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# Advances in Abdominal Trauma

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Emergency practitioners routinely encounter patients who suffer from abdominal trauma, be it blunt or penetrating. These injuries are often confounded by altered mental status, distracting injuries, or lack of historical information, and may present challenges in management. However, in the last several years new approaches to the diagnosis and management of abdominal trauma, including bedside ultrasound, newer generation computed tomography scans, laparoscopy, and the ability for selected nonoperative management expedite identification of life threatening injury and offer new options in treatment.

## Blunt abdominal trauma

### *Background*

Historically, blunt abdominal trauma (BAT) is more frequently encountered in the emergency department (ED) than penetrating abdominal trauma, and usually results from a motor vehicle collision (MVC). When combined with pedestrian versus auto accidents, these types of abdominal traumas account for up to 75% of cases seen, while direct abdominal blows and falls comprise the remainder [1,2]. The spleen is the most often injured organ and may be the only intra-abdominal injury in over 60% of cases. Liver and hollow viscus injuries follow in decreasing incidence [1]. Blunt abdominal trauma may herald occult domestic violence or child abuse.

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*Initial assessment*

Historical data, while often lacking, may provide invaluable information to the emergency practitioner when evaluating a patient with abdominal trauma. If the patient was involved in a MVC, information regarding fatalities at the scene, vehicle type and velocity, roll over, intrusion, steering wheel deformity, use of seatbelts and air bags, and the patient's location within the vehicle offer guidance in management [3–5].

*Physical examination*

While some studies cite physical examination as only 55% to 65% sensitive for diagnosing injury in those sustaining BAT, it is still the cornerstone for primary assessment [6]. Patients with BAT may present to the ED anywhere on the spectrum from normotensive and alert to obtunded and in shock. Careful attention to physical findings helps drive decision making and proper sequencing of diagnostic tests.

Hypotension after BAT typically results from visceral organ injury and hemorrhage, usually of the spleen [1]. These patients need emergent evaluation of the peritoneal cavity, and coincident appraisal of any extra-abdominal injury creating hemorrhage or hemodynamic instability, such as long bone fracture, scalp laceration, hemothorax, pneumothorax, or, in infants, severe head injury [7].

In awake, hemodynamically stable patients with isolated BAT, abdominal pain, tenderness, and peritoneal signs are the most reliable findings for intra-abdominal injury and can be found in up to 90% of those with injury. However, several studies demonstrate that even in these patients, significant injury may be missed with physical exam alone. Therefore, absence of physical findings does not preclude injury and the need for further observation and diagnostic testing [8,9].

Salim and colleagues' study [9], published in 2006, evaluated 592 subjects with significant blunt multisystem trauma, who had no visible chest or abdomen injury, were hemodynamically stable, and had a normal abdominal physical examination. Of these, 19.6% had clinically significant findings on chest computed tomography (CT) and 7.1% on abdominal CT, leading to a change in clinical management in almost 19% of the subjects.

When extra-abdominal injuries are present, suspicion for concomitant intra-abdominal injury is paramount. Up to 10 % of those with closed head injury, and 7% of those with a distracting extremity injury, will have an abdominal injury even with no signs or symptoms of abdominal trauma [10,11]. Pleuritic left costal margin pain may indicate underlying splenic injury [12]. Ecchymosis across the lower abdomen, a "seatbelt sign," portends intra-abdominal injury in up to one third of patients [13].

Some recent small studies suggest that in awake, hemodynamically stable adult patients who are going to the operating room for extra-abdominal injuries, physical exam will exclude most intra-abdominal injuries requiring

immediate operative intervention [14–16]. In 2004, Gonzalez and colleagues [15] evaluated 162 hemodynamically stable patients after BAT and with extra-abdominal injuries requiring operative repair. These patients had a Glasgow Coma Score (GCS) greater than or equal to 14, no findings on physical examination of the lower ribs, abdomen, and pelvis, and no neurologic deficits. Two injuries (a grade one splenic laceration and a small bowel mesenteric hematoma) were missed by physical examination but detected on CT. Neither of these patients required surgical intervention or transfusion. Thus, the investigators conclude that physical examination alone may be sufficient for evaluating for surgically significant injury in patients with extra-abdominal injury. However, they suggest that larger prospective studies are still needed.

