Management guidelines for penetrating abdominal trauma
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Introduction
The optimal management of patients with penetrating abdominal injuries has been debated for decades, since mandatory laparotomy (LAP) gave way to the concept of ‘selective conservatism’ [1]. There is little disagreement that hemodynamic compromise, peritonitis, impalement, or evisceration mandate prompt LAP. But there is considerable divergence of opinion regarding the approach to a hemodynamically stable, asymptomatic patient. Furthermore, the concept of selective nonoperative management has recently been applied to gunshot wounds (GSWs). The current review will focus on the selective nonoperative management of penetrating abdominal trauma.

Mandatory laparotomy and its consequences
Mandatory LAP was considered the standard of care for abdominal stab wounds until 1960 and for GSWs until much more recently. Whereas LAP may be considered the most conservative, safest approach to identify and treat all injuries in a timely manner, it is unnecessary in as many as 70% of abdominal stab wound cases [1]. Moreover, there are significant consequences of unnecessary LAP in terms of complication rates, length of stay (LOS), and costs. Renz and Feliciano [2] performed the first prospective study of patients undergoing unnecessary LAP after trauma. They concluded the following: the mean LOS following an unnecessary LAP for trauma was 8 days; 41% of patients had a complication resulting from the LAP; the mean LOS among patients experiencing a complication was 9 days, compared with 5 days in those without a complication; compared with patients without associated injuries, patients with associated injuries had higher complication rates (61 vs. 26%) and LOS (11 vs. 5 days); and mean LOS following completely negative LAP was still 4.7 days. Retrospective studies have reported similar outcomes, leading to the conclusion that unnecessary LAP should be avoided [3].

Purpose of review
Patients with penetrating abdominal trauma are at risk of harboring life-threatening injuries. Many patients are in need of emergent operative intervention. However, there are clearly patients who can be safely managed nonoperatively. This review evaluates the literature to identify management guidelines for patients with penetrating abdominal trauma.

Recent findings
Accumulating evidence supports nonoperative management of patients with stab wounds to the thoracoabdominal region, the back, flank, and anterior abdomen. Furthermore, select patients with gunshot wounds can be safely managed nonoperatively.

Summary
Shock, evisceration, and peritonitis warrant immediate laparotomy following penetrating abdominal trauma. Thoracoabdominal stab wounds should be further evaluated with chest X-ray, ultrasonography, and laparoscopy or thoracoscopy. Wounds to the back and flank should be imaged with CT scanning. Anterior abdominal stab wound victims can be followed with serial clinical assessments. The majority of patients with gunshot wounds are best served by laparotomy; however, select patients may be managed expectantly.

Keywords
abdominal trauma, guideline, nonoperative management, penetrating trauma, thoracoabdominal trauma

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the thoracoabdomen (from the nipple line to the costal margin). The approach of each of these regions varies.

**Thoracoabdomen**

Injuries in the thoracoabdominal region may create injuries in both the chest and the abdomen, including the diaphragm. Whereas blunt diaphragmatic injuries may be relatively easy to diagnose, penetrating injuries are typically occult. The presence of a small knife wound in the diaphragm can elude detection by the most sensitive imaging modalities. A prospective series from the Maryland Shock-Trauma Center included 50 patients with CT findings suggesting a potential diaphragm injury [4]. The authors considered the CT findings to be ‘specific’ in just 40% of patients; such findings included contiguous organ injury on either side of the diaphragm, and herniation of abdominal fat through a defect in the diaphragm. ‘Non-specific’ findings included a wound tract extending up to the diaphragm, thickening of the diaphragm from blood or edema, and apparent defect in the diaphragm without herniation or adjacent hematoma. Seventeen (34%) patients had surgical evaluation of the diaphragm – LAP in 12 and thoracoscopy in 5 – and diaphragmatic injury was confirmed in only 12 (71%) of that subgroup. Of note, two patients with ‘specific’ findings had no diaphragmatic injury.

