Validating the Western Trauma Association Algorithm for Managing Patients With Anterior Abdominal Stab Wounds: A Western Trauma Association Multicenter Trial

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Abstract: The optimal management of stable patients with anterior abdominal stab wounds (AASWs) remains a matter of debate. A recent Western Trauma Association (WTA) multicenter trial found that exclusion of peritoneal penetration by local wound exploration (LWE) allowed immediate discharge (D/C) of 41% of patients with AASWs. Performance of computed tomography (CT) scanning or diagnostic peritoneal lavage (DPL) did not improve the D/C rate; however, these tests led to nontherapeutic (NONTHER) laparotomy (LAP) in 24% and 31% of cases, respectively. An algorithm was proposed that included LWE, followed by either D/C or admission for serial clinical assessments, without further imaging or invasive testing. The purpose of this study was to evaluate the safety and efficacy of the algorithm in providing timely interventions for significant injuries.

Methods: A multicenter, institutional review board-approved study enrolled patients with AASWs. Management was guided by the WTA AASW algorithm. Data on the presentation, evaluation, and clinical course were recorded prospectively.

Results: Two hundred twenty-two patients (94% men, age, 34.7 years ± 0.3 years) were enrolled. Sixty-two (28%) had immediate LAP, of which 87% were therapeutic (THER). Three (1%) died and the mean length of stay (LOS) was 6.9 days. One hundred sixty patients were stable and asymptomatic, and 81 of them (51%) were managed entirely per protocol. Twenty (25%) were D/C'ed from the emergency department after (−) LWE, and 11 (14%) were taken to the operating room (OR) for LAP when their clinical condition changed. Two (2%) of the protocol group underwent NONTHER LAP, and no patient experienced morbidity or mortality related to delay in treatment. Seventy-nine (49%) patients had deviations from protocol. There were 47 CT scans, 11 DPLs, and 9 laparoscopic explorations performed. In addition to the laparoscopic procedures, 38 (48%) patients were taken to the OR based on test results rather than a change in the patient's clinical condition; 17 (45%) of these patients had a NONTHER LAP. Eighteen (23%) patients were D/C'ed from the emergency department. The LOS was no different among patients who had immediate or delayed LAP. Mean LOS after NONTHER LAP was 3.6 days ± 0.8 days.

Conclusions: The WTA proposed algorithm is designed for cost-effectiveness. Serial clinical assessments can be performed without the added expense of CT, DPL, or laparoscopy. Patients requiring LAP generally manifest early in their course, and there does not appear to be any morbidity related to a delay to OR. These data validate this approach and should be confirmed in a larger number of patients to more convincingly evaluate the algorithm's safety and cost-effectiveness compared with other approaches.

Key Words: Abdominal trauma, Penetrating trauma, Penetrating abdominal trauma, Stab wounds, Algorithm, Multicenter, Local wound exploration, Computed tomography, Diagnostic peritoneal lavage, Laparoscopy.

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The optimal management of patients with anterior abdominal stab wounds (AASWs) has been debated for decades. In 1960, Shaftan[1] first challenged the dictum of mandatory laparotomy (LAP) for AASWs, introducing a policy of "selective conservatism," i.e., management based primarily on clinical evaluation. This arose from the observation that of all AASWs, only 50% to 75% enter the peritoneal cavity—and of those, only 50% to 75% cause an injury requiring operative repair. Recognition of the morbidity and cost of unnecessary LAP has led to widespread adoption of selective management strategies.[2,3] However, to date, a unifying management algorithm for these patients has been lacking.

There is general agreement that shock, evisceration, and peritonitis constitute indications for immediate LAP. However, there is considerable divergence of opinion regarding the approach to the hemodynamically normal, asymptomatic patient. The desire to avoid nontherapeutic (NONTHER) LAP is tempered by the fear of morbidity related to a delay in intervention. In an attempt to identify significant injuries before clinical deterioration, a number of adjuncts have been used. Local wound exploration (LWE) was performed to determine whether the peritoneum had been violated, allowing many patients to be safely discharged (D/C'ed) from the emergency department (ED).[4–6] In the setting of a "positive" (+) LWE (i.e., penetration into the peritoneal cavity), diagnostic peritoneal lavage (DPL) was used to discern significant intra-abdominal injury.[5–8] Subsequently, technology-based approaches were introduced, including computed tomography (CT) scanning,[9,10] laparosocopy,[11,12] and ultrasonography (US).[13,14] The debate has continued to focus on the balance between invasiveness, resource utilization, and timely repair of significant injuries.[15–19]