### *Laboratory testing*

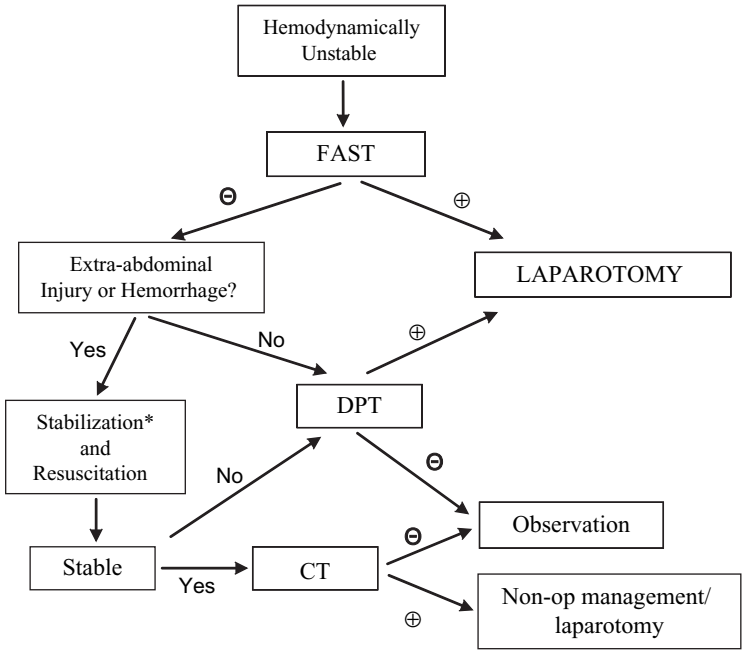
Most hematologic and blood chemistries serve only as adjuvants in the management of patients with abdominal trauma. A baseline hematocrit may be useful, but rarely will alter emergent management. Blood typing should routinely be sent for any patient with abdominal trauma and signs of hemorrhage or potential need for transfusion. Base deficit is often used as a marker for hemorrhagic shock, but as with all laboratory values, it must be interpreted in context of the clinical scenario and what resuscitation has occurred, as correction of the metabolic acidosis will lag behind physiologic correction [17,18]. White blood cell count, pancreatic enzymes, and liver function tests have all been used as markers of intra-abdominal injury in the past; however, most studies now show these are nonspecific and may not provide much guidance in the acute decision-making for patients with abdominal trauma [19,20]. Urinalysis with detection of hematuria (both microscopic and gross) indicates renal injury, and coupled with abdominal tenderness predicts intra-abdominal injury following BAT with 65% sensitivity and 94% specificity [21,22]. Toxicologic studies have little value in the acute management of abdominal trauma, unless there is unexplained altered mental status [23].

### *Emergency management*

#### *Unstable patients*

Determining need for emergent operative care is the top priority in the evaluation of patients sustaining BAT. In those patients who are hemodynamically unstable, the presence of intra-abdominal hemorrhage must be expeditiously established. Risk of death from isolated intra-abdominal injury increases with time spent in the emergency department and severity of hypotension (Fig. 1) [24].

Clarke and colleagues' review [24] of the Pennsylvania Trauma Systems Foundation trauma registry, from October 1986 until July 1999, identified 243 hypotensive patients with intra-abdominal injury who were initially evaluated in a trauma center. Using logistic regression, the probability of




*Pelvic wrap, chest tube placement, whip stitch
FAST – Focused Abdominal Sonography for Trauma
DPT – Diagnostic Peritoneal Tap; ⊕ if ≥10 cc gross blood aspirated
CT – Computed Tomagraphy

Fig. 1. Unstable patients with blunt abdominal trauma. ⊕, ≥10 cc blood aspirated; DPT ⊖, <10 cc blood aspirated

death increased as time spent in the ED increased up to 90 minutes. Also, those patients with initial systolic blood pressures of less than 60 mm Hg had a significantly higher risk of death, while those with a systolic blood pressure of greater than 80 mm Hg had a significantly lower risk of death. Traditionally, bedside diagnostic peritoneal lavage or tap (DPL or DPT) quickly triages unstable patients with multisystem trauma. If 10 cc of gross blood is aspirated then intra-abdominal hemorrhage is present and the patient requires urgent laparotomy. This knowledge is especially useful when multisystem trauma is present and the physician must decide which therapeutic path to tread, be it exploratory laparotomy or angiography with embolization. However, with the advent of bedside ultrasonography (US), DPL is being employed less and is no longer the standard diagnostic procedure in these unstable patients.

Recent literature shows mixed opinion on the use of US in the unstable patient. While some studies cite near 100% sensitivity for hemoperitoneum

requiring surgical intervention in the hypotensive patient [25], others show a wide range of sensitivity and caution against its sole use in this patient population, especially when no intraperitoneal free fluid is detected [26].

Farahmand and colleagues' [25] retrospective review of 128 hypotensive BAT patients demonstrated an assessment of focused abdominal sonography for trauma (FAST) sensitivity of 85% for detection of any intra-abdominal injury. When only those injuries requiring surgical intervention were included, sensitivity rose to 97%, and it was 100% sensitive for all fatal injuries. The only missed surgical injury was a mesenteric injury. Of the other missed injuries, 63% were extraperitoneal. Thus, the investigators concluded that FAST in the hypotensive patient is an effective screening tool and, when coupled with risk assessment, can effectively rule out intra-abdominal injury requiring surgical intervention.

A recent study of 7047 patients demonstrated lower accuracy in those subjects with additional closed head injury and low GCS [27]. However, in most centers, hemodynamically unstable patients with a positive FAST exam proceed to exploratory laparotomy.

Because intra-abdominal injury can not be entirely ruled out in those unstable patients with a negative FAST, further diagnostic testing, bedside DPL or DPT, or—once more stable—CT, must be performed to completely evaluate for intra-abdominal injury, while concurrently pursuing possible extra-abdominal injury as a cause of instability (Fig. 2).