Diagnostic peritoneal lavage (DPL) has been employed to help detect diaphragmatic wounds. Moore and Marx [5] proposed a red blood cell (RBC) threshold of 5000/mm$^3$, as this level was not likely to be ascribed to the procedure and thus implied at least a diaphragmatic defect. More recently, direct assessment of the diaphragm with thoracoscopy or laparoscopy has been suggested. Uribe and colleagues [6] performed routine thoracoscopy and found diaphragmatic injuries in 32% of patients with penetrating thoracoabdominal injuries. On subsequent LAP they found that 89% of the patients with diaphragmatic injuries had intra-abdominal injuries that required surgical repair. In the 1990s, a number of investigators attempted to clarify the role of laparoscopy. Murray and colleagues [7] prospectively studied 110 patients with penetrating injuries to the left lower chest, and found occult diaphragmatic injuries in 26 (24%) of them. Friese and colleagues [8] confirmed these results, also finding diaphragmatic injuries in 24% (8 of 34) of patients with penetrating thoracoabdominal injuries. They further evaluated the accuracy of laparoscopy by following it with LAP, and found just one missed injury.

A reasonable management strategy for stable patients with penetrating thoracoabdominal trauma is outlined in Fig. 1. An upright chest X-ray and Focused Abdominal Sonographic Examination for Trauma (FAST) are performed. If both are normal, DPL is performed with a RBC threshold of 5000/mm$^3$. A (+) DPL mandates LAP or laparoscopy. If there is a hemothorax or pneumothorax with (-) FAST, thoracoscopy is performed. Since the patient already requires tube thoracostomy, this adds little additional morbidity. If there is a diaphragm injury

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**Figure 1 Management of stable patients with penetrating thoracoabdominal trauma**

- Penetrating thoracoabdominal trauma
  - Upright CXR
    - FAST
      - CXR (+), FAST (-)
        - DPL
          - >5000 RBC/ml
            - Enteric contents
              - Laparoscopy/ laparotomy
              - (+) Diaphragm injury
                - Laparoscopy/ laparotomy
                - Laparoscopy/ laparotomy
                - Tube thoracostomy
                - Laparoscopy/ laparotomy
      - CXR (-), FAST (+)
        - Thoracoscopy
      - CXR (-), FAST (-)
        - LAP, diagnostic peritoneal lavage
      - CXR (+), FAST (-)
        - Normal
      - CXR (+), FAST (+)
        - Enteric contents
          - Laparoscopy/ laparotomy
          - Laparoscopy/ laparotomy
          - Laparoscopy/ laparotomy

CXR (+), hemothorax or pneumothorax; DPL, diagnostic peritoneal lavage; FAST (+), hemoperitoneum.

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With improved sensitivity of multidetector-row CT (MDCT), it is generally possible to follow the wound tract and get an accurate assessment. Ultimately, the surgeon must exercise good clinical judgment in determining the most appropriate course of action.

**Back/flank**

Penetrating trauma to the back or flank is associated with a lower likelihood of significant injury. However, these injuries can pose a special problem because of the difficulty in clinically evaluating the retroperitoneal organs with physical exam and FAST. In a stable patient, CT scanning is reliable for excluding significant injury [9,10]. Stable patients may be managed according to CT scan findings (Table 1). Recently, the necessity of rectal sinography has been questioned [11]. With improved sensitivity of multidetector-row CT (MDCT), it is generally possible to follow the wound tract and get an accurate assessment. Ultimately, the surgeon must exercise good clinical judgment in determining the most appropriate course of action.

**Anterior abdomen**

It is recognized that of all anterior abdominal stab wounds (AASWs), only 50–75% enter the peritoneal cavity, and of those, only 50–75% cause an injury requiring operative repair. Thus, only a minority of stable, asymptomatic patients would be expected to require operative intervention [12]. In 1960, Shaftan [1] first challenged the dictum of mandatory LAP for AASWs, introducing a policy of ‘selective conservatism’, that is, management based primarily on clinical evaluation. This approach was promulgated by the groups at Kings County Medical Center [1] and Charity Hospital [13]. But concerns about delays to intervention led to techniques aimed at determining whether the peritoneum had been entered, including sinography [14] and local wound exploration (LWE) [12,15]. Although sinography proved less useful [16], LWE allowed many patients to be safely discharged from the emergency department (ED) if the peritoneal cavity was not violated [12]. On the other hand, it was realized that the decision for LAP should be based not just on peritoneal penetration, but on the presence of a significant intraperitoneal injury. This led to the adoption of DPL to look for evidence of significant intra-abdominal injury in the setting of a ‘positive’ (+) LWE (i.e. penetration into the peritoneal cavity) [12,15,17]. Through the 1990s, technology-based approaches were introduced, including laparoscopy [18,19], CT scanning [20], and ultrasonography [21]. The debate has continued to focus on the balance between invasiveness, resource utilization, and timely repair of significant injuries [22–24].