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Recently, the Western Trauma Association (WTA) Multicenter Trials Group studied the practice patterns of trauma surgeons in an attempt to analyze whether any particular management strategy was superior or inferior to others in safety and resource utilization.[20] In that study, there were three notable findings: (1) if a patient was taken to the operating room (OR) primarily on the basis of a test result, irrespective of the patient's condition, the NONTHER LAP rate was high; (2) performing LWE in stable patients allowed the D/C of nearly half of these patients from the ED; and (3) nonoperative observation with serial clinical assessments (SCA) was safe, i.e., there was no apparent morbidity related to a potential delay to operative treatment of injuries. On the basis of all these findings, a unifying algorithm for the management of patients with AASWs was proposed (Fig. 1).[20] In this algorithm, patients who do not have an indication for immediate LAP undergo LWE. If the penetrating object did not enter the peritoneal cavity, the patient can be D/C'ed from the ED. If there is peritoneal violation, the patient is admitted for SCA. If there is a change in clinical status, the patient is either taken directly to the OR or undergoes further investigation to determine whether there is a significant injury requiring operative intervention. The purpose of this study was to prospectively evaluate the efficacy of this management guideline.

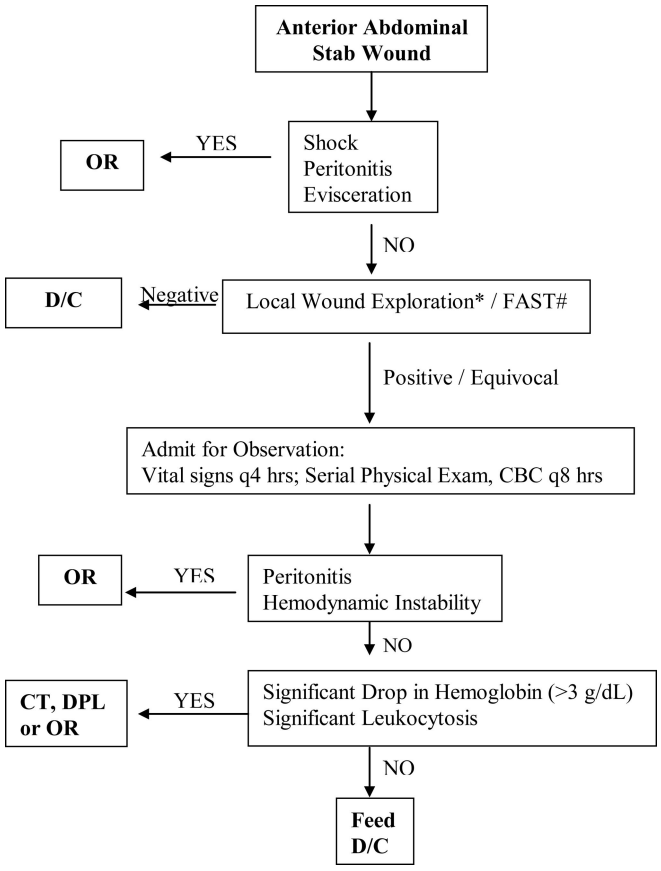

Figure 1. Clinical pathway for management of patients with AASWs. *Consider CT scan if patient is morbidly obese (BMI > 30) or wound tract is long and tangential. #FAST demonstrating hemoperitoneum may be used as evidence of peritoneal penetration, obviating the need for LWE. CBC, complete blood count.

METHODS

Over a 30-month period (May 2008–November 2010), four participating institutions prospectively collected data on patients with AASWs. The institutions were Community Regional Medical Center or University of California-San Francisco (UCSF)-Fresno, Denver Health Medical Center, Harborview Medical Center, and Oregon Health Sciences University. The study was approved by the Institutional Review Board at each of the participating institutions.

Criteria for inclusion in the study were age ≥16 years and an AASW. The anterior abdomen was defined as the area bordered by the costal margin superiorly, the groin creases inferiorly, and the anterior axillary lines laterally. Patients with back, flank, or presumed thoracoabdominal wounds were excluded, as diagnostic evaluations of these wounds might include CT, DPL, or laparoscopy. Other exclusion criteria included pregnancy and incarceration. Extra-abdominal injuries were not exclusionary, nor were intoxication. Patient demographics (excluding patient identifying information), injury details, clinical findings, diagnostic studies, interventions, and patient outcomes were recorded in a prospective fashion on a standardized data collection sheet, and the data sheets were sent to the principal investigator (WLB) for entry into a database.

The investigators agreed that patients with hypotension (systolic blood pressure <90 mm Hg) or other evidence of hemodynamic instability (shock), omental or intestinal evisceration, or peritonitis on physical examination should have prompt LAP. The investigators agreed in principle to manage the remaining asymptomatic patients per the WTA algorithm, although individual surgeons could alter the protocol based on their clinical judgment. With few exceptions, tests were performed within a relatively short (<2 hours) time frame. The Focused Abdominal Sonographic Examination for Trauma (FAST) was performed in select patients in the standard fashion.[13] A "positive" [(+)] FAST was defined as any evidence of hemoperitoneum. The LWE was performed in the ED, by the technique previously described.[6] In brief, local anesthetic was infiltrated into the stab wound area, and the wound was explored to determine its depth of penetration, extending the skin wound as necessary. A (+) LWE was defined as violation of the peritoneal cavity; a negative (−) LWE was one that proved that the peritoneal cavity had not been violated. The DPL technique, as previously described, involved an infraumbilical incision and passage of a catheter into the peritoneal cavity.[7] If the initial aspirate contained >10 mL gross blood, bile, succus entericus, or food, it was considered "grossly positive" and the patient was taken for LAP. If not, 1 L of warm normal saline was instilled and recovered by gravity siphonage and the lavage effluent sent for biochemical analysis. Criteria for (+) DPL included >100,000 red blood cells (RBCs)/mm^3, >500 white blood cells (WBCs)/mm^3, or elevated amylase or alkaline phosphatase or bilirubin in the lavage effluent.[21] There was no defined