Chest and pelvic radiographs determine the presence of extra-abdominal causes of hypotension or hemorrhage, namely pneumothorax or hemothorax and pelvic ring fracture, respectively (Fig. 3). Needle decompression, chest tube placement, or pelvic wrapping and subsequent angiography

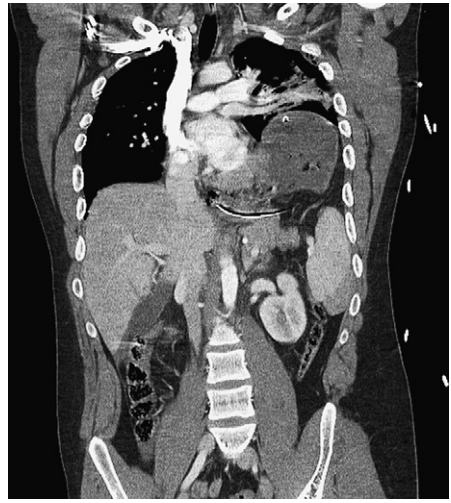


Fig. 2. Ruptured left diaphragm and grade 3 splenic laceration.

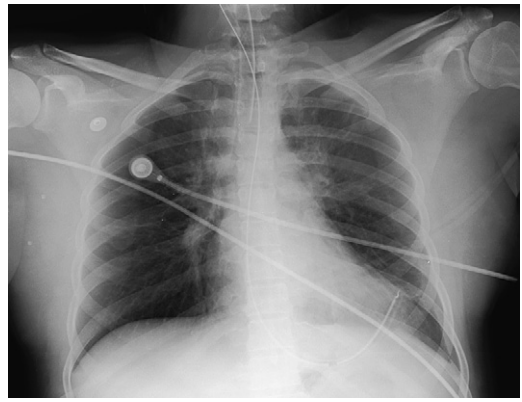


Fig. 3. Nasogastric tube in left chest with diaphragmatic rupture.

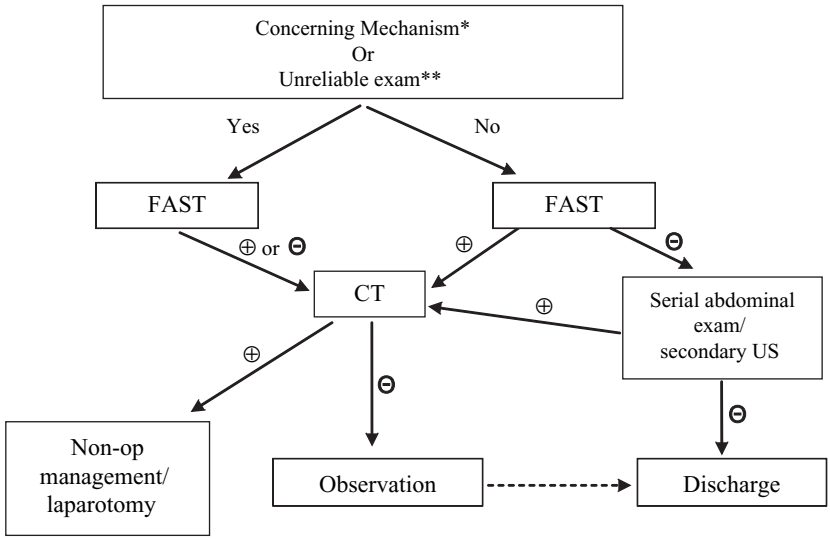
control further blood loss and aid in resuscitation. Large scalp lacerations may also prove a source of hemorrhage and should be whip-stitched (or Rainey clipped) closed.

*Stable patients*

New advances in computed tomography and ultrasound continue to alter the management of stable patients with BAT (Fig. 4). Hemodynamically stable patients allow for a more time intensive evaluation and alternative testing to diagnose intra-abdominal injury. While physical exam in the stable, alert, nonintoxicated patient is reasonably accurate, it is not infallible and clinical observation with serial examinations is warranted [8]. Furthermore, one recent study advocates for CT evaluation in all patients sustaining BAT. The authors cite missed significant injury, one requiring alteration of treatment, at a rate of 7% in a patient population with no signs of external trauma and normal abdominal examination [9].

Most centers employ US as part of their initial survey in trauma resuscitation. Studies demonstrate a range in sensitivity for hemoperitoneum from 65% to 95%, although most recent studies cite ranges of 86% to 89% [28–30]. If the FAST is noted to be positive, these stable patients then proceed to CT for delineation of intraperitoneal injury and quantification of the hemoperitoneum (Fig. 5).

If the FAST is negative, concern for intra-abdominal injury is still present, as US is notoriously poor at identifying solid organ subcapsular injury, bowel injury, or injury to the retroperitoneum or diaphragm [26,31,32]. However, some report that a negative FAST coupled with a negative physical exam, followed by an observation period of 12 to 24 hours in an alert, stable patient virtually excludes intra-abdominal injury [33]. Others recommend serial abdominal US to increase the sensitivity of the FAST exam [34,35].




* Concerning mechanism: fatality at scene, rollover, intrusion, prolonged extrication
** Unreliable exam: altered mental status, intoxication, distracting injury

FAST – Focused Abdominal Sonography for Trauma
CT – Computed Tomagraphy

Fig. 4. Stable patients with blunt abdominal trauma. DPT ⊕, ≥10 cc blood aspirated; DPT ⊖, <10 cc blood aspirated.