**Multicenter study of anterior abdominal stab wound management**

A recent study advocating serial clinical assessments (SCAs) [25] prompted discussion of this issue among members of the Western Trauma Association (WTA) Multicenter Trials Group. It was agreed that there was no uniformity in this area, and that an organized outcomes analysis was warranted. A prospective study was performed to determine whether any particular management strategy stood out as being either superior or inferior, compared with other strategies, in the evaluation and management of asymptomatic patients with AASWs [26].

Over a 2-year period (2006–2007), 11 participating institutions prospectively collected data on patients with AASWs. Each institution/surgeon followed its own established protocol or clinical judgment. There was no aspect of the management of the patient that was dictated by the study. Criteria for inclusion in the study were age at least 16 years and an AASW. The anterior abdomen was defined as that 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. Extra-abdominal injuries were not exclusionary, nor was intoxication.

In general, the WTA investigators agreed that patients with hypotension (systolic blood pressure <90 mmHg) or other evidence of hemodynamic instability (‘shock’), omental or intestinal evisceration, or peritonitis on physical exam should have prompt LAP. The remaining asymptomatic patients were then managed per institutional protocol or surgeon’s judgment, with tests performed ad lib. For the most part, tests were carried out within a relatively short (<2 h) time frame. The FAST was performed in select patients in the standard fashion [21]. A (+) FAST was defined as any evidence of hemoperitoneum. The LWE was performed in the ED, by the technique previously described [12]. In brief, local anesthetic was infiltrated into the wound area, and an incision was made that allowed adequate evaluation of

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Table 1: Classification and management recommendations for CT scan findings following penetrating flank/back injuries

<table>
<thead>
<tr>
<th>Risk</th>
<th>CT findings</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>No penetration</td>
<td>Discharge from ED</td>
</tr>
<tr>
<td></td>
<td>Penetration into subcutaneous tissue</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Penetration into muscle</td>
<td>Serial clinical assessments</td>
</tr>
<tr>
<td></td>
<td>Retropertitoneal hematoma, not near critical structure</td>
<td>Laparotomy</td>
</tr>
<tr>
<td></td>
<td>Contrast extravasation from colon</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Major extravasation from kidney</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hematoma adjacent to major retropertitoneal vessel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Free air in retroperitoneum, not attributed to wounding object</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Evidence of injury above and below diaphragm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Free fluid in peritoneal cavity</td>
<td></td>
</tr>
</tbody>
</table>

Adapted from Himmelman et al. [9].

As expected in 24% of patients [7,8] – LAP or laparoscopy is performed to exclude injury below the diaphragm [6]. If there is a (+) FAST, LAP or laparoscopy is necessary.
the wound tract to its distal extent. A (+) LWE was defined variably as violation of either the anterior or posterior fascia; a negative (−) LWE was one that revealed intact fascia and proved that the peritoneal cavity had not been violated. The DPL technique involved an intraumbilical incision and passage of a catheter into the peritoneal cavity [27]. If the initial aspirate contained more than 10 ml gross blood, bile, succus entericus, or food, it was considered ‘grossly positive’ and the patient went for LAP. If not, 11 of warm normal saline was instilled and recovered by gravity siphonage, and the lavage effluent sent for biochemical analysis. Criteria for (+) DPL varied slightly among different centers, but the majority considered more than 100 000 RBCs/mm$^3$, more than 500 white blood cells (WBCs)/mm$^3$, or elevated amylase/alkaline phosphatase/bilirubin in the lavage effluent to represent a (+) DPL [28]. There was no defined protocol for CT scanning, but most centers employed MDCT scanners. The protocol for SCAs included clinical assessments, including physical examination and measurement of a complete blood count (CBC), every 8 h [25]. A change in hemodynamic status, the development of peritonitis, evidence of ongoing blood loss, or leukocytosis was further investigated by CT scan, DPL, or LAP. Absent any of these findings, patients were discharged after tolerating feeding. All patients were given follow-up appointments at the time of discharge. The necessity of each LAP was determined by the operating surgeon to be either non-therapeutic (NON THER) or therapeutic (THER). The principal management strategy (i.e. the one on which decisions were made to discharge, operate, or admit) was determined from the data sheets, and patients were grouped accordingly for certain analyses.