protocol for CT scanning. All centers used multidetector-row ("16-slice" or greater) scanners, but contrast administration varied from intravenous only to "triple contrast" (i.e., intravenous, oral, and rectal). The protocol for SCA included clinical assessments as well as measurement of a complete blood count, every 8 hours for 16 hours to 24 hours.[19] A change in hemodynamic status, the development of peritonitis, evidence of ongoing blood loss, or leukocytosis were further investigated by CT scan, DPL, or LAP. In the absence of any of these findings, patients were D/C'ed after tolerating feeding. All patients were given follow-up appointments at the time of D/C.

The necessity of each LAP was determined by the operating surgeon to be negative, NONTHER, therapeutic-nonessential, or therapeutic-essential. The principal investigator entered and statistically analyzed all the data in a Microsoft Office Excel 2003 database. The principal management strategy (i.e., the one on which decisions were made to D/C, operate, or admit) was determined from the data sheets. Patients were grouped for certain analyses: negative and NONTHER were combined in the "NONTHER" group and therapeutic-nonessential and therapeutic-essential were combined into the "THER" group. Categorical variables were compared using χ^2 analysis.

RESULTS

Over the 30-month study period, a total of 222 patients were enrolled from the four centers. Two hundred nine (94%) were men and 13 women. The mean age was 34.7 years ± 0.3 years. The vast majority of wounds (95%) were caused by knives, and 64 (29%) patients had two or more wounds.

Immediate LAP

Immediate LAP was performed in 62 (28%) patients, 57 (92%) men and 5 women. Like the overall group, the mean age of this subset was 34 years, and 17 (27%) had more than one wound. The indications for LAP, and a breakdown of the therapeutic necessity, are shown in Table 1.

Fifty-four (87%) of the immediate LAPs were THER, and eight were deemed NONTHER. The most significant injury in each of the 62 patients included 33 hollow visceral, 5 vascular, 4 omental or abdominal walls, 3 solid organs, and 1 diaphragmatic injury. Twelve patients had no injuries other than the fascial defect; of these, eight repairs were considered THER by the surgeon, and the other four were considered NONTHER. Four had no injuries, and thus NONTHER LAP.

Of the 62 patients undergoing immediate LAP, 9 had FAST performed. All seven patients with (+) FAST and clinical indications for immediate LAP had a THER LAP. Of the two with (−) FAST, one had a THER LAP. Hospital length of stay (LOS) was 6.9 days after THER LAP and 3.4 days after NONTHER LAP ($p < 0.05$). Three (5%) of the patients died—one exsanguinated in the OR, one died of complications related to cirrhosis, and one, an 85-year-old man, had withdrawal of life-sustaining measures. Nine other patients had complications, including five surgical site infections, one postoperative bleed, one pancreatic fistula, one aspiration pneumonia, and one alcohol withdrawal.

TABLE 1. Immediate LAP: Indications and THER Efficacy

Indication	THER (N = 54)	NONTHER (N = 8)
Shock (11)	10	1
Shock + omental evisceration (3)	3	
Shock + intestinal evisceration (2)	2	
Shock + diffuse peritonitis (1)	1	
Omental evisceration (19)	17	2
Intestinal evisceration (8)	8	
Omental evisceration + peritonitis (3)	3	
Local peritonitis (1)		1
Diffuse peritonitis (4)	1	3
Other (10)*	9	1

* Hemorrhage from wound (5), impaled knife (3), and gastrointestinal bleed (2).

Management of Stable, Asymptomatic Patients

At the time of initial evaluation in the ED, 160 (72%) patients did not have an indication for immediate LAP. Of these, 152 (95%) were men and 8 women, with a mean age of 33 years, and 47 (29%) patients had multiple wounds. A flow diagram of the evaluation of the patients is provided in Figure 2.