A recently published study prospectively illustrates that US use in patients with abdominal trauma changed management decisions in 32.8% of cases and decreased the need for CT and DPL or DPT. This prospective study compared 419 patients who required trauma team activation. A convenience sample of 194 subjects received an initial bedside FAST after the trauma team leader specified the patient management plan. After the FAST, the plan was reviewed and a revised plan was documented. The remaining 225 subjects did not undergo FAST examination and proceeded with the trauma leader's original plan. Of those with a FAST examination, the subsequent use of CT decreased from 47% to 34% and DPL from 9% to 1% [36]. Other studies cite decreased time to laparotomy and improved use of hospital resources when US was part of the initial trauma evaluation in those with abdominal trauma.

Branney and colleagues [37] prospectively evaluated 486 BAT patients who followed an ultrasound-based key clinical pathway during a 3-month period. He compared these with a similar cohort for 3 months and found that those using the US pathway had significant reductions in the use of CT (56% to 26%) and DPL (17% to 4%).

Fig. 5. Free fluid in Morrison's Pouch.

Most recently Melniker and colleagues' [38] point-of-care limited ultrasonography (PLUS) for trauma study prospectively evaluated the amount of time from ED arrival to transfer to operative care. The 29 subjects in the PLUS group who went to the operating room had a decrease of 64% in time to operative care when compared with the 34 controls. Secondary measures noted a coincident decrease in use of CT, length of stay, and complications for the 111 subjects in the PLUS cohort when compared with the 106 control subjects.

The advent of 64-slice helical CT scanners has improved diagnosis of both solid and hollow viscus injury post-BAT (see Fig. 3). Recent studies advocate the use of CT, even in patients with no signs of injury, be it intra- or extra-abdominal [9]. Most admit to its low yield in those patients who are alert with no signs of trauma; however, missed injury in these studies was at times significant and, therefore, routine use of CT can not be abandoned in certain patient populations, namely those with extra-abdominal injuries, ethanol ingestion, and otherwise unreliable abdominal examination [8,14,39].

The 2004 American College of Emergency Physicians Clinical Policy statement, based on review of the literature, touts CT as reliably excluding liver and spleen injury after BAT. This clinical policy also states that CT alone could not reliably rule out hollow viscus, diaphragmatic, or pancreatic injury [40].

Hollow viscus injury (HVI) remains difficult to detect despite advances in diagnostic modalities. Coincident solid organ injury often masks CT findings of HVI, increasing morbidity and mortality because of delay in diagnosis [41]. Recent studies suggest physical examination for signs of peritonitis, coupled with CT with intravascular (IV) contrast only, may be adequate for diagnosing bowel injury [42–45]. However, the low incidence of HVI makes large prospective studies for noncontrast CT identification difficult.

Stuhlfaut and colleagues [43], restrospectively evaluated 1082 patients with BAT who had a noncontrast CT of the abdomen and pelvis. Eleven patients were diagnosed with HVI requiring operative repair. Noncontrast CT had a sensitivity of 82% and specificity of 99% for detecting these injuries.

In 2004 Allen and colleagues [54] prospectively evaluated 500 patients after blunt abdominal trauma with noncontrast CT of the abdomen and pelvis. A CT was considered positive for HVI if there was presence of bowel wall thickening, bowel perforation, free intraperitoneal air, free fluid without solid organ injury, and mesenteric laceration or hematoma. Of these 500, 19 of 20 subjects with HVI were detected on initial CT read (a duodenal perforation was missed). There were two false-positive studies that were read as suspicious for bowel injury but at laparotomy had only splenic injury, and another misinterpreted as a gastric hematoma on the initial CT read, but correctly refuted on immediate follow up CT with oral contrast. In this study, noncontrast CT had a sensitivity of 95% and specificity of 99.6% for HVI.

In 2003 the Eastern Association for the Surgery of Trauma (EAST) multi-institutional hollow viscus injury study reviewed trauma registries from 95 trauma centers over 2 years. They concluded that no test or combination of findings could reliably exclude colonic injury. They noted that, though only used in 22 % of cases, DPL was the only diagnostic test with a sensitivity of 97% and negative predictive value of 80% for HVI [42].

If liver or splenic injury is detected by CT in a hemodynamically stable patient, nonoperative management with close observation, serial examinations, and hematocrits is now standard [46–48]. This is in part due to improved resolution on CT, which allows better definition of the injury and quantification of hemorrhage [47]. Even high-grade liver lacerations can be initially managed nonoperatively; however, complications and the possible need for therapeutic laparotomy should be expected [48].

In 2005, Kozar and colleagues [48] evaluated 230 patients with grade 3 or higher blunt hepatic injury initially managed nonoperatively. Of these, 25 had complications (11%) including bleeding, biliary tract related complications, abdominal compartment syndrome, liver abscesses, and liver necrosis. Grade 5 injuries had a 63% complication rate, whereas only one of the grade 3 patients had a complication (a peripheral bile duct leak). Operative intervention was required in 5.2% of all study subjects initially managed nonoperatively.

### *Special considerations*

Pelvic fracture is routinely managed nonoperatively with angiography. Therefore determination of concurrent hemoperitoneum in unstable patients is paramount, as need for laparotomy in these patients may require external fixator placement in the operating room for fracture stabilization.