Over the 2-year study period a total of 359 patients were enrolled from 11 centers. Three hundred and eighteen (89%) were men and 41 women. The mean age was 33.4±0.3 years. There were two or more wounds in 121 (34%) patients.

Immediate laparotomy
Immediate LAP was performed in 81 (23%) patients. Sixty-eight (84%) of the immediate LAPs were THER. The indications for LAP, and a breakdown of the therapeutic necessity, are shown in Table 2. Of note, FAST was normal in 11 of these patients, and 7 (64%) had THER LAP. On the contrary, 22 patients with (+) FAST, 2 (9%) had NON THER LAP. The (LOS) was 4.3 days after NON THER LAP and 5.1 days after THER LAP ($P = n.s.$). Seventeen (21%) of the immediate LAP patients had complications, including two (2%) deaths.

Management of stable, asymptomatic patients
At the time of initial evaluation in the ED, 278 (77%) patients did not have an indication for immediate LAP.

Ultrasound (FAST) was performed in 134 (48%) patients. Twelve patients had (+) FAST and two had equivocal studies. Five patients – four of those with (+) and one with equivocal FAST – were taken directly for LAP based on FAST result, in the absence of shock, evisceration, or peritonitis (Table 3). Three of them had THER LAP (hollow viscus, diaphragm, and solid organ) and two (40%) had NON THER LAP. The second patient with equivocal FAST had (+) LWE and grossly positive DPL and went to the operating room, but had a NON THER LAP. Of the other eight patients with (+) FAST, three had a THER LAP. Thus, in all, six (50%) of the patients with (+) FAST but no indications for immediate LAP had a NON THER LAP. The FAST was interpreted as ‘normal’ in 120 patients; of them, 23 (19%) had THER LAP. Including patients who had indications for immediate LAP, and with the endpoint of needing THER LAP, 23% of FAST exams were false (−). The sensitivity (SENS) of FAST was 21%, specificity (SPEC) 94%, positive predictive value (PPV) 50%, and negative predictive value (NPV) 81% (Table 4). No patient was discharged from the ED based on FAST alone.

CT scanning was employed as the primary decision-making tool in 138 (50%) patients. Twenty-nine (21%) of the 138 patients were discharged from the ED based on normal CT findings. A LAP was performed because of CT findings in 46 (33%) patients. Of these, 11 (24%) were NON THER and 35 were THER (Table 3). Eight

### Table 2 Immediate laparotomy (LAP) (indications and therapeutic efficacy)

<table>
<thead>
<tr>
<th>Indication</th>
<th>Nontherapeutic</th>
<th>Therapeutic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shock</td>
<td>3 (13%)</td>
<td>21</td>
</tr>
<tr>
<td>Evisceration</td>
<td>5 (14%)</td>
<td>31</td>
</tr>
<tr>
<td>Peritonitis</td>
<td>5 (29%)</td>
<td>12</td>
</tr>
<tr>
<td>Other</td>
<td>0 (0%)</td>
<td>4</td>
</tr>
</tbody>
</table>

Other: hemorrhage from wound (2), ‘extensive wounds’ (1), impaled knife (1). Adapted from Biffl et al. [26**].

### Table 3 Summary of outcomes associated with primary management strategies

<table>
<thead>
<tr>
<th>Strategy</th>
<th>N</th>
<th>ED D/C</th>
<th>OR</th>
<th>NON THER LAP</th>
<th>THER LAP/NEG TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>138</td>
<td>29 (21%)</td>
<td>46 (33%)</td>
<td>11 (24%)</td>
<td>8/108 (7%)</td>
</tr>
<tr>
<td>LWE</td>
<td>132</td>
<td>31 (23%)</td>
<td>23 (17%)</td>
<td>13 (57%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>DPL</td>
<td>45</td>
<td>7 (16%)</td>
<td>13 (29%)</td>
<td>4 (31%)</td>
<td>2/32 (6%)</td>
</tr>
<tr>
<td>SCA</td>
<td>26</td>
<td>3 (12%)</td>
<td>3 (12%)</td>
<td>1 (33%)</td>
<td>n/a</td>
</tr>
<tr>
<td>FAST</td>
<td>5</td>
<td>0</td>
<td>5 (100%)</td>
<td>2 (40%)</td>
<td>23/120 (19%)</td>
</tr>
</tbody>
</table>