Management Per Protocol

LWE was performed according to protocol in 109 (68%) eligible patients. The other 51 patients underwent CT scanning (47) or FAST (4) (see below). Twenty (18%) patients were D/C'ed from the ED after (−) LWE (Table 2). In seven (6%) patients, LWE was unsuccessful in determining the depth of penetration. Five of them underwent CT scan to further assess depth of penetration, but all seven were still admitted for SCAs. Fifty-four additional patients were admitted after (+) LWE. Of these 61 patients admitted for SCAs, 11 (18%) were subsequently taken for LAP (Table 2). All "delayed" LAPs occurred within 4 hours except one, which occurred at 15 hours after initial patient arrival. Six were

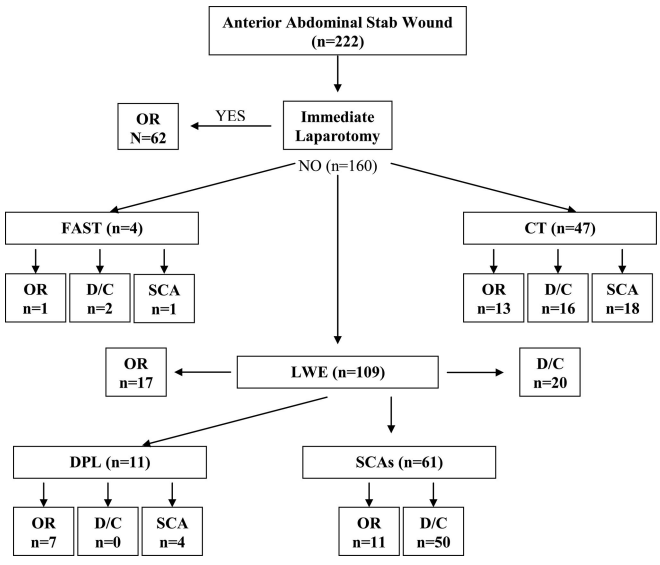

Figure 2. Flow diagram for patients.

TABLE 2. Summary of Outcomes Associated With Primary Management Strategies

STRATEGY	N	ED D/C	OR	NONTHER LAP	THER LAP/NEG TEST
FAST	4	2 (50%)	1 (25%)	0 (0%)	8/53 (15%)
CT	47	16 (34%)	13 (28%)	4 (31%)	0/28
LWE	109	20 (18%)	17 (16%)	9 (53%)	0/109
DPL	11	0 (0%)	7 (64%)	4 (57%)	1/9 (11%)
SCA	50	—	11 (22%)	2 (18%)	0/50

N, number of patients managed primarily by strategy; ED D/C, number of patients D/C from ED based on the results; OR, number of patients taken to the OR based on the results; THER LAP/NEG TEST, patients ultimately requiring THER LAP who initially had a normal test result.

TABLE 3. Summary of SENS, SPEC, PPV, and NPV of Tests for THER LAP

TEST	N	PTP	SENS	SPEC	PPV	NPV
FAST	57	11 (19%)	36%	96%	67%	86%
CT	47	9 (19%)	89%	82%	53%	97%
LWE	109	20 (18%)	100%	22%	22%	100%
DPL	11	3 (27%)	67%	100%	100%	89%
SCA	61	9 (15%)	100%	96%	82%	100%

N, total number of patients having the test who did not have indications for immediate LAP; PTP, pretest probability, number (percentage) of patients having that test who ultimately had a THER LAP.

TABLE 4. CT Findings and Management Among the 47 Patients Undergoing CT Scanning

CT Finding	THER LAP	NONTHER LAP	SCA	D/C
Signs of HVI	3	1	1	0
Solid organ injury	2	2	4	0
Abdominal wall or omental bleeding	3	0	0	0
Fascial defect	1	1	1	0
Superficial penetration	0	0	12	16

HVI, hollow viscus injury (signs include bowel wall irregularity, mesenteris stranding, and hemo-pneumoperitoneum).

taken to the OR for the development of "peritonitis" on examination; four of them had hollow viscus injuries, and the other two had NONTHER LAP. Three developed shock, all had liver injuries, and all had THER LAP. One patient had delayed evisceration after a coughing fit and was found to have a gastric injury. One patient had ongoing bleeding from the wound and had THER LAP for abdominal wall and liver bleeding. There were no complications among these delayed LAP patients. Among the patients admitted for SCAs, the probability of requiring THER LAP was 15%. The sensitivity (SENS) and specificity (SPEC) of SCAs were 100% and 96%, respectively; the positive predictive value (PPV) and negative predictive value (NPV) were 82% and 100%, respectively (Table 3).

In sum, 81 patients, 51% of those eligible, were managed entirely per protocol. Of these 81, 20 (25%) were D/C'ed from the ED, and 11 (14%) were taken to the OR for LAP. Two (2%) of the protocol group underwent NONTHER LAP, and no patient experienced morbidity or mortality related to delay to treatment.

Deviations From Protocol

In 79 (49%) patients, there was deviation from the algorithm (Fig. 2). Fifty-one patients did not undergo LWE: 47 had CT scanning and 4 patients were triaged based on FAST alone. Twenty-eight additional patients were managed variably after LWE: 11 underwent DPL, and 17 who had (+) LWE were taken directly to the OR for LAP.