Ultrasound and DPT have both proven efficacious in the management of this patient population [49].

Closed head injury renders physical exam less useful in the triage of patients with BAT. Furthermore, the ability perform more time intensive diagnostic testing, such as CT, may be limited. When no lateralizing signs are present, the need for urgent craniotomy is less and a quick head CT follow by abdominal CT may be possible. However, those with lateralizing signs and hemodynamic instability may need a burr hole with concurrent laparotomy. Others that respond to resuscitative measures may have time for a "quick" head CT just before abdominal CT [50,51].

There is evidence that patients with serious abdominal trauma, especially those requiring surgical intervention, do better at regional trauma centers. Consultation and transfer should occur early in the evaluation of patients. However, a subset of patients with hemodynamic instability and known hemoperitoneum will benefit from laparotomy with hemorrhage control before transfer [52].

## Penetrating abdominal trauma

### *Background*

Penetrating trauma is increasing because of the growth of violence in our society. Stab wounds are encountered three times more often than gunshot wounds, but have a lower mortality because of their lower velocity and less invasive tract. As a result of their greater force and extensive missile tract, gunshot wounds account for up to 90% of the mortality associated with penetrating abdominal trauma. Injury to the bowel (small, then large) is most often found, followed by hepatic injury, regardless of type of penetrating injury [53].

### *Initial assessment*

For those with penetrating abdominal trauma, it is important to note in stab wounds the implement used, its trajectory, and length, and in gunshot wounds, the type of gun, number of shots heard, the position of the patient during the assault, and the distance of the patient from the gun. Shotgun wounds create a special scenario, as their velocity and trajectories differ from gunshot wounds. As distance is gained, shotgun pellets disperse and thus mortality is decreased; however, debris carried into these resulting multiple wounds increases morbidity [54].

### *Physical examination*

It is vital that patients sustaining penetrating trauma be completely undressed and thoroughly examined for injury. Often these patients will present with an obvious wound to the anterior abdomen, only to have

a secondary wound in an axilla, perineum, scalp, or skin fold that may be unnoticed and perhaps lethal.

The tenet of evaluating penetrating abdominal trauma is to determine peritoneal violation and then peritoneal injury. Physical exam may reveal peritonitis, evisceration, or other indications of peritoneal violation, and thus the need for operative management [55]. Those patients with unstable vital signs may have an intra-abdominal injury with hemorrhage; however, tension pneumothorax, hemothorax, and pericardial tamponade must be considered and evaluated.

*Emergency management*

With the advent of anesthesia, sterilization, and surgical training, post World War I treatment of penetrating injury to the abdomen was mandatory laparotomy. This dogmatic approach was predicated by battlefield experience with trauma laparotomies and translated to civilian populations in the post-war era. However, as nontheraputic laparotomy rates approached 30%, surgeons found that the injuries and morbidity associated with noncombat penetrating wounds differed from those produced by military weapons. In 1960 Shaftan [56] published a paper advocating nonoperative management in select patient populations sustaining stab wounds, and the tenet of mandatory laparotomy was lost. Today, nonoperative treatment of abdominal gunshot wounds is also gaining favor [57–60].

*Indication for mandatory laparotomy*

The mainstay of evaluation of those with penetrating abdominal trauma is identification of the need for immediate surgical intervention. Physicians agree that immediate laparotomy is indicated if there is hemodynamic instability or the presence of peritoneal signs on physical examination [9,57,61–69].

When evisceration is present, surgical intervention is generally accepted as the next step in management. Nagy and colleagues' [63] prospective study in 1999 included 81 patients with abdominal stab wounds and evisceration: either omentum (75%), small intestine (22%), colon (1%), or both small bowel and colon (1%). Peritoneal signs or hemodynamic instability were absent in 76% and evisceration was therefore the sole indication for surgical exploration. A necessary laparotomy was performed in 76% of this subgroup, and of those with only omental evisceration, the necessary laparotomy rate was 73%. This high incidence of intra-abdominal injury following stab wounds with evisceration has made exploratory laparotomy in these patients standard [9,61–63].

Newer studies are challenging this standard in those with anterior stab wounds. Arikan [64] published a small study in 2005, evaluating nonoperative management for abdominal stab wounds with evisceration. Thirty-one patients were managed non-operatively, despite evisceration of omentum (28) or organ (3). Of these, 24 were discharged home without exploratory

laparotomy, including two with organ evisceration. Seven patients were explored because of development of concerning physical exam findings during the observation period. There were two negative, five therapeutic, and no nontheraputic laparotomies. Those patients with nonoperative management had decreased hospital length of stay and complication rates when compared with a group of 21 patients managed with mandatory laparotomy. Patients with refractory hypotension, peritonitis, blood from a nasogastric tube, or obviously perforated bowel were excluded. Evisceration after gunshot wounds mandates immediate laparotomy because of increase injury and contamination associated with these injuries [57].