CT, computed tomography; DPL, diagnostic peritoneal lavage; ED D/C, number of patients discharged from emergency department based on results; FAST, focused sonographic assessment for trauma; LWE, local wound exploration; N, number of patients managed primarily by strategy; NON THER LAP, nontherapeutic laparotomy; OR, number of patients taken to the operating room based on results; SCA, serial clinical assessments; THER LAP/NEG TEST, patients ultimately requiring therapeutic laparotomy who initially had a normal test result. Adapted from Biffl et al. [26**].
patients with normal CT scans ultimately underwent a THER LAP. The SENS, SPEC, PPV, and NPV of CT were 77, 73, 47, and 91%, respectively (Table 4).

LWE was performed in 132 (47%) patients. In seven (5%) patients, it was unsuccessful in determining the depth of penetration. Seventy-one patients had (+) LWE and 23 of them were taken directly to the operating room based on this finding: 13 (57%) had NONTHER LAPs (Table 3). Fifty-four patients had (−) LWE. Of these, 31 (57%; 23% of the total LWE group) were discharged from the ED. The other 23 with (−) LWE were admitted for observation and were all ultimately discharged uneventfully. The SENS was 100%, SPEC 54%, PPV 35%, and NPV 100% (Table 4).

DPL was performed in 45 (16%) patients (Table 3). Eight were grossly positive and the patients went to the operating room – six had THER LAP and two had NONTHER LAP. Three patients had (+) DPL based on more than 100,000 RBCs/mm³ and all had THER LAP. Three had more than 500 WBCs/mm³ and two of them had NONTHER LAP. Two patients had elevated amylase, alkaline phosphatase, and/or bilirubin levels, and both had THER LAPs with hollow viscus injuries. In total, out of 13 patients who had abnormal DPL results, 4 had NONTHER LAP. Three patients with normal DPL results underwent LAP because they developed peritonitis; two of them had THER LAP for hollow viscus injuries. To sum up, in this group with a pretest probability of 25%, the SENS and SPEC of DPL were 82 and 88%, respectively; the PPV and NPV were 69 and 94%, respectively (Table 4).

Twenty-six (9%) patients were managed primarily on the basis of SCAs (Table 3). Three (12%) of them were discharged from the ED after a period of observation. Three were taken to the operating room for the development of peritonitis, at 5, 6, and 8 h after presentation. Two of them had hollow viscus injuries, and the other one had a NONTHER LAP. There were no complications among these patients.

Nine patients underwent laparoscopy. Seven were NONTHER. Both cases requiring therapeutic interventions were converted to open.

Laparotomy findings and outcomes

A total of 174 (48%) of the 359 patients had LAP. One hundred and twenty-nine (36%) of the overall group had a THER LAP. Of all the LAPs, 45 (26%) were NON-THER. Most patients (77%) who did not have LAP and were admitted for observation stayed 1 day or less. Prolonged stays were generally attributed to psychiatric or social issues, or to the need for chest tube management. The mean LOS of patients undergoing LAP was 4.7 days; the LOS following a THER LAP was 5.1 days, and 3.6 days following NONTHER LAP. There was a morbidity rate of 20% following THER LAP, and 4% following NONTHER LAP. The LOS associated with complications after LAP was 7.8 days, compared with 4.1 days without complications.

**What do we conclude from the Western Trauma Association multicenter study?**

Shaftan’s [1] concept of ‘selective conservatism’ was based on the observation that only one-half of stab wounds that penetrated the peritoneal cavity caused an injury that required operative repair. Over the years a variety of strategies have been employed in an attempt to diagnose and treat significant injuries in a timely manner, but to avoid unnecessary LAP. In the WTA series, only 36% of AASW victims required LAP, reinforcing the fact that most patients can be managed without intervention. Further, 26% of the LAPs were NONTHER, suggesting there is still room for improvement [26**].