Computed Tomography Scanning

CT scanning was used as the primary decision-making tool in 47 (29%) patients (Fig. 2). Sixteen (34%) of the 47 patients were D/C'ed from the ED based on normal CT findings. Conversely, LAP was performed because of CT findings in 13 (28%) patients. Of these, four (31%) were NONTHER (Table 2). A breakdown of CT findings and patient outcomes is depicted in Table 4. Of five patients with signs of hollow viscus injury (bowel irregularity, mesenteric stranding, or significant hemo-pneumoperitoneum), three had THER LAP, one had NONTHER LAP, and one was managed nonoperatively. Eight patients had solid organ injury on CT. Four were managed nonoperatively, whereas three had THER LAP and one had NONTHER LAP. Three patients were taken to the OR because of abdominal wall or omental bleeding, and all were felt by the surgeon to have had THER LAP. Three patients were taken to the OR because of fascial defect; only one of them had THER LAP. Twenty-eight (60%) of the 47 patients who underwent CT had no evidence of intraperitoneal injury or fascial penetration on the CT scan, but only 16 (57%) of them were D/C'ed from the ED. In the CT-evaluated group, with a pretest probability of THER LAP of 19%, the SENS, SPEC, PPV, and NPV of CT were 89%, 82%, 53%, and 97%, respectively (Table 3).

Ultrasonography

Ultrasound (FAST) was performed and recorded in 57 (33%) stable, asymptomatic patients. Four patients were managed solely on the basis of FAST (Fig. 2). One was taken to the OR for LAP based on (+) FAST, in the absence of shock, evisceration, or peritonitis (Table 2). That patient was a hemophiliac and had a THER LAP. Two patients with (−) FAST were D/C'ed from the ED and one was admitted for SCAs without further testing. Fifty-three patients had FAST followed by some other test. Five of them had (+) FAST and were evaluated with another test, and ultimately all five were taken to the OR. Three of them had THER LAP and two (33%) had NONTHER LAP. Forty-eight patients had (−)

TABLE 5. DPL Findings and LAP Results*

Patient	RBCs/mm^3	WBCs/mm^3	LAP?	NONTHER/THER?	Injuries
1	1,43,453	224	Yes	THER	Psoas hematoma
2	1,33,000	197	Yes	THER	Small bowel
3	59,000	43	Yes	THER	Small bowel
4	42,077	99	Yes	NONTHER	Abdominal wall
5	11,281	45	Yes	NONTHER	Liver
6	3,747	0	Yes	NONTHER	Retroperitoneal hematoma
7	512	0	Yes	NONTHER	None
8	766	0	No	—	—
9	123	15	No	—	—
10	108	0	No	—	—
11	24	0	No	—	—

* No patient had a grossly positive lavage, and no patient had elevated levels of enzymes in lavage effluent.

FAST and underwent further testing. Of them, seven (14%) ultimately had a THER LAP. In this population of stable, asymptomatic patients, the SENS of FAST was 36%, SPEC 96%, PPV 67%, and NPV 86% (Table 3).

Diagnostic Peritoneal Lavage

Eleven patients had DPL after (+) LWE (Table 5). No patient had grossly positive initial aspiration. On lavage fluid analysis, two patients had RBC >100,000/mm^3; both had THER LAP. No other patient had RBC >100,000/mm^3, WBC >500/mm^3, or elevated enzyme levels. Five other patients were taken to the OR based on DPL results, with RBC ranging from 512/mm^3 to 59,000/mm^3 and WBC ranging 0/mm^3 to 99/mm^3. One of the five, with RBC 59,000/mm^3 and WBC 43/mm^3, had a THER LAP. The SENS and SPEC of DPL were 67% and 100%, respectively, and the PPV and NPV were 100% and 89%, respectively (Table 3).

LAP for (+) LWE

Seventeen patients were taken to the OR based on (+) LWE, with no other specific indications (Fig. 2). Of these, eight were deemed THER LAP by the operating surgeon, although six of the eight required only repair of the fascial defect. The other nine (53%) had NONTHER LAP (Table 2). Among those undergoing LWE, with a pretest probability of THER LAP of 18%, the SENS was 100%, SPEC 54%, PPV 35%, and NPV 100% (Table 3).

Laparoscopy

Fifteen (9%) stable patients underwent laparoscopy, of which one was therapeutic.

Summary

In sum, 79 (49%) patients had deviations from protocol. Among these 79 patients, there were 47 CT scans, 11 DPLs, and 9 laparoscopic explorations performed. Aside from the laparoscopic procedures, 38 (48%) patients were taken to the OR based on test results rather than a change in the patient's clinical condition. Seventeen (45%) of these patients had a NONTHER LAP. Eighteen (23%) patients were D/C'ed from the ED. A comparison of patients managed according to protocol with patients whose management deviated from protocol is offered in Table 6.

