CHAPTER 39

Abdominal Trauma

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PRINCIPLES

Background

The management of abdominal trauma relies on applying knowledge and organization to key clinical features and the timely use of diagnostic procedures. Advancements in imaging have helped to decrease missed or delayed diagnoses, yet abdominal injuries can be notoriously occult, requiring both diligence and vigilance to achieve the best outcomes.[1]

Penetrating Abdominal Trauma

Whether by accident or intention, penetrating trauma can result from a wide variety of weapons or instruments, and certain elements of therapy vary accordingly. The careful integration of physical examination and certain diagnostic procedures, notably local wound exploration (LWE), ultrasonography, computed tomography (CT), laparoscopy, and in rare instances, diagnostic peritoneal tap (DPT), now provides an accurate and reliable means of determining whether laparotomy should be undertaken. The approach varies according to the clinical status of the patient, the instrument responsible for injury, and the site of penetration. Nonoperative management has gained favor predominantly for stab wounds, though also for carefully selected gunshot wounds, with the intent to reduce the incidence of and morbidity from nontherapeutic laparotomies.[2,3]

Wounds from stabbing implements occur nearly three times more often than from firearms, but the latter are responsible for 90% of penetrating trauma mortality. The small intestine, colon, and liver are the most likely organs to sustain injury after penetrating trauma. The highest risk of death from penetrating abdominal injury occurs among African Americans in the 15- to 34-year-old age range, followed by Hispanic persons in that same age group. The rate for non-Hispanic whites is greatest at 75 years of age and older. The predominant intent is homicide among African Americans and suicide among non-Hispanic whites.

The use of firearms in the United States contributes heavily to the morbidity and mortality of trauma. The number of homicides committed with firearms exceeds the number of homicides resulting from all other forms of violence combined. More than 850,000 American civilians were killed by bullets in the 20th century.[4] Please see Chapter e2 for a more complete discussion of injury prevention.

Blunt Abdominal Trauma

Despite advances in imaging, blunt injuries carry a greater risk of mortality than penetrating injuries because they are more difficult to diagnose and are commonly associated with severe trauma to multiple intraperitoneal organs and extra-abdominal systems. Historical data may be incomplete, absent, or presumptive. The symptoms and signs can be unreliable and obfuscated by head injury, alcohol, or other toxins. The likelihood of extra-abdominal systems trauma adds further complexity, underscoring the need for a carefully organized approach.

The spleen is the organ most often injured; and in nearly two thirds of these cases, it is the only damaged intraperitoneal structure. The liver is the second most commonly injured intra-abdominal organ, and injury to any hollow viscus is uncommon by comparison, with the intestine is the most likely hollow viscus to be damaged. Most cases of blunt abdominal trauma are caused by motor vehicle collisions, whereas blows to the abdomen and falls make up a minority of blunt abdominal trauma cases.

Anatomy and Physiology

The abdominal cavity and its contents can be reached not only through the anterior abdominal wall and lower chest but also through the flank, back, and buttocks. Rarely, missiles lodge intraperitoneally after traversing proximal extremities, as well. The *anterior abdomen* is defined as that region between the anterior axillary lines from the costal margins to the groin creases. The *low chest* begins at the nipple line or fourth intercostal space anteriorly and the inferior scapular tip or seventh intercostal space posteriorly, and then extends down to the inferior costal margins. The *flank* is between the anterior and posterior axillary lines bilaterally from the inferior scapular tip to the iliac crest. The *back* is between the posterior axillary lines, beginning at the inferior scapular tip and extending down to the iliac crest. The intraperitoneal cavity is vulnerable when penetration occurs as high as the fourth intercostal space anteriorly and the sixth or seventh laterally and posteriorly because the diaphragm can ascend to this level during expiration. Simultaneous thoracic and abdominal penetration can be found in 20% to 40% of cases of abdominal thoracic trauma. Scrutiny of entrance and exit sites, as well as wound tracts, is imperative.

Pathophysiology

Penetrating Abdominal Trauma

Penetrating abdominal injuries predominantly are caused by knives and firearms. Injuries caused by impalement objects, such as fences, stakes, or similar objects are treated as stab wounds. Various propelled missiles from lawn mowers or other machinery are managed as gunshot wounds, based on their velocity. Fragmentation injuries produced by grenades and bombs are rare in this country, but industrial explosions can produce similar injuries, and blunt abdominal trauma from blast effect can coexist in this setting. Domestic terrorist acts may involve improvised bombs that are loaded with shrapnel, such as BBs, ball bearings, or nails, with penetrating abdominal trauma often the least dramatic of the injuries.[5]

The liver, followed by the small bowel, is the organ most often damaged by stab wounds, in keeping with the location and surface area of these structures. The frequency of organ injury caused by gunshot wounds is greatest for small bowel, followed by the

colon, and then the liver. Typically, multiple organ injuries are sustained.

Stab Wounds. A variety of implements besides knives can induce stab wounds, which occur most commonly in the upper quadrants. Nearly one quarter of cases have multiple wounds, and up to 10% of cases involve the chest. Most stab wounds do not cause an intraperitoneal injury, although the incidence varies with the implement used and the direction of entry. Anterior stab wounds penetrate the peritoneum in approximately 70% of cases but inflict a visceral injury in only half of these.[2] Left lower chest wounds are associated with a 17% incidence of intraperitoneal damage in addition to the high rate of thoracic and diaphragmatic injuries, whereas right lower chest wounds have a much lower incidence of 0% to 4%. Abdominal entries from the flank and back have reported incidences of up to 44% and 15%, respectively. The liver and spleen are the viscera most commonly damaged in cases of back and flank wounds, but the injury pattern cannot be well predicted by the site of entry in the abdominal wall.

Gunshot Wounds: Ballistics. The science of ballistics is complex, but a few basic principles are helpful in understanding the pathophysiologic processes. The magnitude of the injury is proportional to the amount of kinetic energy imparted by the bullet to the victim, according to the following equation:

$$E = \frac{7000\,mv^2}{2\,ga}$$

where E is the kinetic energy (in foot-pounds), m is the mass of the bullet, v is the velocity of the bullet (in ft/s), and ga is gravitational acceleration (in ft/s). The degree of injury depends on the mass of the bullet and the square of its velocity, although the resistance and viscoelastic properties of the tissue affect the resultant injury, as well. Missile velocities are categorized as low (slower than 1100 ft/s), medium (1100 to 2000 ft/s), and high (faster than 2000 to 2500 ft/s). Impact velocity is the most important determinant of wounding capability, which depends on the distance between the firearm and the victim, the muzzle velocity, and characteristics of the missile. At medium and high velocities, the missile has an explosive effect and creates a temporary passage in the tissue along its course, directly proportional to the specific gravity of the penetrated tissue. This sudden formation of a tract displaces nearby organs and vascular structures, and bone and viscera may be fractured or torn without being directly struck by the missile. Several cases of an intraperitoneal injury caused by a bullet that remained extraperitoneal throughout its entire course have been reported. Solid viscera, such as the liver and spleen, are more vulnerable to this effect.

High-Velocity Missiles. Wounds from high-velocity missiles involve additional problems. External contaminants tend to be dragged into the wound, high-velocity bullets can fragment internally, and closure of the tract immediately after the bullet's passage may lead to an underestimation of tissue damage. A missile at any velocity can fragment after contact with bone and cause additional multiple trajectories and injuries, which makes assumptions regarding bullet tracts dangerous in the assessment of the patient. Civilian wounds usually result from low-velocity handguns, but there has been a trend toward more destructive weapons.

Shotgun Wounds. Because of the ballistic shape of the individual pellets, a rapid falloff in velocity occurs, making this weapon ineffective in producing severe wounds at long distances. An initial muzzle velocity of 1300 ft/s drops to 950 ft/s within 20 yards, a decrease of 25%. At close range (<15 yards), however, the shotgun is extremely lethal, which has implications for patient care. Although the kinetic energy depends on the pellet's size, the number of striking pellets, the type and amount of powder, and the barrel choke (constriction), the most important clinical variable is the distance between the shotgun and the victim. At a distance of 10 yards (9 meters), 19% of the pellets cluster in a 9-inch (23 cm) diameter circle if fired from a full choke (maximum constriction) barrel. At a distance of 20 yards (18 meters), the circle is approximately double that diameter. Because the kinetic energy is proportional to the square of the velocity, a 25% loss of velocity at 20 yards (18 meters) results in a significant decrease in the damage produced by the blast.