There is uniform agreement that immediate LAP is indicated for certain indications. Shock is one clear indication for emergent abdominal exploration. Indeed, in the WTA series, 88% of patients presenting with shock had THER LAPs. Evisceration is also an accepted indication for immediate LAP. In the WTA study, intestinal evisceration was associated with THER LAP in 100% of cases. However, there has been some debate regarding omental evisceration. The Denver 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 [12]. On the other hand, recent series have argued the opposite but based on similar incidences (65–80%) of significant intra-abdominal injury [29,30]. In the WTA series, 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 the authors that since the

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**Table 4 Summary of sensitivity, specificity, positive predictive value, and negative predictive value of tests for therapeutic laparotomy**

<table>
<thead>
<tr>
<th>TEST</th>
<th>N</th>
<th>PTP</th>
<th>SENS</th>
<th>SPEC</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>145</td>
<td>35</td>
<td>77%</td>
<td>73%</td>
<td>47%</td>
<td>91%</td>
</tr>
<tr>
<td>FAST</td>
<td>132</td>
<td>29</td>
<td>21%</td>
<td>94%</td>
<td>50%</td>
<td>81%</td>
</tr>
<tr>
<td>LWE</td>
<td>125</td>
<td>25</td>
<td>100%</td>
<td>54%</td>
<td>35%</td>
<td>100%</td>
</tr>
<tr>
<td>DPL</td>
<td>45</td>
<td>11</td>
<td>82%</td>
<td>88%</td>
<td>69%</td>
<td>94%</td>
</tr>
<tr>
<td>SCA</td>
<td>28</td>
<td>2</td>
<td>100%</td>
<td>96%</td>
<td>67%</td>
<td>100%</td>
</tr>
</tbody>
</table>

CT, computed tomography; DPL, diagnostic peritoneal lavage; FAST, focused sonographic assessment for trauma; LWE, local wound exploration; N, total number of patients having the test who did not have indications for immediate laparotomy; NPV, negative predictive value; PPV, positive predictive value; PTP, pretest probability = number (percentage) of patients having that test who ultimately had a therapeutic laparotomy; SCA, serial clinical assessments; SENS, sensitivity; SPEC, specificity. Adapted from Biffl et al. [26**].
patient has, at the very least, a symptomatic hernia, it should be repaired, and given the relatively high likelihood of finding a significant intra-abdominal injury, it is best done in the operating room rather than in the ED. ‘Peritonitis’ is a relatively subjective finding, and thus it is not surprising that this finding, in the absence of shock or evisceration, led to NONTHER LAP in 29% of patients. Of note, only 50% of patients with local peritonitis on presentation had a THER LAP, compared with 81% of those with diffuse peritonitis. It is difficult to justify delaying intervention in a patient with peritonitis, but an experienced clinician should attempt to differentiate true peritoneal signs from physical findings related to the wound.

Once the hemodynamically unstable and symptomatic patients are selected out, the number requiring THER LAP decreases considerably. In the WTA series, THER LAP was required in only 61 (22%) of 278 patients who did not initially have shock, evisceration, or peritonitis. Thus, the goal is to identify these patients in a timely manner while minimizing costs and potentially morbid interventions. To that end, a variety of strategies are employed by trauma surgeons.

There is no question that the introduction of FAST in the mid-1990s dramatically changed the management of blunt trauma patients [21]. However, its utility in patients with penetrating abdominal wounds is less clear [31]. In the WTA study, FAST was performed in 134 (48%) of the patients, but the primary management decision was based on FAST in only 5 (4%) of them. Thus, whereas many trauma surgeons appear to employ the test, it is recognized that the simple presence of hemoperitoneum does not necessarily correlate with a significant injury requiring operative intervention. In fact, 10 (28%) of 36 patients with abnormal FAST in the WTA series had a NONTHER LAP or did not require LAP. The major value of the test is probably in identifying patients who have hemoperitoneum, so that they may be observed. On the other hand, the absence of hemoperitoneum does not equate with the absence of injury. In this series, 23% of patients with a ‘normal’ FAST ultimately had a THER LAP. Thus, we agree with Udobi and colleagues [31] that patients should not be discharged from the ED based solely on a normal FAST. And although ultrasonography has been advocated for identifying fascial defects following penetrating trauma [32], it is probably not reliable enough to determine a patient’s suitability for ED discharge.

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 [4,33,34]. In the WTA series, CT was performed more frequently than any other test. Proof of extraperitoneal trajectory allows safe ED discharge, and this occurred in 21% of the patients who had the test. On the other hand, a (+) CT scan – that is, one showing intra-abdominal abnormalities – can be misleading. Forty-six (33%) asymptomatic patients who had CT scans were taken to the operating room based on CT findings, and 24% of the resultant LAPs were NONTHER. Further, of 35 patients with a ‘THER LAP,’ 18 had only solid organ injuries or fascial defects, which in many cases are amenable to nonoperative management. Like FAST, CT scan reveals evidence of injuries, for example, free intraperitoneal fluid, that are of questionable clinical significance. Consequently, we do not advocate it as the sole determinant of the need for LAP.