LAP Findings and Outcomes

A total of 111 (50%) of the 222 patients had LAP. Eighty-four (38%) of the overall group had a THER LAP, including 87% of those who had indications for immediate LAP and 30 (19%) of 160 who did not. Of all the LAPs, 27 (24%) were NONTHER. Of those taken for immediate LAP, 8 (13%) were NONTHER. In contrast, the NONTHER LAP rates were 45% (17 of 38) in patients taken for LAP based on test results (FAST, CT, LWE, DPL) and 18% (2 of 11) in patients taken for LAP based on a change in SCAs ($p < 0.05$). The mean LOS of patients undergoing LAP was 5.5 days ± 1.3 days (range, 1–52), and the mean LOS of those undergoing THER LAP was 6.1 days ± 1.3 days. The mean LOS did not differ significantly among those having immediate THER LAP (6.9 days ± 1.3 days), versus THER LAP after CT or DPL (6.1 days ± 1.0 days), or THER LAP after a period of SCAs (3.8 days ± 0.9 days) (p = ns). The LOS after a NONTHER LAP was 3.6 days ± 0.8 days. The only reported morbidity among patients undergoing LAP following testing was a case of alcohol withdrawal and pneumonia in a patient who had NONTHER LAP after DPL. Most

TABLE 6. Comparison of Patients Managed According to Protocol With Patients Whose Management Deviated From Protocol

	Protocol	Nonprotocol
Patients (n)	81	79
ED D/C	20 (25%)	18 (23%)
LAP	11 (14%)	38 (48%)*
NONTHER LAP (% of LAP/ % of total)	2 (22%/2%)	17 (45%/21%)*
CT scan	0	47 (59%)*
DPL	0	11 (14%)*
Laparoscopy	0	9 (11%)*
Delay-related morbidity	0	1 (1%)

* $p < 0.05$.

patients (77%) admitted for observation stayed for 1 day or less. Prolonged stays were generally attributed to psychiatric or social issues, or to the need for chest tube management.

DISCUSSION

In this study, we sought to evaluate the WTA algorithm for management of patients with AASWs. The results of this study were remarkably consistent with the first WTA AASW study.[20] Compared with the first WTA study, the patient demographics in this series were similar, as were the percentage of patients who underwent immediate LAP (28% vs. 23%). In addition, the overall percentage of patients who ultimately required THER LAP was nearly equal: 38% versus 36%. In fact, these data were consistent with the published literature of the past four decades,[1,22] and therefore suggest the applicability of these data to general populations of AASW victims. The conclusions are largely the same as in the prior WTA study, but a number of points are worthy of further discussion.

There is uniform agreement that immediate LAP is warranted for certain indications. Shock is one clear indication for emergent abdominal exploration; indeed, in this series, 94% of patients presenting with shock had THER LAPs. Evisceration is also a well-accepted indication for immediate LAP. In this study, intestinal evisceration was associated with THER LAP in 100% of cases. There has been some debate regarding omental evisceration. The Denver General group challenged the concept of routine LAP for patients with omental evisceration many years ago, based on their experience that 29% of such patients had no significant intra-abdominal injuries.[6] However, some groups have argued the opposite, even though their incidences of significant intra-abdominal injury have been similar (65–80%).[23,24] In the first WTA series,[20] 16 (76%) of 21 patients with isolated omental evisceration had THER LAPs. These numbers are remarkably consistent and do not settle the argument. However, it is the feeling of many of the authors that because the patient has, at the very least, a symptomatic hernia, it should be repaired and given the relatively high likelihood (65–80%) of finding a significant intra-abdominal injury, and it is best done in the OR rather than in the ED. In this series, 89% of patients with isolated omental evisceration had THER LAP. This high rate of THER LAP could reflect bias among the operating surgeons, but it still reinforces evisceration as an indication for LAP. "Peritonitis" is a relatively subjective finding, and in this series, if a patient had "peritonitis" without either shock or evisceration, the NONTHER LAP rate was 80% (Table 1). We still contend that it is difficult to justify delaying intervention in a patient with peritonitis, but an experienced clinician should attempt to differentiate true peritoneal signs from tenderness related to the wound. This is true of SCA as well: the attending surgeon must corroborate the finding of peritonitis before committing a patient to LAP. In this series, continued hemorrhage from the wound, impaled stabbing objects, and gastrointestinal hemorrhage all proved to be good reasons to proceed to immediate LAP, as the THER LAP rate was 90%.

Once the hemodynamically unstable and symptomatic patients are selected out, the number requiring THER LAP decreases considerably. In this series, THER LAP was required in only 30 (19%) of 160 patients who did not have indications for immediate LAP. A major goal of the WTA algorithm was to minimize excessive resource utilization in the management of stable, asymptomatic patients with AASWs. Given the excessive LOS, morbidity, and cost associated with NONTHER LAP, it is not unreasonable to strive for a 0% NONTHER LAP rate. However, surgeons are highly motivated to avoid missed injuries and the potential morbidity of delayed interventions.