Shotgun wounds have been previously classified in three groups according to the range and pattern of distribution. More recently, classification has been according to the pattern of injury on the victim. Based on distance from the weapon to the victim, type I wounds involve a long range (>7 yards or 6.4 m) and a penetration of subcutaneous tissue and deep fascia only. Type II wounds occur at a distance of 3 to 7 yards (2.7 to 6.4 m) and may create a large number of perforated structures. Type III wounds occur at point-blank range (<3 yards or 2.7 m) and involve a massive destruction of tissue. When categorized by pattern, type I wounds produce a spread greater than 25 cm in diameter; type II, 10 to 25 cm in diameter; and type III, less than 10 cm in diameter. Close-range shotgun wounds, in addition to the shot, force external contaminants (eg, clothing and parts of the shell wadding) into the wounds. Type III wounds carry a substantial mortality risk.

Blunt Abdominal Trauma

Sudden and pronounced rises in intra-abdominal pressures created by outward forces, such as lap-belt-only restraints, can cause rupture or burst injury of a hollow organ. Compression of abdominal viscera between the applied force to the anterior wall and the posterior thoracic cage or vertebral column produces a crushing effect. Solid viscera are especially vulnerable to this injury, which is why liver and spleen injury are so common in blunt abdominal trauma. Crush injuries are more likely to occur with the lax abdominal wall characteristics of elderly or intoxicated patients. Finally, acceleration and deceleration cause organs and vascular pedicles to shear at the relatively fixed points of attachment.

Seatbelt Injuries. Unrestrained passengers are at unequivocally greater risk of intra-abdominal injury than their restrained counterparts. The three-point shoulder-lap belt is the most effective restraining system and is associated with the lowest incidence of abdominal injuries. However, abdominal injuries are still ascribed to combined shoulder-lap belt systems. The shoulder belt component can lead to right-sided and left-sided rib fractures for the driver and front seat passenger, respectively, with potential for injury to underlying abdominal viscera, particularly in the case of improper underarm usage of the shoulder belt.

Injuries resulting from solitary lap belts are most often to the abdomen. The pathogenesis is usually the compression of bowel between the belt and the vertebral column, resulting in a contusion or perforation of the intestines or a tear of the mesentery. Approximately one fourth of these patients develop evidence of a hemoperitoneum secondary to mesenteric lacerations. In the remainder, the intestinal injury most commonly involves the jejunum, and the initial signs and symptoms are often absent or considered insignificant. Subsequent delays in diagnosis of up to 8 weeks have rarely been reported. The "seatbelt sign," contusion or abrasion across the lower abdomen, is found in less than one third of patients with abdominal injuries caused by lap belts. Its presence, however, is highly correlated with intraperitoneal

pathologic lesions. Rupture of the diaphragm can also occur in cases of high speed frontal impact.[6] Rare cases of acute abdominal aortic dissection with incomplete or complete occlusion have been described, and injuries to the lumbar spine are not uncommon.

Iatrogenic Injuries. Abdominal injuries may be sequelae of various medical procedures. External cardiac compressions, manual chest thrusts to clear an airway obstruction, and the Heimlich maneuver can cause rib fractures and injury to abdominal viscera. Misadventure with tube thoracostomy can cause injury to the liver or spleen because of unrecognized elevation of the diaphragm or improper technique or placement of the tube. Peritoneal lavage, paracentesis, and peritoneal dialysis can cause vascular penetration or bowel perforation. A liver biopsy can lead to a hemoperitoneum or a biloma, whereas endoscopic procedures of the bowel may cause a hollow viscus perforation and peritonitis.[7] Colonoscopy can cause splenic injury and hemoperitoneum, and although specific mechanisms and risk factors are unclear, does not necessarily seem to be associated with biopsy.[8]

Clinical Features

The patient's history may be unobtainable, elusive, or temporarily deferred while resuscitative measures are carried out. When the situation permits and a reliable source is available, certain information is valuable. The patient's ability to relate the course of events may be compromised by head or spinal cord injury, alcohol intoxication, developmental delay, psychiatric illness, and any number of toxins that will affect the clinician's assessment of the patient. At times, the trauma may have preceded the onset of symptoms by days, weeks, or even years, and may have been forgotten or considered trivial by the patient. This is particularly true of delayed presentation of diaphragmatic hernia related to a prior penetrating lower chest injury. Witnesses at the scene, particularly paramedical personnel, often provide the most reliable data.

Appreciation of comorbid medical conditions, particularly cardiovascular disease and coagulopathies, optimizes fluid and blood component therapy. When a prehospital care team or transferring hospital is involved, the vital signs, physical assessment, prehospital course, and response to therapy should be obtained. Clinical records and laboratory and radiologic studies obtained at an outlying hospital should be carefully reviewed.

Abdominal pain is the most obvious symptom of abdominal trauma. A hematic, infectious, acidic, or enzymatic irritation of the peritoneum produces pain. The pain may be clearly present at the outset or delayed for hours to days. The perception and communication of such pain may be dulled or ineffectual, or the perception of pain may be impaired by a spinal cord injury or an underlying medical problems. Occasionally, intense, competing pain at another body site dominates and distracts both the patient and physician away from the abdomen. Abdominal pain can be localized, because it sometimes is in the left upper quadrant with a splenic injury, or diffuse, such as in septic peritonitis subsequent to bowel perforation.

Pain need not be localized to the abdomen, and irritation of the diaphragm by hemoperitoneum can cause referred pain to the right and left shoulder tips or neck, particularly when the patient has been in the Trendelenburg position. This most often is a marker of hepatic or splenic injury. Pain can also be referred to the testicle in the setting of retroperitoneal injury and is seen most commonly with urogenital and duodenal trauma.

A variety of other extraabdominal symptoms may be present as well. If substantial enough, volume loss may produce orthostatic or frank dizziness, light-headedness, and confusion. Nausea and vomiting can accompany peritoneal irritation or hypovolemia, or can result from an obstruction, such as following a duodenal hematoma. Dyspnea sometimes occurs with gastric distention or diaphragmatic irritation or when abdominal contents herniate into the chest, impairing respiratory dynamics.

Penetrating Abdominal Trauma

Stab Wounds. The number of stabs inflicted, type and size of the instrument, posture of the victim relative to the direction of assault, estimated blood loss at the scene, time of injury, and response to fluids help to gauge the nature and severity of injuries. However, a significant proportion of victims of stab wounds are found under the influence of alcohol or another drug making an accurate history a futile effort and potentially compromising the validity of symptoms and signs.

Gunshot Wounds. Clinically helpful information for gunshot wound victims includes the weapon used, its distance from the victim when shot, the position of the victim in relationship to the weapon when fired, the suspected number of shots, the blood loss at the scene, the amount and type of field fluids administered, and the vital signs during the prehospital course.

Blunt Abdominal Trauma

Clinically relevant information for passengers in motor vehicle crash includes the nature of the crash; extent of damage to the car; the patient's location within the car; whether the patient struck the steering wheel; whether seat belts were used and, if so, what type; and whether front or side air bags were deployed. The magnitude of injury to pedestrians varies with the speed and size of the striking vehicle. A triad of injuries to the torso, cranium, and lower aspect of the lower extremity has been well described, and pathologic lesions discovered in two of these sites should prompt careful attention to the third. Motorcycle crashes can be placed in one of four categories: frontal, lateral or angular ejection, or "laying the bike down." Different pathologic lesions can be projected based on the offending mechanism.

Physical Examination

Abdominal trauma provokes a wide spectrum of presentations that range from seemingly insignificant symptoms and signs to severe shock and coma. Evidence of abdominal tenderness, peritoneal irritation, gastrointestinal hemorrhage, and hypovolemia not attributable to extra-abdominal causes represents most of the signs suggestive of an intraperitoneal injury. These signs may be initially absent or obscure but may emerge during serial examinations.