### *Identification of peritoneal injury*

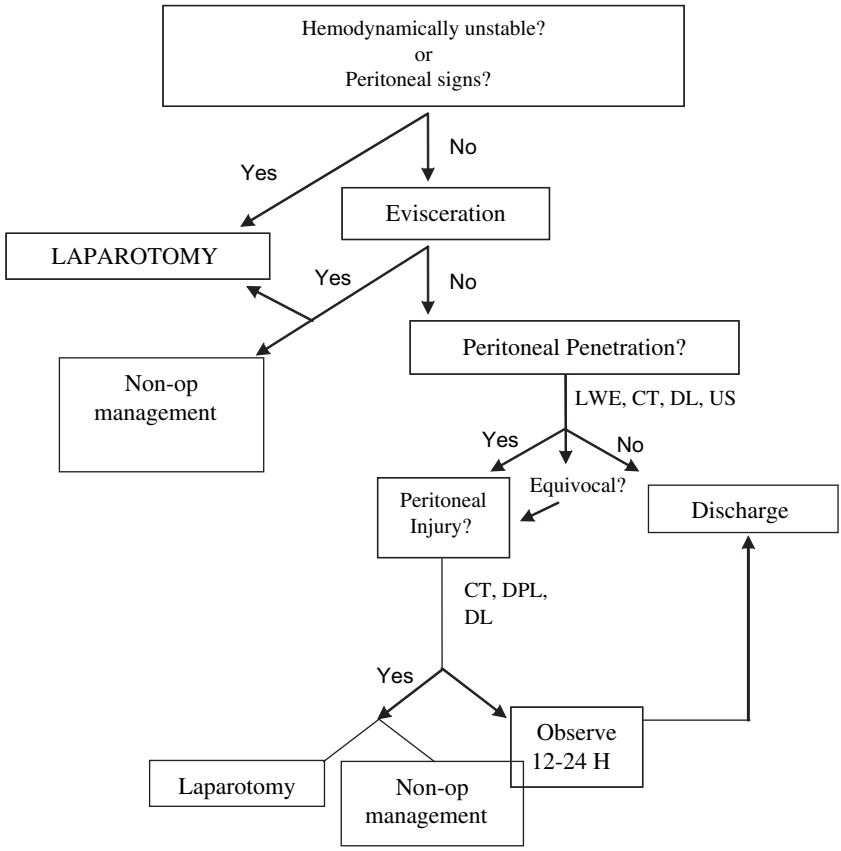
#### *Stab wounds*

Stab wounds produce peritoneal violation in up to 70% of instances, but of these only one fourth to one third will require operative intervention (Fig. 6) [65,70]. For those patients without evisceration, peritonitis, or hemodynamic instability, studies show that judicious use of local wound exploration, CT, DPL, laparoscopy, and US, coupled with physical examination, can safely select patients appropriate for nonoperative management [66,69,71].

Local wound exploration is easily and safely performed at the bedside in those patients with abdominal stab wounds. If the stab wound tract ends before violation of the abdominal fascia, studies show these patients are safe for discharge. However, if the tract is not completely visualized because of body habitus, other injuries, or technical inability then further testing is necessary.

Most centers employ CT as the next step in evaluation of these stable patients as it is noninvasive, offers information about the extent of injury to visceral organs, and can help plan both operative and nonoperative management [9,72,73]. While triple contrast CT is still routinely used for its 97% sensitivity and 98% specificity [72], one recent study evaluated the use of CT with only IV contrast and found a similar sensitivity and specificity. This protocol reserves use of oral and rectal contrast for specific patient populations, thus decreasing the amount of time needed to perform the diagnostic test in most patients [59]. Injuries to the bowel, diaphragm, and pancreas are poorly visualized on CT (even with triple contrast), and in those patients with high suspicion for injury (such as those with hepatic injury and right-sided hemothorax), further diagnostic testing with laparascopy or DPL may be warranted despite negative CT [60,72].

The role of ultrasound in penetrating abdominal trauma is still evolving. A positive FAST may indicate intraperitoneal hemorrhage and injury, but in this group of stable patients, more definitive testing must follow as there is potential for nonoperative management. A negative FAST does not exclude injury and requires further evaluation [74]. A small study of 35




LWE Local Wound Exploration
CT Computed Tomagraphy
DL Diagnostic Laparoscopy
DPL Diagnostic Peritoneal Lavage

Fig. 6. Abdominal stab wounds. US, ultrasonography.

hemodynamically stable patients with anterior abdominal stab wounds used US to determine fascial violation. After anesthetizing the wound, the 8.0 MHz probe was used to assess abdominal fascial integrity directly beneath the wound and in a 10-cm by 10-cm area surrounding the injury. All stab wounds were then evaluated with standard local wound exploration. While overall sensitivity was only 59%, this increased as the operator's years of training increased (specificity was 100%) [75]. As emergency practitioners become more facile with alternative applications of US, this less invasive test for peritoneal violation may play a larger role.

At some centers, diagnostic laparoscopy (DL) is used as a screening tool for those with abdominal stab wounds. It is useful for inspecting the diaphragm and evaluating the depth of wound tracts [67,76,77]. Its routine use for penetrating trauma, however, is controversial.