A LWE was performed in 132 (47%) patients in the WTA study. The primary value of LWE is in its ability to determine whether or not the stabbing object violated the peritoneal cavity. In this series, 54 patients had a (–) LWE, but only 31 (57%) of them were discharged from the ED, suggesting that it has even greater potential to facilitate ED discharge. Conversely, it is clear from the data that a (+) LWE should not be used as an indication for LAP; 57% of the LAPs performed for this indication were NONTHER. 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 [35]. The procedure requires adequate exposure of the wound to follow the tract of the stabbing object [12]. Further, there was some variation in defining a (+) LWE in the WTA series. Some surgeons considered violation of anterior fascia to constitute a (+) LWE. This definition ignores the muscle and/or posterior fascia, and does not correlate with violation of the peritoneal cavity. A stricter definition of (+) LWE – that is, violation of the posterior fascia and peritoneum – would likely increase the number of patients eligible for ED discharge. 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. On the basis of the WTA results that LWE has a SENS and NPV of 100%, we advocate LWE to rule out peritoneal penetration and allow ED discharge; we suggest that those asymptomatic patients with (+) LWE be admitted for SCAs (Fig. 2).

DPL has been used to identify significant peritoneal injuries following AASWs for at least 30 years [12,15,17]. Whereas DPL is a good test, it has some noteworthy limitations. It is an invasive procedure with a risk of iatrogenic injury, and therefore a (–) result requires a period of observation. 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 [23,36]. The RBC
threshold has been debated over the years [17,23,36]. The generally accepted threshold for positivity (>100,000 RBCs/mm^3) was selected based on missing injuries with NONTHER LAPs. Lowering the threshold to 50,000, 10,000 or 1000 RBCs/mm^3 increases the number of NONTHER LAPs with diminishing returns on finding occult injuries. In fact, in the WTA series, if a threshold of more than 10,000 RBCs/mm^3 were used, there would have been two NONTHER LAPs. The SENS (82%), SPEC (88%), PPV (69%), and NPV (94%) are similar to those reported by Henneman and colleagues [23] in 1990 for abdominal stab wounds (72, 91, 74, and 90%, respectively). Although there is still a role for DPL in trauma care today, it may not be in the setting of AASWs [42]. On the basis of the results of the WTA study, it may be reasonable to conclude that as experience with DPL decreases – and thus potential morbidity increases – it may be best to take it out of the decision-making arm for these patients.

Serial clinical assessments were used as the primary management strategy in only 26 patients in the WTA study. The major theoretical shortcomings of this strategy are an over-reliance on subjective findings and a potential for delayed intervention and consequent morbidity. Whereas ‘peritonitis’ has been found to lead to a number of NONTHER LAPs [25], we contend that it is still a reliable indicator of the need for intervention, particularly if the clinical finding is corroborated by an experienced examiner. Ultimately, if the finding of peritonitis is being documented, the most conservative approach is to explore the abdomen. Regarding the safety issue, as noted in previous studies, admission for SCAs appears to be a well tolerated strategy [22,24,25]. And whereas the number in this series was relatively small, it represents an extension of a previous series by one investigator (W.L.B.), in which 30 patients were managed safely without a single delayed LAP [25]. In the WTA series, there were three patients managed with this strategy who went to the operating room in a delayed fashion (they all without a single delayed LAP [25]. In the WTA series, there were three patients managed with this strategy who went to the operating room in a delayed fashion (they all developed peritonitis within 8 h of presentation). Two of the three had THER LAP. The LOS in these patients was 1.5 days longer than other patients undergoing THER LAP, raising the possibility that there may have been a consequence of the delayed intervention. However, the numbers are too small to draw any conclusions, and there could have been other factors involved that were not evident. Although delayed intervention is
potentially deadly in the setting of blunt small bowel injury [43], this does not seem to translate to penetrating trauma victims [44,45**].