The physical examination of a hemodynamically unstable patient is performed coincident with therapy, but care and thoroughness are not precluded by these circumstances. When an obvious intracranial, thoracic, or orthopedic injury is present, abdominal symptoms or findings may be obscured, and abdominal injury should be considered. Chest trauma is a risk factor for coincident intraperitoneal injury. This is particularly true in cases of suspected blunt trauma accompanied by a head injury, coma, or obtunded mental status resulting from drugs or alcohol.

After removal of the patient's clothing, abdominal examination occurs as part of the secondary survey (see Chapter 33).

Acute hypotension resulting from hemorrhage is most often from a solid visceral or vascular injury. Traumatic pancreatitis may evolve to produce significant third-space fluid loss but is virtually never the sole cause of acute shock. When unexplained hypotension accompanies significant blunt trauma, one should assume the presence of intraperitoneal hemorrhage until it is excluded. A known extra-abdominal source of hemorrhage does

not mitigate the need to evaluate the peritoneal cavity. Solitary cranial or spinal injury should not be considered the sole cause of shock until intra-peritoneal injury has been excluded.

In cases of penetrating trauma, inspecting the abdomen for entrance and exit wounds may help determine the path of injury. Distention can occur as a result of hemoperitoneum or pneumoperitoneum, gastric dilation, or ileus secondary to peritoneal irritation. An ecchymotic discoloration of the flanks (Gray-Turner sign) or umbilicus (Cullen's sign) indicates retroperitoneal hemorrhage, but these signs are usually delayed for 12 hours to several days. Abdominal contusions can result from various implements; and when caused by lap-seat belts, they herald abdominal injuries in one third of cases. Presence or absence bowel sounds does not reliably identify or exclude the presence of intra-abdominal injury.

Although palpation elicits local or generalized tenderness in the vast majority of alert patients with an intra-abdominal visceral injury, it is less reliable in patients with altered mental status. However, physical examination can be unreliable even in conscious, responsive patients. Local and generalized rebound tenderness and rigidity can be signs of peritoneal irritation but occur less commonly. These signs lack specificity and can be found with lower rib fractures and contusions of the thoracoabdominal wall as well. Rarely, encapsulated bleeding into regions walled off by blood clots or adhesions can form palpable intra-abdominal masses; these usually appear at least several hours later. Severe contusions of the abdominal wall can cause tenderness and voluntary guarding that is localized and usually exacerbated by use of the affected muscle. A palpable mass can represent a rectus hematoma or ventral hernia.

Rectal examination, once a routine part of trauma assessment, rarely, if ever, provides clinical useful information and is not indicated in the vast majority of trauma patients. This is particularly true in conscious patients of both sexes, for whom rectal examination is uncomfortable, unnecessary, and potentially humiliating. The sole remaining value of rectal examination is as part of the neurological assessment (for anal sphincter tone) for patients with identified neurological deficit believed to be caused by spinal cord injury.

Although the presence of physical findings makes intraperitoneal injury more likely, their absence does not preclude serious pathology, and no finding is exclusively diagnostic of a specific injury. Extended observation and the use of certain laboratory procedures greatly help prevent erroneous or missed diagnoses.

Penetrating Abdominal Trauma

Stab Wounds. Serial physical examination performed by the same observer is useful in appropriately staffed and experienced centers, particularly with patients who are alert, communicative, and neurologically intact. The presence of intoxicants does not necessarily preclude reliance on examination but may decrease its value until sobriety is regained. Even among patients with evidence of shock, peritonitis, or evisceration after penetrating trauma to the abdomen exploratory laparotomy fails to reveal intraperitoneal organ injury in over 10% of cases.[3] In contrast, up to one third of patients with significant intra-abdominal injuries have no suggestive physical signs, particularly when a retroperitoneal injury has occurred.

Gunshot Wounds. As with blunt or other modes of penetrating trauma, there are limitations to physical examination of patients with abdominal gunshot wounds. Up to 20% of patients with a documented intraperitoneal injury have no peritoneal signs before exploration, whereas objective physical findings suggestive of intra-abdominal damage may be present in up to 15% of patients in whom laparotomy reveals no injury.

Blunt Abdominal Trauma

Overall, the accuracy of the physical examination in patients with blunt abdominal trauma is only 55% to 65% because the initial presentation may be deceptively benign. The most reliable symptoms and signs in alert patients are pain, tenderness, and peritoneal findings, particularly when risk factors for abdominal injury are present. When altered sensorium intercedes, the physical signs become less reliable. Frequent evaluations by the same examiner are indicated even in alert patients, but especially in sensorium-altered patients, particularly as their mental status and sensorium normalize.

DIFFERENTIAL DIAGNOSES

Trauma Versus Medical Condition

Medical and traumatic pathologic conditions can be coincident or lead one to the other. For instance, hypoglycemia or a generalized convulsive seizure may precipitate a motor vehicle collision, and the patient's altered mental status may incorrectly be ascribed to closed head injury, delaying diagnosis of the medical condition. Patients with infectious mononucleosis can experience splenic rupture after relatively trivial trauma, and presentation may be delayed. Finally, patients with premorbid coagulopathy or who are on therapeutic anticoagulation may sustain serious intracranial or intra-abdominal hemorrhage from otherwise unimpressive trauma (see Chapters 33 and 34).

Single Versus Multisystem Trauma

Emergency clinicians should be wary and not miss the proverbial forest for the trees. For instance, the pedestrian struck by a car who has an alleged isolated tibial-fibular fracture may well harbor significant intra-abdominal pathology, irrespective of a nontender abdomen.

Single Versus Multiple Intraperitoneal Organ Injury

There has been an increasing trend toward nonoperative management of known intraperitoneal solid organ injury, specifically of the spleen and liver.[9,10] However, coincident hollow viscus pathologic lesions may exist but not be discernible initially on clinical examination or diagnostic studies. In addition, patients without solid organ pathology who have increasing amounts of free peritoneal fluid or tenderness warrant careful consideration for hollow viscus damage.

Intraperitoneal Injury Versus Necessary Laparotomy

Formerly, suspicion or knowledge of any intraperitoneal injury mandated laparotomy. Now, diagnostic effort is appropriately aimed at determining whether surgery is necessary or whether the injury is self-limited and does not require repair.

DIAGNOSTIC TESTING

Ultrasonography

Extended focused assessment with sonography for trauma (E-FAST) examination is indicated in all poly-trauma patients and all patients with suspected abdominal injury, whether by blunt or penetrating mechanism. Ultrasonography's primary role is detecting free intraperitoneal blood after blunt trauma. This is accomplished by an examination of Morrison's pouch, the