A small prospective study of 232 subjects demonstrated that in patients with clear peritoneal violation (43 subjects), diagnostic laparoscopy (N = 20) performed no better than exploratory laparotomy (N = 23). In this study, no therapeutic laparoscopies were performed and nine subjects were converted from DL to laparotomy. However, in those 63 subjects with local wound exploration showing equivocal penetration, those randomized to laparoscopy (N = 28) had more minor and occult organ injury detected than those in the selected nonoperative management group (N = 31). But, this was at the expense of increased length of stay, hospital cost, and time to recovery in the DL group, leading the investigators to recommend against routine use of DL in penetrating abdominal trauma [78].

Other advocates of DL point to decreased cost and length of stay when laparoscopy is employed rather than exploratory laparotomy; albeit, this is at centers adept at DL [67,79]. Simon and colleague's [79] 5-year review of over 9,000 trauma patients at Jacobi Medical Center in New York found 344 explorations for penetrating abdominal trauma (300 laparotomies and 44 laparoscopies). During the last 4 years of the study period, he noted a rise in the use of DL for stab wound evaluation from 19.4% to 27%, which correlated to a decrease in the negative laparotomy rate during that time period. Of the 44 laparoscopies, 22 were positive for peritoneal violation and 15 of those required conversion to laparotomy for repair (there was 1 nontheraputic laparotomy). The remaining seven were three nonbleeding liver lacerations managed nonoperatively and four left diaphragmatic injuries repaired laparoscopically. There were 238 positive, 31 nontheraputic, and 31 negative laparotomies in those patients managed with initial laparotomy.

Length of stay for those patients with no other injuries and a negative laparotomy (N = 21; length of hospital stay 4.0 plus or minus 1.7 days) and those with no other injuries and a negative DL (N = 5; length of hospital stay 2.2 plus or minus 1.1 days) were compared and noted to be significantly less in the DL group ($P = .0349$). Neither of these groups had any significant complications. The investigators concluded that in a trauma center with an aggressive DL program, patients with anterior stab wound can benefit from this approach [79].

A small prospective study of 52 subjects with penetrating abdominal trauma, by Ahmed and colleagues [67], demonstrated that 77% of stable patients could avoid laparotomy when DL was employed. Of the 38% with visceral injury, almost half were managed nonoperatively. In this small series, only 12 subjects required open therapeutic laparotomy. When compared with National Trauma Data Bank matched patients, the use of DL was estimated to reduce hospitalization by over 55% in this series.

Diagnostic peritoneal lavage performed at the bedside determines both peritoneal violation and peritoneal injury. This rapid, yet invasive, test provides information about solid viscus, bowel, and diaphragmatic injury. While there has been debate over what red blood cell counts to use for detecting injury, most agree that the presence of greater than 10,000 red blood cells per high-power field (RBCs/hpf) indicates visceral injury in penetrating abdominal wounds [55,80]. A reduced range of 5 to 10,000 RBCs/hpf should be used for thoracoabdominal wounds [54]. When coupled with physical examination, DPL helps identify those patients who are candidates for nonoperative management [66,68,71]. However, as other less invasive diagnostic modalities are gaining favor, routine use of DPL is decreasing [57].

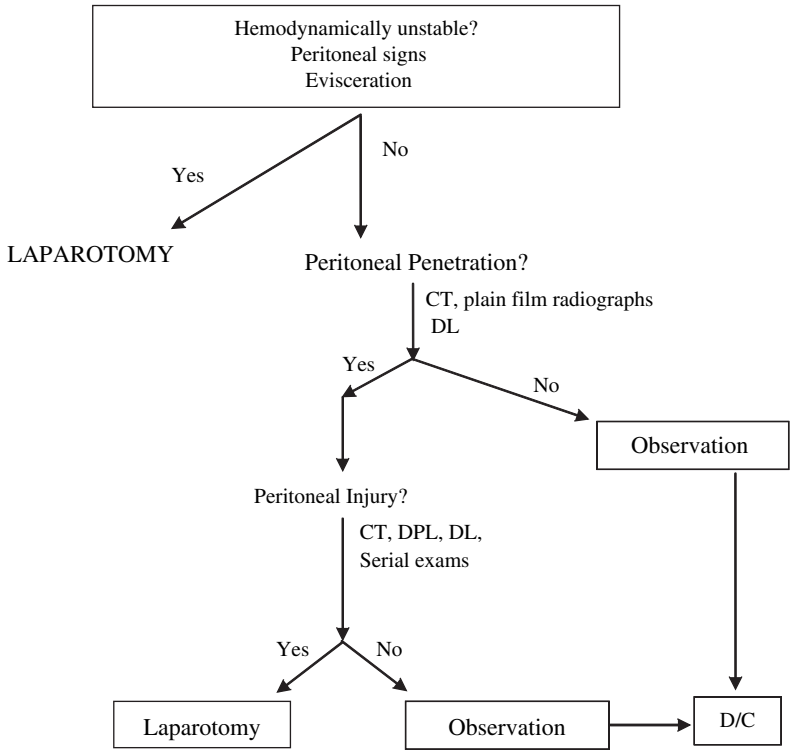
*Gunshot wounds*

Determining trajectory of gunshot wounds helps to determine the presence of intraperitoneal injury (Fig. 7). Once a thorough physical exam is completed and the number of wounds counted, plain film radiographs elucidate the missile path. Radio-opaque markers on any wounds, coupled with anteroposterior and lateral films, create a three dimensional estimation of trajectory path. Caution should prevail, as even wounds suggesting a superficial path may have intraperitoneal injury. If an odd number of wounds are present, careful attention to radiographs should reveal the missile location [57].