In designing the WTA management algorithm, we attempted to reconcile these concerns. Based on the recognition that only 50% to 75% of AASWs actually enter the peritoneal cavity, LWE is performed to determine the depth of penetration.[1,6,22] If the peritoneal cavity is not violated, the patient can be D/C'ed from the ED, as the NPV of (−) LWE is 100%. However, in clinical practice this does not always occur. In the first WTA trial, 41% of patients had (−) LWE but only 23% were D/C'ed from the ED.[20] In this series, 20 (18%) of patients were D/C'ed from the ED after (−) LWE.

Another area of variation is the management of patients with (+) LWE. It was observed decades ago that only 50% to 75% of peritoneal penetrations result in significant injury,[1,6,22] and the first WTA trial reinforced that the large majority of these patients manifest the injury at the time of presentation.[20] Although some groups currently recommend LAP based on peritoneal violation,[25] the WTA algorithm called for admission and SCAs of patients who are stable and asymptomatic. However, in this series, 28 (31%) of 89 patients with (+) LWE were either taken directly to the OR or subjected to DPL. Given that 13 (46%) of these were NONTHER LAPs, it reinforces the concept that LAP is not necessary simply based on peritoneal penetration. In fact, in this series, of 160 patients who did not have indications for immediate LAP, 111 were found to have peritoneal violation by either CT or LWE—but only 30 (27%) required THER LAP and 7 (23%) of these were to repair fascial defects. That said, it is important to recognize that LWE must be technically adequate to be used in this regard. A simple probing of the stab wound is not reliable to rule out peritoneal violation.[26] The procedure requires adequate exposure of the wound to follow the tract of the stabbing object.[6] Further, there was some variation in defining a (+) LWE in both of the WTA trials. Some surgeons apparently consider violation of anterior fascia to constitute a (+) LWE. In this series, in 15 patients, the depth of penetration was considered "(+)" but was recorded as "no deep penetration," "muscle," or "anterior rectus sheath." These interpretations ignore the muscle and posterior fascia and do not correlate with violation of the peritoneal cavity. This remains an area for improved resource utilization, as a stricter definition of (+) LWE, i.e., violation of the posterior fascia and/or peritoneum, would likely increase the number of patients eligible for ED D/C. The surgeon must keep in mind that LWE may be compromised in very obese patients or those with a tangential wound tracking through muscle layers. In these patients, CT scan-

ning may be helpful in attempt to follow the trajectory, but one must be cognizant of the limitations of CT.

With advancing imaging technology and whole-body techniques, CT scanning is being used more and more broadly in trauma, supplanting plain radiography and arteriography for many applications.[27–29] Not surprisingly, in the previous WTA series,[20] CT was performed more frequently than any other test. In the setting of penetrating back or flank wounds, CT can demonstrate the trajectory and depth of penetration and is thus useful in guiding management.[30] But based on the two WTA trials, the value of CT in the management of AASWs is dubious. The anterior abdominal wall is generally much thinner than the back, and it can be difficult to ascertain whether the peritoneum has been breached by a small knife blade. This fact was emphasized in the first WTA trial, in which eight patients with no CT evidence of intraperitoneal injury ultimately required THER LAP.[20] This was not as much of an issue in this study, as the NPV of CT was 97%, but it reinforces that CT probably should not be used to D/C patients from the ED. Similarly, CT should not be used as the sole determinant of the need for LAP. In the two WTA trials, 28% to 33% of stable, asymptomatic patients were taken to the OR based on CT findings, and 24% to 31% of them underwent NONTHER LAP. When one considers that the mean charge for CT in the study institutions exceeds $2000, it is difficult to justify it because it does not increase ED D/C rates, does not obviate the need for admission and SCA, and often leads to NONTHER LAP.

DPL has been used to identify significant peritoneal injuries after AASWs for at least 30 years.[5–8] Although DPL still has a role in trauma care,[31] it has some noteworthy limitations. It is an invasive procedure with a risk of iatrogenic injury, and therefore a (−) result still requires a period of observation. Furthermore, declining use may be associated with a greater risk of technical complications. In addition, DPL can be associated with a relatively high number of NONTHER LAPs, such as when there is moderate bleeding from the wound, omentum, or liver.[16,32] The RBC threshold has been debated over the years.[8,16,32] The current, generally accepted threshold for positivity (>100,000 RBCs/mm^3), was selected based on balancing missed injuries with NONTHER LAPs. Lowering the threshold to 50,000, 10,000, or 1,000 RBCs/mm^3 increases the number of NONTHER LAPs with diminishing returns in terms of finding occult injuries. In this series, if a threshold of >50,000 RBCs/mm^3 were used, it would have detected all three patients who required THER LAPs. Unfortunately, in this series, it appears that the threshold for (+) DPL was extremely low, resulting in four NONTHER LAPs (Table 5).