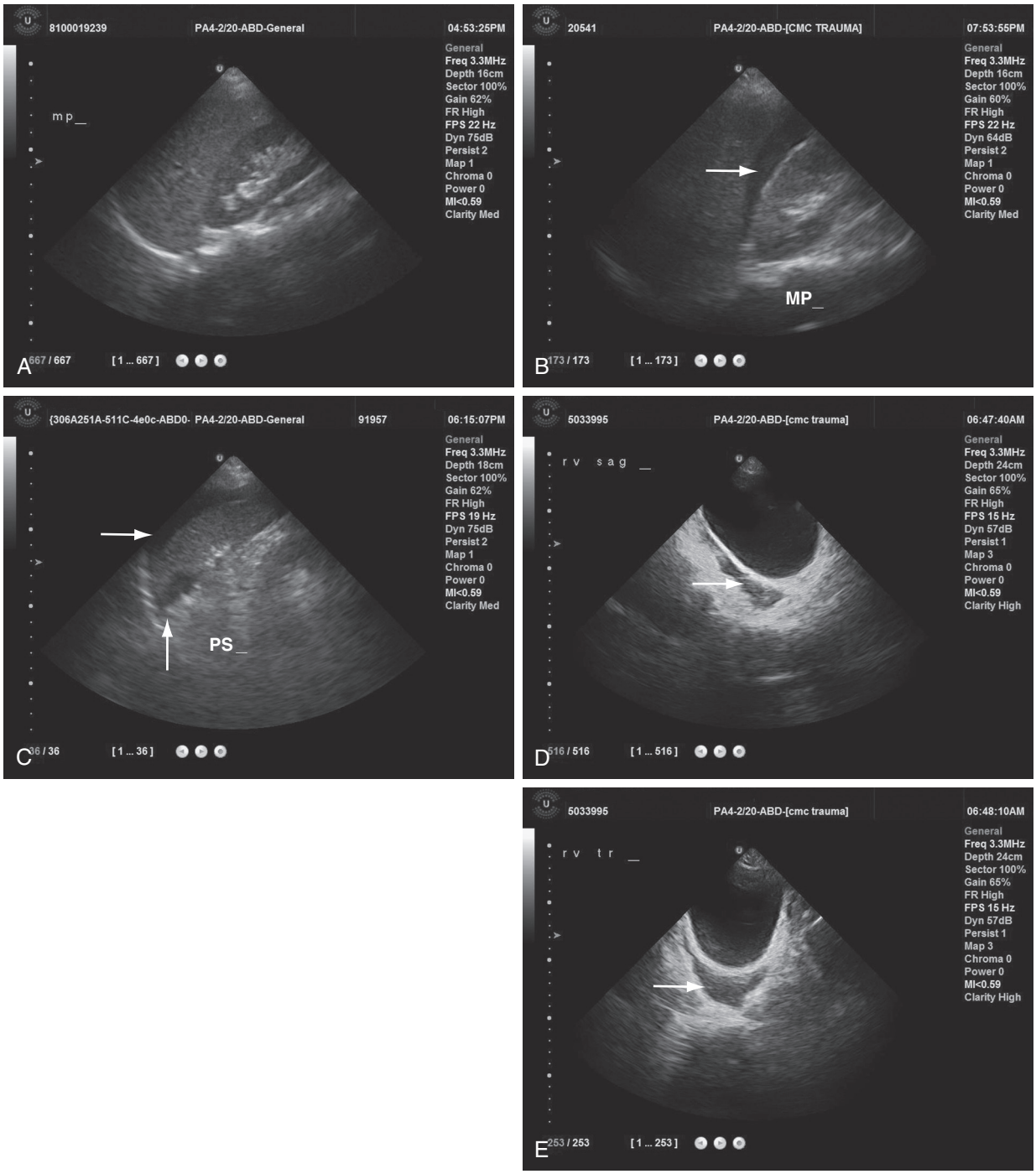

Fig. 39.1. **A,** Normal Morrison's pouch view. Note absence of an anechoic stripe, which would represent a fluid collection between the liver and kidney. **B,** Positive Morrison's pouch view. Note presence of an anechoic stripe representing a fluid collection between the liver and kidney *(arrow)*. **C,** Positive perisplenic view. Note anechoic fluid around spleen *(arrows)*. **D,** Positive fluid in the sagittal retrovesicular view *(arrow)*. Note anechoic stripe indicative of retroperitoneal fluid. **E,** Positive transverse retrovesicular view. Note anechoic area indicative of retroperitoneal fluid *(arrow)*.

splenorenal recess, and the pouch of Douglas, which are dependent portions of the intraperitoneal cavity where blood is likely to accumulate (Fig. 39.1). The thoracic portion of the examination detects pneumothorax, hemothorax, and pericardial effusion or tamponade (Fig. 39.2). Ultrasound applications in the trauma patient are discussed in Chapter e5. The E-FAST study is aimed precisely at the determinations described earlier and is limited for visualizing solid parenchymal damage, the retroperitoneum, or diaphragmatic defects.

Laboratory

Hematologic and chemical values are of limited use in the management of the acutely traumatized patient and should be considered adjuncts to diagnosis and not substitutes for clinical assessment. Laboratory assessment for patients with severe or multi-system trauma has historically relied on "trauma panels," which are a form of standing or automated order of myriad tests, the majority of which are not indicated. Both payers and

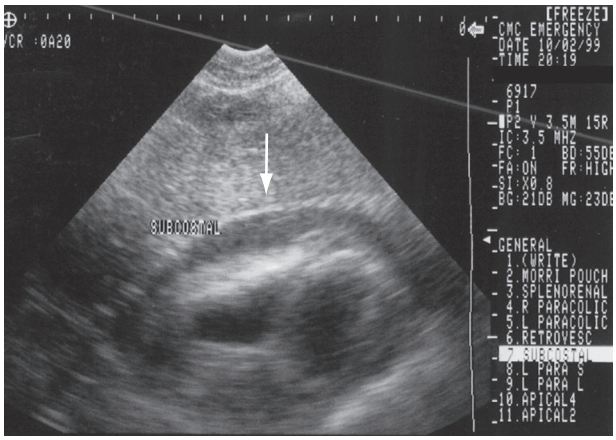

Fig. 39.2. Pericardial effusion seen on subcostal view *(arrow)*. The *white line* is the pericardium, and the anechoic space below represents a fluid collection in the pericardial space.

evidence-based practice argue strongly for the cessation of this wasteful and often clinically misleading practice. This is particularly true for patients with suspected abdominal trauma. Targeted laboratory evaluation, however, can provide significant guidance in the assessment and management of the traumatized patients.

Hematocrit

The hematocrit reflects baseline value, extent of and time from hemorrhage, exogenous fluid administration, and endogenous plasma refill. The last of these is a physiologic compensatory shift of extracellular fluid into the intravascular space, the intent of which is to restore the original blood volume. Based on a study of volunteers sustaining a 10% to 20% blood loss, this restoration requires over 24 hours for completion. Patients with hemorrhagic shock (at least 40%) demonstrate much faster plasma refill rates, with significant decreases in hematocrit within 90 minutes. Although easily measured, hematocrit is often a conundrum when viewed in isolation, and serial determinations are more helpful.

White Blood Cell Count

The white blood cell (WBC) count has little discriminatory value in cases of abdominal trauma, particularly its acute phase. The WBC count may be normal or may show a modest leukocytosis (12,000 to 20,000/mm^3 with or without left shift), which can occur in the setting of multisystem trauma as a result of stress-induced demargination in the absence of any intra-abdominal process, or as a result of tissue injury, acute hemorrhage, or peritoneal irritation.

Chemistry

Although included in many "trauma panels," neither serum amylase nor lipase is useful in the evaluation of acute abdominal trauma. Normal levels do not exclude a major pancreatic injury, and elevated values may be caused by any of an assortment of reasons in addition to an injured pancreas, including alcohol, drug toxicity, or systemic hypotension and pancreatic hypoperfusion without pancreatic injury. Elevated or rising levels may indicate damage but in themselves are not conclusive.[11] In all cases, clinical examination and status direct further investigation.

Metabolic acidosis in the setting of trauma can suggest the presence of hemorrhagic shock. This can be witnessed chemically as a decreased serum bicarbonate level, increased base deficit, or elevated lactate level. Although normal values do not exclude abdominal injury, abnormalities, such as a base deficit greater than or equal to 6, elevated lactate greater than 4 mmol/L, or increase over time in either of these indices, suggests perfusion compromise or injury.[12] These findings should be considered in clinical context, because the cause of the abnormalities may be extra-abdominal and trending of laboratory findings lags behind the clinical deterioration or improvement of the patient.

Elevated serum transaminases can result from hepatic trauma but do not distinguish minor contusions from severe injury. Alternatively, these may be symptomatic of alcohol-induced liver damage. Elevated liver transaminase levels may be useful for screening pediatric patients for intentional trauma (see Chapter 177).

Screens for ethanol and drugs are often used in trauma centers. Their utility in the management of abdominal trauma, per se, has not been established, particularly in patients with normal mental status. Positive study findings may prompt the emergency clinician to interdict and the patient to decrease the recidivistic use of ethanol or drugs, and physician intervention during this "teachable moment" has been shown to be effective.