Laparoscopy did not prove useful in the WTA series. Of nine procedures performed, seven were NONTHER. The two patients requiring THER procedures had open LAP. As noted above, the authors do not feel the presence of peritoneal violation is an independent criterion for LAP; thus, there is not a major role for laparoscopy in the setting of AASWs.

There are a number of limitations of the WTA study. First, management was not controlled prospectively. The investigators agreed in principle on indications for immediate LAP, but further management was based entirely on individual/institutional protocols and clinical judgment. On the contrary, it offered a ‘real-life’ view of current trends in the treatment of AASWs in trauma centers in the USA. Another limitation was that adjudication of the therapeutic necessity of LAPs was the responsibility of the attending surgeon who entered the case. Clearly, this introduced the potential for bias and should be addressed in future investigations in this area. However, if the percentage of THER LAPs has been overstated, it further suggests that diagnostic tests in asymptomatic patients lead to NONTHER LAPs. Another shortcoming is the lack of follow-up. Although there were no reports of patients being readmitted after discharge for treatment of a missed injury in this series, it is conceivable that patients were seen elsewhere. The fact that not everyone had a LAP might be considered a limitation. The SENS, SPEC, PPV, and NPV data were all calculated based on a THER LAP as the outcome. However, we once again submit that the mere presence of an injury is not necessarily the major issue. Many injuries may be safely managed nonoperatively, and this study is about identifying those who need LAP, not those who do not.

In summary, then, the prospective multicenter WTA study reinforced that shock, evisceration, and peritonitis mandate immediate LAP following AASWs. Patients without these findings are at much lower risk. The series demonstrated that performing tests to help identify significant intraperitoneal injury in the low-risk group was associated with a substantial number of NONTHER LAPs, as well as increased resource utilization. No study proved superior – they all led to similar numbers of NONTHER LAPs, with their attendant complications and prolonged LOS. Conversely, there is no evidence that a strategy of SCAs is any less well tolerated than any other strategy. Thus, we proposed the clinical pathway outlined in Fig. 2. In order to limit the number of hospital admissions, LWE should be performed in the ED to definitively determine the depth of penetration. Absence of peritoneal penetration suggests the patient may be safely discharged. In the presence of morbid obesity or a long tangential knife tract, CT scanning may be used as an alternative to LWE. On the contrary, peritoneal penetration, absent evidence of ongoing hemorrhage or hollow visceral injury, should not be considered an indication for LAP. Rather, patients with evidence of peritoneal penetration are admitted for SCAs. It is important that a skilled examiner perform the serial abdominal examinations. There is currently a prospective multicenter trial to document the safety and cost-effectiveness of this approach.

**Gunshot wounds**

Mandatory LAP has long been considered the standard of care for management of abdominal GSWs, given that over 90% of patients with peritoneal penetration have an injury requiring operative management [46]. In recent years, however, a number of reports have identified a subset of patients who may be candidates for nonoperative management [47–49,50]. Stable, asymptomatic patients are candidates for CT scanning. Those who have clear evidence of extracavitary trajectory can be discharged from the ED. Patients with isolated solid organ injuries may be candidates for nonoperative management. However, the setting must be appropriate, as the patient’s condition could change abruptly. As much of the literature has come primarily from two centers, this approach should be undertaken with caution.

**References and recommended reading**

Papers of particular interest, published within the annual period of review, have been highlighted as:

- of special interest
- of outstanding interest

Additional references related to this topic can also be found in the Current World Literature section in this issue (p. 672).

Management of penetrating abdominal trauma Biffi and Moore 617

11 Ramirez RM, Cureton EL, Ereso AQ, et al. Single-contrast computed tomo-
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This study demonstrates the safety and accuracy of CT scanning without oral or rectal contrast.


13 Nance FC, Wennar MH, Johnson LW, et al. Surgical judgment in the manage-


This multicenter study evaluates the utility of various diagnostic modalities, and concludes with a new management guideline for stable patients with AASWs that should be both safe and cost-effective.


29 Leppaniemi AK, Voutilainen PE, Haapainen RK. Indications for early manda-


45 Clarke DL, Alforto NL, Thomson SR. An audit of failed nonoperative manage-

This study documents the safety of expectant nonoperative management of patients with abdominal stab wounds.


48 Demetriades D, Hadjizacharia P, Constantinos C, et al. Selective nonopera-


This study reaffirms the safety of nonoperative management of liver GSWs of all grades, even with associated injuries.