Computed tomography scanning is frequently employed after abdominal gunshot wounds, as it allows for determination of trajectory path, identifies organ injury and, therefore, optimal patients for nonoperative management [57,59,72]. As discussed previously, sensitivity and specificity remain high for this modality, even when IV contrast is solely used [59]. Many studies use CT as an adjuvant to nonoperative management [57,60,69,73]. It is especially helpful for defining hepatic injury that may be ideal for conservative treatment with observation only.

While more invasive, DPL has known high sensitivity for intra-abdominal injury after gunshot wounds [55,57,80]. It is an excellent means of determining peritoneal violation: using 10,000 RBCs/hpf as the threshold, it has a sensitivity of 96% [55]. Brakenridge and colleagues [80] also demonstrated its utility in shotgun wounds, citing a sensitivity of 87.5% in these patients. But, while DPL is sensitive for hemoperitoneum, it does not give specific information regarding organ injury and is therefore less useful in determining nonoperative management in stable patients, and its use as a screening exam in these patients is declining [57].

Conversely, laparoscopy is slowly gaining favor in the management of abdominal gunshot wounds. Laparoscopy serves primarily to determine the presence of peritoneal violation and to inspect the diaphragm. Drawbacks include the need for anesthesia, inability to repair certain injuries (requiring conversion to laparotomy), and difficulty in visualizing the posterior




CT Computed Tomagraphy
DL Diagnostic Laparoscopy
DPL Diagnostic Peritoneal Lavage

Fig. 7. Abdominal gunshot wounds.

diaphragm, subtle bowel injuries, and the retroperitoneum [57,67,76]. As for stab wounds, as trauma centers become more adept at this procedure laparoscopy may be used more frequently, especially in those patients with left sided thoracoabdominal injuries in which diaphragmatic injury must be ruled out [57].

*Selective nonoperative management*

Once the need for mandatory laparatomy is ruled out, patients may be triaged to nonoperative management. These patients must be serially observed with frequent physical examination. If peritoneal signs develop, conversion to laparotomy follows. Some centers use additional diagnostic testing (as described above) to further stratify patients for nonoperative

management. Numerous studies have touted this approach for management of abdominal stab wounds, showing it safely reduces rates of nontherapeutic and negative laparotomies, as well as decreasing the length of hospital stay and cost [60,69,71].

Now studies confirm that similar algorithms for abdominal gunshot wounds are also safe practice in centers able to perform frequent re-examination of patients and transition to laparotomy when indicated [57–60,72]. Velmahos and colleagues' study [59] of 100 subjects with nontangential abdominal gunshot wounds selected for nonoperative management showed CT had a sensitivity of 90.5% and specificity of 96% for identifying injury. In this study, 26 subjects went on to laparotomy, of which 5 were nontherapeutic. In another study of nonoperative management of penetrating abdominal trauma, 41 patients with gunshot wounds were evaluated. Of these, 17 had a positive CT and 24 had a negative CT. There were no false-negative CTs in this select group. Thirteen went on to laparotomy, of which 11 were therapeutic, 1 was nontherapeutic and 1 was negative (this patient had a negative CT but clinical indications for laparotomy). There were five nonoperative hepatic injuries, three hepatic injuries that had angioembolization, and one video-assisted thoracoscopic diaphragm repair [72].

*Special considerations*

Flank and back penetrating injury present a difficult situation, as visualization of those areas via local wound exploration, US, DPL, and laparoscopy is challenging, if not impossible. Computed tomographic scan with triple contrast has become the test of choice in hemodynamically stable patients, and may safely allow triage to nonoperative management [58,81]. There is growing evidence for nonoperative management, but these studies remain small and are only applicable at trauma centers. As most patients with these injuries have indication for mandatory laparotomy, larger more translatable studies are probably not forthcoming [57].

Thoracoabdominal wounds are especially difficult, as the trajectory of penetration cannot be reliably determined because of movement of the diaphragm. As noted above, if DPL is used in this group, then a lowered RBC/hpf threshold of 5000 must be used [54]. While exploratory lapartomy has been mandatory for these types of injuries in the past, use of laparoscopy continues to gain favor. This approach reduces negative and nontherapeutic laparotomy rates previously documented [57].

## Summary

Several advances in diagnostic modalities challenge the traditional dogmatic approach to abdominal trauma. Ultrasonography is now routinely used in the initial assessment of those with blunt abdominal trauma,

and its role in penetrating trauma is being defined. Improved CT resolution with multislice and helical CT scanners allows for better identification of injuries with improved ability to grade their severity. This in turn, offers a nonoperative approach for certain patients with penetrating or blunt abdominal trauma. As competence with laparoscopy continues to evolve, this more invasive screening tool shows promise for evaluation of certain types of patients with penetrating injury, and may lead to less morbity and more cost-effective use of hospital resources. Finally, selective nonoperative management for both BAT and abdominal stab wounds and gunshot wounds is no longer a novelty, finally accumulating the literature necessary to make its practice standard in most trauma centers.

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