TABLE 39.1

Diagnostic Studies in Blunt Abdominal Trauma

STUDY SCENARIO	PRIMARY PURPOSE	STUDY	COMPENSATORY
HEMODYNAMICALLY UNSTABLE			
General	IPH	FAST, DPA	—
Pelvic fracture	IPH	FAST, DPA[a]	—
HEMODYNAMICALLY STABLE			
General	OI[b,c], HVI	FAST, CT	DPL, SPEs
Nonoperative management[d]	OI	FAST, CT[e]	DPL,[f] SPEs
Closed head injury	OI	FAST, CT[e]	SPEs[g]
Blunt aortic injury	IPH	FAST	CT[h]

[a]Positive peritoneal aspirate necessitates laparotomy.
[b]To discover fluid or blood suggesting injury.
[c]FAST for OI much less reliable than for IPH.
[d]Institutional capability should be carefully considered.
[e]CT less reliable for HVI than for solid visceral injury.
[f]Complementary to CT if HVI suspected.
[g]SPEs are unreliable in the patient with CHI.
[h]May be more appropriate if helical CT is primary study for blunt abdominal injury or can be rapidly acquired.
CT, Computed tomography; *DPA,* diagnostic peritoneal aspiration; *DPL,* diagnostic peritoneal lavage; *FAST,* focused assessment with sonography in trauma; *HVI,* hollow viscus injury; *IPH,* intraperitoneal hemorrhage; *OI,* organ injury; *SPE,* serial physical examination.

Radiology

Resuscitation and initial stabilization measures precede abdominal radiographic studies. The purpose of diagnostic studies is twofold (Table 39.1): to discern or eliminate the presence of hemoperitoneum in the patient whose condition is critical and unstable to properly sequence management and, in less urgent circumstances, to demonstrate organ injury that requires operative repair. Basic plain radiography of the abdomen in the trauma bay is not indicated, except for missile location or identification. Portable chest x-ray examination has been a staple to screen for significant hemothorax or pneumothorax before the patient is transferred to the CT scanner, but this is largely being replaced by

the chest portions of the E-FAST examination, which has proven at least as sensitive and specific as portable chest radiography for both conditions.[13]

Hemodynamically stable patients who will undergo expedient abdominopelvic CT can forego pelvic radiographs in the trauma bay. Indications for pelvic radiography are discussed in Chapters 33 and 48. In patients whose evaluation, including E-FAST results, demonstrates likely intra-peritoneal injury requiring laparotomy, delay in operation to obtain further diagnostic radiology studies is permissible only when the patient has been stabilized and only if studies might aid in determining management.

Plain Radiographs

The chest radiograph and anteroposterior pelvic films can be invaluable in some cases of penetrating and blunt trauma, depending on the presentation and results of initial evaluation. Chest radiographs can provide extra-peritoneal causes of hypotension in the unstable patient. Plain abdominal films can demonstrate the location or presumed track of the missile(s) in gunshot and shotgun injury but are of little value in blunt trauma or non-projectile penetrating trauma, particularly if CT imaging of the abdomen is anticipated. If plain radiography of the abdomen is done, the finding of rib, pelvic, vertebral body, or transverse spinous process fractures in the blunt trauma patient warrants special consideration for nearby visceral damage.

Although free intraperitoneal air can be detected on plain films, the small amounts and location of air associated with small bowel injuries are seen more readily on CT. Free intraperitoneal air uncommonly can be generated by mediastinal or pulmonary injury, as well as by barotrauma, and its presence is not pathognomonic of hollow viscus perforation. Intraperitoneal air is mobile; in upright films, air is located under the diaphragm or the central tendon of the diaphragm anteriorly. In supine films, air tracks under peritoneal attachments, such as the falciform ligament and urachus, up to the anterior abdominal wall. On films in which the patient is in a lateral decubitus position, air is located in the superior flank and outlines the lateral liver edge. Extraperitoneal colonic perforations may extravasate air, which outlines the psoas muscle and perinephric region. All of these injuries are much more readily identified and localized on abdominal CT and thus remains the imaging modality of choice.

Foreign bodies and missiles are easily identified on abdominal films. Therefore their absence without a known exit wound warrants further search of other body cavities (eg, the chest, upper thighs, buttocks). A ricochet off the spine or pelvis into the chest or proximal extremities can occur. An entry into the vascular system may carry the object toward and into the right side of the heart or peripherally into the arterial tree. It may also find its way into the gastrointestinal tract and either produce obstruction or pass through unnoticed. Thus, the location of a bullet and its fragments may provide its primary value in suggesting if extraabdominal injuries are present.

Computed Tomography

CT scanning is the primary diagnostic imaging test for trauma. CT scanning can define the injured organ and the extent of the injury. It is most accurate for solid visceral lesions and discerns the presence, source, and approximate quantity of intraperitoneal hemorrhage (Fig. 39.3). It can demonstrate active bleeding from the liver or spleen and can be used to determine whether observation, therapeutic angiographic embolization, or open operative intervention is indicated. By minimizing the incidence of nontherapeutic laparotomies for self-limited injury to the liver or spleen, it decreases morbidity and cost.[10] CT scanning also evaluates the retroperitoneum (Fig. 39.4), an area not sampled by E-FAST, while simultaneously evaluating the vertebral column, and can be readily extended above or below the abdomen to visualize the thorax or pelvis. CT scanning also provides definitive evaluation for most possible injuries to the urinary tract, including renal artery injury.[14] It can also detect other vascular hemorrhage and obviate the need for angiography in some patients. Little additional information is provided by the addition of oral contrast, and most trauma centers use intravenous contrast alone, which decreases aspiration risk for the patient.

CT scanning, however, is relatively insensitive for injury of the pancreas, diaphragm, small bowel, and mesentery, although detection of these injuries is improving (Fig. 39.5). The last two are particularly worrisome because coincidental hollow viscus injury in patients with blunt trauma, although uncommon, is not rare, and increased morbidity and death can ensue if diagnosis is missed or the condition goes undetected for a prolonged period. Findings on CT scans, including the suspected quantity of hemoperitoneum or the presence of isolated free fluid, are not able to forecast well the need for operative intervention. Complications

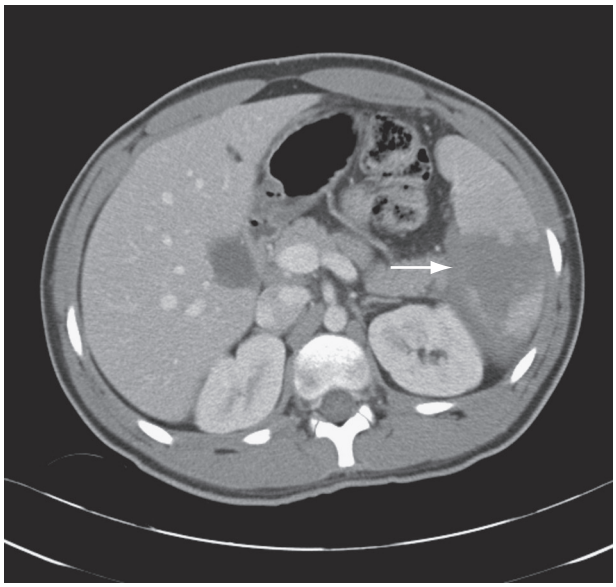

Fig. 39.3. Grade 4 splenic laceration.