Difficulties in interpreting the DPL WBC count have also been widely discussed, and to date, there is no threshold that offers 100% accuracy.[33–35] In this series, as in the first WTA trial, two patients with hollow viscus injuries had a subthreshold lavage WBC count (i.e., <500 WBCs/mm^3). Recognizing the problem of equivocal DPL results, measurements of amylase and alkaline phosphatase have been suggested to improve the SENS of DPL.[21,36,37] These results, like the WBC count, are somewhat dependent on the timing of DPL; furthermore, the enzymes may not reliably diagnose colon injury.[34,36,37] Unfortunately, in this series, enzyme levels were no better than WBC counts at identifying bowel injuries. In contrast to the previous WTA trial, the issue with DPL in this series was not false (+) studies, but rather LAP based on DPL when results were below the usual thresholds. It still does not appear that DPL is going to be particularly useful for AASWs. On the basis of the reports by Dallas[8] and Denver,[16] false (−) results (i.e., WBC <500/mm^3) are found in 3% to 10% of patients with hollow viscus injuries when DPL is performed relatively soon after injury. However, waiting for 6 hours to 7 hours may result in a 35% incidence of false (+) studies based on high WBC counts.[33] Ultimately, based on the data from the WTA studies, the vast majority of patients will clinically manifest the need for LAP, so the role for DPL in managing patients with AASWs is questioned.

Although FAST is reliable for detecting intraperitoneal fluid, its SENS for significant injury in the setting of penetrating abdominal trauma has been reported to be as low as 18%.[38] Consequently, it is not recommended as a triage tool for either ED D/C or LAP in a stable, asymptomatic patient.

In this series, as in the previous WTA trial and other studies,[20,39] it does not appear that laparoscopy has a role in the management of patients with AASWs. Employing laparoscopy to look for peritoneal violation is not necessary, for reasons discussed above. Moreover, the procedure does not appear to be cost-effective, because it is rarely therapeutic (only 1 of 24 patients in the two WTA trials). We think that an asymptomatic patient should simply be observed with SCAs and avoid the expense and possible complications related to laparoscopy.

To the argument that the finding of significant injuries leads to earlier LAP and avoids morbidity associated with delayed intervention, we submit that (1) all but one patient who required THER LAP while being managed with SCAs exhibited their clinical change within 4 hours of initial presentation; and (2) the experience of the WTA trials shows that there is no morbidity associated with any delay to operative management. In fact, in this series, the mean LOS was 2 days shorter for patients having THER LAP after a period of SCAs, compared with those undergoing THER LAP immediately, or after CT or DPL. We harken back to Nance and Cohn,[22] who wrote (emphasis theirs):

> … the incidence of complications was the *same* in the patients operated on immediately and in those whose surgery was delayed. Further, the incidence of complications reflected more the *nature* of the injury (i.e., whether or not a hollow viscus was entered) than it did a delay in surgery. This observation is confirmed in the data of Wilson and Sherman[40] and in the report of McNabney and McCanse.[41] The oft-expressed fear that a delay in exploration will increase morbidity and/or mortality is not supported by these nor by any other data we can find.

Of note, in contemporary series delays of 24 hours to 72 hours are not associated with any specific morbidity in the absence of confounding factors.[42]

On the basis of the results of this study, admission for SCAs still appears to be safe. Eleven patients were taken for

LAP when their clinical condition appeared to change. Nine of them had a THER LAP. Eight of the nine manifested within 4 hours and the other patient manifested 15 hours after injury. Among these patients, there was no notable morbidity and their LOS after THER LAP was 4.2 days. This compares favorably with all the other patients undergoing THER LAP in this study. Those taken for immediate LAP had a LOS greater than 6 days, as did those who had a LAP based on CT or DPL results. Although the numbers are too small to draw any definitive conclusions, this study represents a follow-up to the first WTA study,[20] which was in turn prompted by a previous report of one of the authors (WLB).[19] In the aggregate of these studies, with patients managed using similar protocols, there is no demonstrable morbidity related to SCAs and LAP based on clinical condition.

A major argument raised against this management protocol is that SCAs are too difficult in this era of restricted resident duty hours. We have not found this to be an issue. The initial decision to admit and observe a patient rather than go directly to the OR should be made by a senior-level surgeon. At the time this decision is made, it is recommended that multiple members of the trauma team examine the patient and review the pertinent clinical data. Given that the vast majority of these patients manifested a clinical change within 4 hours of initial presentation, some or all of the original team members are likely to be available to compare the clinical assessment.

There are several limitations of this study, with a major one being the self-reporting by surgeons of the therapeutic benefit of the operation as well as the complications. Without rigorously controlled data collection, it is possible that the therapeutic benefit of certain operations was overstated and complications were underreported. It is also possible that some patients D/C'ed from the ED after a (−) LWE or CT were overlooked and not included in this study. The numbers of patients are still relatively small to draw firm conclusions. However, one of the notable findings is that the data were so consistent with the previous WTA study as well as the aggregate of published literature on AASWs.

We conclude from this study that the WTA algorithm outlines a management strategy that minimizes unnecessary testing and NONTHER LAPs, without any demonstrable detrimental effect in terms of delayed diagnosis or operative intervention. We recommend further evaluation of this algorithm in larger populations of patients to confirm its utility as a cost-effective approach to patients with AASWs.

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