we continue to be comfortable with the negative CT scan.

Dr Eastman, you mentioned the problem of patients with multiple stab wounds. These patients were mixed. Some of our patients did have multiple stab wounds. However, in every study we have done on both anterior and posterior stab wound cases, multiple stab wounds have not changed the reliability of nonoperative management strategies that we have used, even when we rely heavily on physical findings.

Regarding cost, it is very hard to get real good financial data at our county hospital. They use a standard per diem charge, so it isn't useful for us to do that kind of analysis. We would expect, though, that if we can shorten hospital stay, we would save money that way. Also, getting patients to the operating room earlier should ultimately save morbidity.

Dr Cornwell, first of all, I would like to correct your comment on the 1776 posterior abdominal stab wounds whose charts we reviewed. It was Dr Peck who actually did that. I just cracked the whip. Now regarding your question about the 4 patients with positive CT scans who had nontherapeutic operations and how we might change our algorithm, I think there is a little confusion about the nontherapeutic operations. There were 2 patients with a normal CT scan and nontherapeutic operations. They were taken to the OR [operating room] based on changes in the physical examination. Similarly, the 2 patients with abnormal CT scans who had nontherapeutic operations were also taken to the OR based on changes in the physical examination. The CT scan findings by themselves did not lead to nontherapeutic operations; rather, it was changes in the clinical examination. I do not think we need to revise our algorithm. We are not saying to replace physical examination with CT; rather, the combination of both seems to be quite useful. We still need more experience and more patients before we can make a definitive conclusion.

Dr Wisner asked why is it that some of the patients were selected for CT scans and others were not. There were just certain attendings who didn't want to get them. They believed our old line, which was that serial examinations were all that was needed. They didn't want to take the time or spend the money to do it, and they just didn't get the CT scans. But, I think in terms of the kinds of patients that ended up in each arm, it was pretty much random from that point of view.

Back to the big question about if the CT scan was negative, would we send a patient with no clinical signs of peritonitis or hemorrhage home? No, not immediately. However, if there had been a significant period of observation of maybe 6 hours or 8 hours, we would.

Finally, Dr Wisner, you asked about the type of CT scan we used. Unfortunately, we are still using older-generation CT scanners.