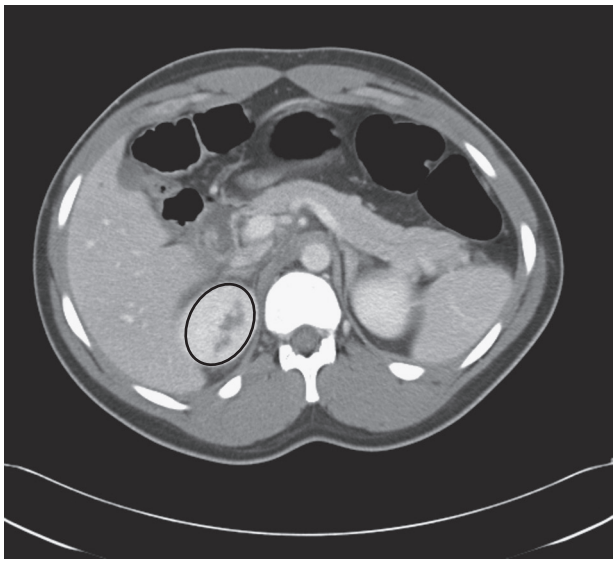

Fig. 39.4. Grade 3 right renal laceration *(encircled).*

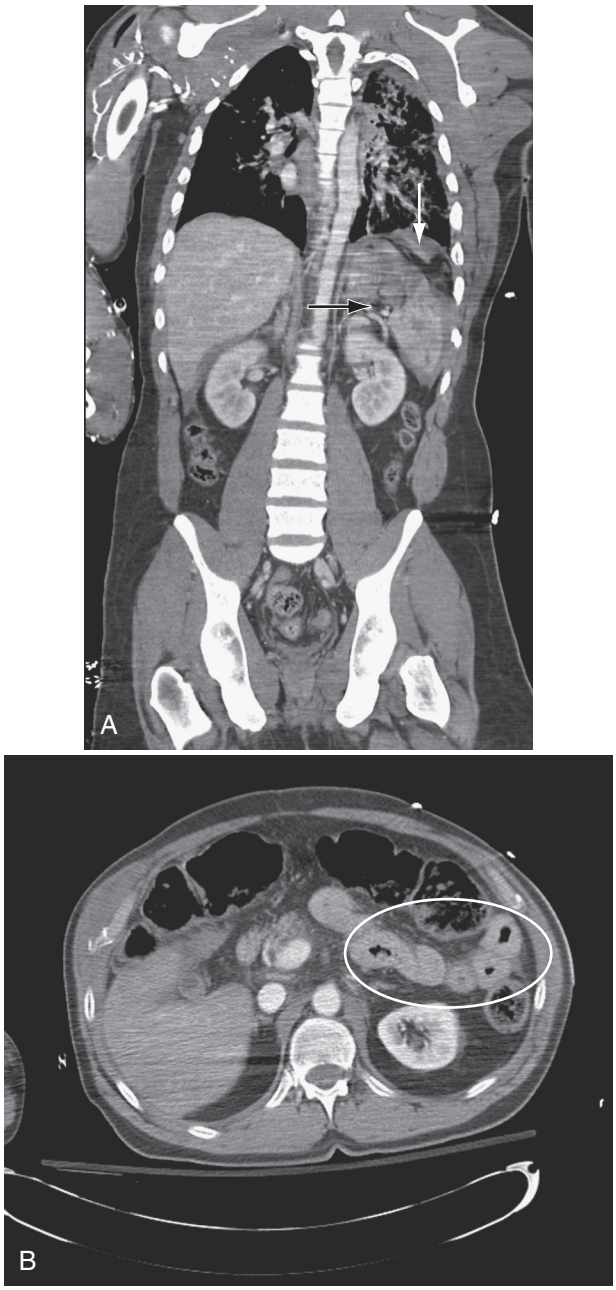

Fig. 39.5. A, Grade 4 splenic laceration *(black arrow)* with diaphragmatic rupture *(white arrow).* **B,** Small bowel edema concerning for hollow viscus injury *(encircled).*

may result from intravenous contrast administration, including contrast-induced nephropathy, and the patient is subjected to ionizing radiation, both of these factors compelling clinicians to be selective in ordering these studies. Finally, patients must be temporarily removed from the resuscitation area for the study to be accomplished, which can put the patient at risk in the case of rapid clinical deterioration. Nevertheless, CT scanning remains the cornerstone of diagnosis.

Increasingly, there is concern regarding the negative long-term effects from exposure to ionizing radiation resulting from medical imaging. Although direct evidence of increased cancer risk from CT scans has not yet been demonstrated, several methods are available to reduce radiation exposure. The scanner should be adjusted to the lowest possible setting without losing sensitivity in diagnosing intra-abdominal injury.[15] Attempted limiting scanning only through the region of abdominal tenderness turned out to be excessively insensitive for significant injury, and this practice is not recommended.[16] Digital images should accompany patients transferred between facilities, to avoid unnecessary repetition of the study.[17]

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is usually impractical and sometimes impossible to perform in the acute phase of multiple blunt trauma. Currently, in acutely injured trauma patients, MRI should be reserved for the evaluation of spinal cord injuries and elusive diaphragmatic defects not amenable to laparoscopy or thoracoscopy in the fully stabilized patient.

MANAGEMENT

The field approach to multiple or serious trauma focuses on rapid transportation to a capable receiving emergency department (ED) and is discussed in Chapter 33. An emerging body of evidence has evolved around the concept of "permissive hypotension," where a mild degree of hypotension (mean arterial pressure >50 mm Hg) is tolerated to decrease unnecessary fluid resuscitation, which can worsen trauma-induced coagulopathy, hypothermia, and may increase the risk of destabilizing relatively "soft" clots. Although animal and some human data support this practice, definitive clinical trial evidence mandating the practice is currently lacking.

In the ED, assessment of abdominal injury is part of the general management of the trauma patient (see Chapter 33).

In patients who are intubated, have a massively distended abdomen, or in whom there is a high concern for stomach or duodenal injury, a nasogastric tube should be placed to decompress the abdomen, decrease the likelihood of aspiration, and determine whether blood is present, respectively. Placement of an orogastric tube is preferable in patients with midface or skull base fractures. Foley catheterization, once fairly routine, is reserved for unconscious patients, and those in shock, for whom urine output is an indicator of adequate end-organ perfusion. Thoracotomy and subsequent cross-clamping of the descending aorta have been used to stabilize patients with thoracoabdominal injuries and profound hypovolemic shock, but this is best undertaken as a temporizing rescue maneuver in the operating room when laparotomy identifies critical injuries not amenable to abdominal repair. ED thoracotomy for management of intra-abdominal injuries, even exsanguinating injuries, rarely is indicated, and the decision to undertake thoracotomy rests with the treating trauma surgeon.

Antibiotics, given prophylactically, are effective in decreasing the incidence of intra-abdominal sepsis. Intestinal perforation and soiling can occur with penetrating, and uncommonly with blunt trauma to the abdomen. A single preoperative dose of a broad-spectrum antibiotic or combination of antibiotics that covers both aerobic and anaerobic organisms, such as piperacillin-tazobactam 3.375 g intravenously, is recommended.

Penetrating Abdominal Trauma: Stab Wounds

Selective management of abdominal stab wounds is now well accepted because of the relatively low incidence of intraperitoneal injuries coupled with the success of various diagnostic strategies.[3,18] This strategy is based on the site of penetration, the clinical status of the patient, and the experience and judgment of the hospital institution and its personnel. Compared to the former practice of mandatory laparotomy, selective management has resulted in a tremendous reduction in unnecessary laparotomies and their associated morbidity, with minimal and acceptable loss in sensitivity for significant intraperitoneal injury.[3,18] Overall, the nontherapeutic laparotomy rate should be less than 15%.

Anterior Abdomen

In approaching the management of stab wounds to the anterior abdomen, the clinician is faced with three fundamental tasks. The first and most important is to determine whether clinical indications exist for emergent laparotomy. The presence of one or more of these indications, particularly in the context of an unstable patient, sets the course to exigent operation. If none is found, the clinician may address the second issue of whether the peritoneal cavity has been violated. If it can be definitively demonstrated that it has not, no further diagnostic evaluation is required, and the patient can be discharged after appropriate wound care. If the cavity has been violated, or if it cannot be determined whether the cavity has been violated, the third question is pursued: Does an intra-peritoneal injury exist and, if so, is laparotomy required? One general approach to abdominal stab wounds founded on these three queries is summarized in Figure 39.6. This algorithm is largely based on clinical indicators of injury, LWE, CT, and other radiologic modalities. Other strategies rely more heavily on other techniques, such as serial abdominal examinations or laparoscopy.

Step I: Clinical Indications for Emergent Laparotomy. Various clinical determinants can be used to determine the need for emergent laparotomy (Table 39.2) based on the likelihood of associated intra-abdominal injuries requiring surgical repair. These clinical determinants are summarized in the following list by reasons for immediate laparotomy, followed by clinical indications that require additional supportive evidence.

A: Emergent laparotomy immediately indicated

1. Hemodynamic compromise: This is the preeminent indication of the need for laparotomy in the setting of a stab wound and is the most likely reason that a patient will be taken urgently to the operating room without preliminary diagnostic studies.
2. Peritoneal signs: There is considerable debate over the reliability of peritoneal signs, particularly in the early post-injury period. Among physical examination findings, unequivocal peritoneal signs have the highest positive predictive value, whereas an entirely normal examination even in the presence of mild to moderate intoxication has the greatest negative predictive value for therapeutic laparotomy. In general, however, clear peritoneal signs indicate the need for laparotomy.
3. Evisceration: Patients with viscus evisceration sustain up to an 80% incidence of major intraperitoneal injury, and most surgeons will take these patients for exploratory laparotomy. In rare cases, for isolated omental evisceration without viscus evisceration and absence of free intraperitoneal blood on E-FAST examination, the surgeon may ligate, excise, and restore the omentum to the peritoneal cavity. This is done at the bedside in the trauma bay.
4. Left-sided diaphragmatic injury: Although rarely diagnosed acutely, left-sided diaphragmatic injury may be diagnosed through the observation of stomach or bowel in the left chest on bedside chest radiographs, and indicates the need for operative intervention.

B: Laparotomy only considered with additional clinical evidence

5. Gastrointestinal hemorrhage: Again, although rarely diagnosed because nasogastric tubes are rarely used in this clinical scenario, recovery of blood via a nasogastric tube or emesis may reflect a violation of the stomach or duodenum. However, blood without coincident peritoneal violation does not necessarily require surgical exploration.

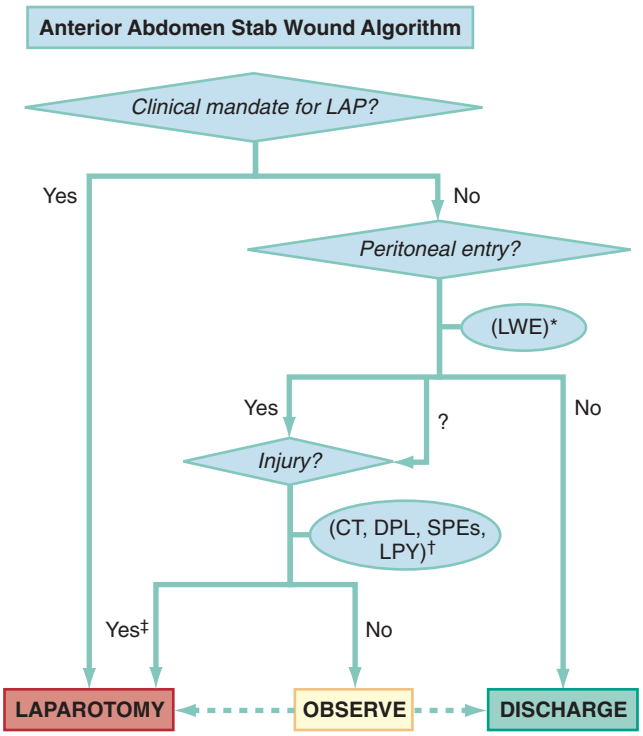

Fig. 39.6. Anterior abdomen stab wound algorithm. *LAP,* Laparotomy; *LWE,* local wound exploration.*Plain films, focused assessment with sonography in trauma (FAST), laparoscopy *(LPY),* and computed tomography *(CT)* can also assess peritoneal entry. †CT, diagnostic peritoneal lavage *(DPL),* serial physical examinations *(SPEs),* or LPY can be used in singular or complementary fashion, depending on the clinical scenario. ‡Expectant management of injuries is infrequently attempted.

TABLE 39.2

Clinical Indications for Laparotomy Following Penetrating Trauma

MANIFESTATION	PREMISE	PITFALL
EMERGENT LAPAROTOMY INDICATED		
Hemodynamic instability	Major solid visceral or vascular injury	Thorax or mediastinum, causal or contributory
Peritoneal signs	Intraperitoneal injury	Unreliable, especially immediately post injury
Evisceration	Additional bowel, other injury	No injury in one fourth to one third of stab wound cases
Diaphragmatic injury	Diaphragm	Rare clinical, radiographic findings
LAPAROTOMY REQUIRES ADDITIONAL CLINICAL EVIDENCE		
Gastrointestinal hemorrhage	Proximal gut	Uncommon, unknown accuracy
Implement in situ	Vascular impalement	Comorbid disease or pregnancy creates high operative risk
Intraperitoneal air	Hollow viscus perforation	Insensitive; may be caused by intraperitoneal entry only or may have cardiopulmonary source

Modified from Marx JA: Diagnostic peritoneal lavage. In Ivatury RR, Cayten CG, editors: The textbook of penetrating trauma, Baltimore, 1996, Williams & Wilkins.

6. Implements in situ: The conservative and widely held maxim is to remove implements in situ of the torso in the operating room. However, there is little evidence to support this practice and removal of such instruments in the ED under controlled circumstances, and in consultation with a surgeon, is reasonable.
7. Intraperitoneal air: See later.

Step II: Peritoneal Violation. If clinical indications for laparotomy are absent, a logical next step is assessing the wound tract itself. The presence of peritoneal violation can be determined by a variety of means. There is great value in establishing that a wound tract is superficial to the peritoneal, retroperitoneal, intrathoracic, and pericardial cavities. In this event, the patient can be discharged from the ED after receiving appropriate wound care. If a study is inconclusive, it should be assumed that one or more of these cavities has been violated and further means of assessment are required. The five methods of assessing whether the peritoneum is intact are as follows:

1. Evisceration: Evisceration of bowel or omentum is clear evidence of peritoneal entry. Although typically mandating laparotomy, exceptions exist (see earlier).
2. Intraperitoneal air: Although a finding of intraperitoneal free air on an upright chest or a lateral decubitus abdominal radiograph may indicate bowel perforation, it may simply establish that the implement has entered the peritoneal cavity and drawn air in with it. Therefore, although intraperitoneal air is a strong indication of peritoneal violation, it does not necessary imply bowel injury and is therefore not used in isolation to determine the need for emergent laparotomy. Rarely, a false-positive determination of peritoneal entry can be made when the actual source of intraperitoneal free air is the pulmonary tract.
3. LWE: This has been demonstrated to be an effective tool in determining if the peritoneal cavity has been penetrated.[3] Superficial wounds can be repaired if needed and the patient discharged from the ED.
4. Ultrasonography: E-FAST examination demonstrating hemoperitoneum, pneumoperitoneum, or pericardial effusion (see Fig. 39.2) identifies peritoneal penetration or injury. A negative E-FAST does not rule out peritoneal violation. Presence of intraperitoneal blood on ultrasonography precludes the need for LWE.
5. Laparoscopy or thoracoscopy in the operating room: This has compared favorably with LWE in assessing the wound tract but requires a surgeon's expertise and carries a greater risk of complications. Benefits include the ability to detect organ injury (including diaphragmatic injury) and simultaneously repair some injuries, thus decreasing negative and nontherapeutic laparotomy rates. Its primary use is in evaluating for diaphragmatic violation in left anterior lower chest stab wounds.

Step III: Injury Requiring Laparotomy. In this algorithm, patients requiring an operation on clinical grounds have proceeded to laparotomy, and those in whom peritoneal violations have been excluded are discharged home. The patients remaining have presumed or known peritoneal violation. The next consideration is whether injury exists that dictates operative repair, because organ injury is present in only just over 60% of patients with peritoneal violation.[2] In any case, patients who reach this stage of evaluation should be observed for at least 12 to 24 hours.

Initial CT scanning coupled with serial E-FAST, and physical examinations are used to identify significant wounds not initially obvious. Hollow viscus and occult diaphragmatic injuries remain the most frequently missed injuries on CT. Laparoscopy is performed when serial evaluation suggests possible, but not obvious, need for laparotomy.

Thoracoabdominal Penetration

Even a single stab wound to the low chest can violate the mediastinum, thoracic cavity, diaphragm, peritoneal cavity, and retroperitoneum. Nearly 20% of left thoracoabdominal stab wounds will be found to have diaphragmatic violation. When all thoracoabdominal wounds are considered, the risk of occult injury is 7%. Ultrasonography can be extremely useful by permitting quick assessment for hemopericardium and hemoperitoneum in the marginally stable patient if thoracotomy or laparotomy is not already clinically indicated. LWE of slash-type wounds may obviate the need for further evaluation, but the depth of investigation cannot be taken beyond the anterior rib margin to maximize safety and accuracy.

Diagnosis of diaphragmatic injury is particularly problematic. CT has sensitivity and specificity in the low 90% range for detecting diaphragmatic injury. However, equivocal scans should be followed up with more definitive management, such as laparoscopy or thoracoscopy.

Flank and Back

The incidence of retroperitoneal injuries after stab wounds to the flank and back is greater than with injury to the anterior wall. However, risk of intraperitoneal organ injury also is significant, ranging up to 40%. LWE is less accurate than in anterior wounds because the paraspinal muscles are quite thick, so the procedure is only useful if the wound is obviously superficial (such as, a slash wound). CT with intravenous contrast is the method of choice for evaluating wounds not identified to be clearly superficial. A negative CT scan, followed by serial examination over a period of 24 hours, can effectively exclude serious injury management of these patients.

Penetrating Abdominal Trauma: Gunshot Wounds

Unlike stab wounds, almost all gunshot wounds penetrate the peritoneal cavity and typically produce multiple organ injuries and a high incidence of hollow visceral injury. Accordingly, the risk of mortality is significantly greater and increases with the velocity of the missile. Missiles striking the low chest commonly penetrate both intrathoracic and abdominal structures, including the diaphragm.

Abdominal gunshot wounds enter the peritoneal cavity in approximately 80% of cases, and in more than 90% of those involving penetration, there is intraperitoneal damage. Although selective management is widely accepted for stab wounds, its application in the management of gunshot wounds is extremely limited, and therefore mandatory laparotomy generally is the rule, rather than the exception. First and foremost, are there clinical grounds for immediate operation? Second, if none exists, has peritoneal violation occurred? If the answer to either of these questions is yes, the patient is taken emergently to laparotomy with very few exceptions. If no peritoneal violation occurred, or it is unclear, admission for serial examinations is indicated (Fig. 39.7).

Step I: Clinical Indications for Laparotomy

If the patient is hemodynamically unstable, or peritoneal signs are present, the patient is taken immediately for operative intervention.

Step II: Peritoneal Violation

If is patient does not meet indications for immediate laparotomy, assessments are made to determine if peritoneal violation is

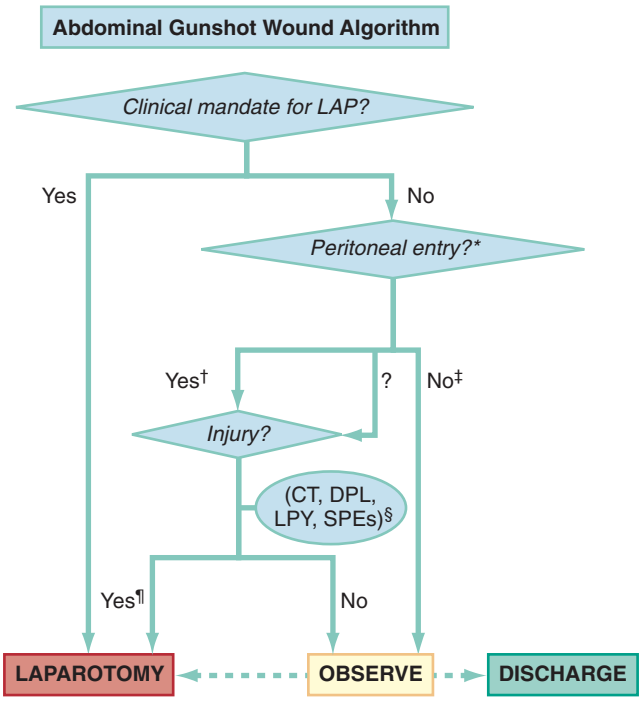

Fig. 39.7. Abdominal gunshot wound algorithm. *LAP,* Laparotomy.*Can be assessed by missile path, plain films, local wound exploration (LWE), ultrasonography, and laparoscopy. †Most centers proceed to laparotomy if peritoneal entry is suspected. ‡Patients with documented superficial and low-velocity injuries can be discharged; unknown-depth or high-velocity injuries require further tests or observation. §Computed tomography *(CT),* diagnostic peritoneal lavage *(DPL),* laparoscopy *(LPY),* or serial physical examinations *(SPEs)* can be used in singular or complementary fashion, depending on the clinical scenario. ¶Expectant management of injuries caused by gunshot wounds is rarely attempted.

present. Six methods are used to determine whether the missile has entered or traversed the peritoneal cavity:

1. Missile path: If the missile clearly just grazed the superficial tissue of the abdominal wall, it can be identified as non-penetrating.
2. Plain radiographs: An anteroposterior and lateral projection of the abdomen can assist in placing the missile in the peritoneal cavity, but such estimations are imprecise and are largely unhelpful in patients with through-and-through or multiple gunshot wounds.
3. LWE: This is used highly selectively in apparent grazing injuries or occasional injuries from handguns that appear to go through and through the lateral abdominal wall, well outside the confines of the peritoneum. If LWE confirms the path as superficial, violation has not occurred.
4. Ultrasonography: Presence of fluid on E-FAST indicates penetration, regardless of the impression one has derived from the apparent path of the missile.
5. Laparoscopy: Laparoscopy is used when peritoneal violation is known or suspected, but physical examination and E-FAST suggest that intraperitoneal injury is minimal or absent.
6. CT: CT has been helpful when trajectory is indeterminate and has extremely high sensitivity and specificity for identifying intra-abdominal injury. It can also identify the wound track, whether fragmentation has occurred, and indicate vascular structures at risk for injury, although this is more useful in neck wounds.

Thoracoabdominal

Half of the patients with gunshot wounds to the low chest have intraperitoneal injuries. Clinical indications for emergent or urgent laparotomy are as for abdominal gunshot wounds. CT scanning is highly accurate for identification of both chest and abdominal injury and should be obtained before the patient goes to the operating room, unless the patient's instability will not allow this.[19]

Flank and Back

CT scan is highly accurate for identification of retroperitoneal injury and is the diagnostic test of choice in a stable patient. Most patients are then taken to the operating room. In some cases of low velocity gunshot wound to the flank, laparoscopy or observation alone can be used if the CT scan shows no evidence of injury and the bullet track does not traverse any anatomically important structures.

Shotgun Wounds

Type I injuries can be effectively managed by reserving laparotomy for patients with clear peritoneal signs or progressive abdominal tenderness. Certain authors advocate an expectant approach to type II injuries, stating that small punctures of the bowel cause no wound eversion and no peritoneal leakage and will spontaneously close. A more prudent approach is to perform laparotomy in cases of these penetrating wounds, especially if there are signs of peritonitis. Reconstruction of abdominal wall defects may be required. Type III injuries are commonly associated with multiple organ injuries, shock, and pronounced tissue destruction, requiring hemostasis and extensive débridement.

Blunt Abdominal Trauma

In cases of blunt trauma, it is the exception when a patient undergoes laparotomy based on clinical grounds alone. Far more typically, one or a complementary battery of diagnostic tests are performed. The choice of these tests is influenced by the patient's hemodynamic status, the clinical scenario, and the institution's resources and preferences (Fig. 39.8).

The decision to perform immediate laparotomy after injury from a blunt mechanism is rarely determined solely by clinical parameters. Immediate transport to the operating room is reserved to patients with (Table 39.3):

1. Refractory hypotension in a patient with positive E-FAST examination for hemoperitoneum and absence of an unstable pelvic fracture
2. Obvious peritonitis with positive E-FAST examination
3. Evidence on E-FAST of intra-abdominal injury in the context of other life-threatening injuries, such as uncontrollable chest hemorrhage, which require transfer to the operating room

In patients who are hemodynamically stable, CT scanning is the diagnostic modality of choice, as outlined earlier.

Operative Versus Nonoperative Management

Patients with certain intraperitoneal injuries, even moderate- to high-grade liver or spleen trauma, often can be managed without laparotomy.[9,10] The patient with normal sensorium and minor to intermediate severity of mechanism is a superior candidate for expectant management. It is critical that an institution appraise its ability to manage such patients, which includes having experienced nursing staff, trauma surgeons, adequate blood resources, and radiologists and the ability for the patient to undergo laparotomy urgently if the need arises at any time of day or night.

Several pitfalls in the expectant approach are noteworthy. First, hollow viscera injury, when present, requires operative management. The ability of the CT scan to detect injury to these structures is discussed earlier. The patient with multisystem injury

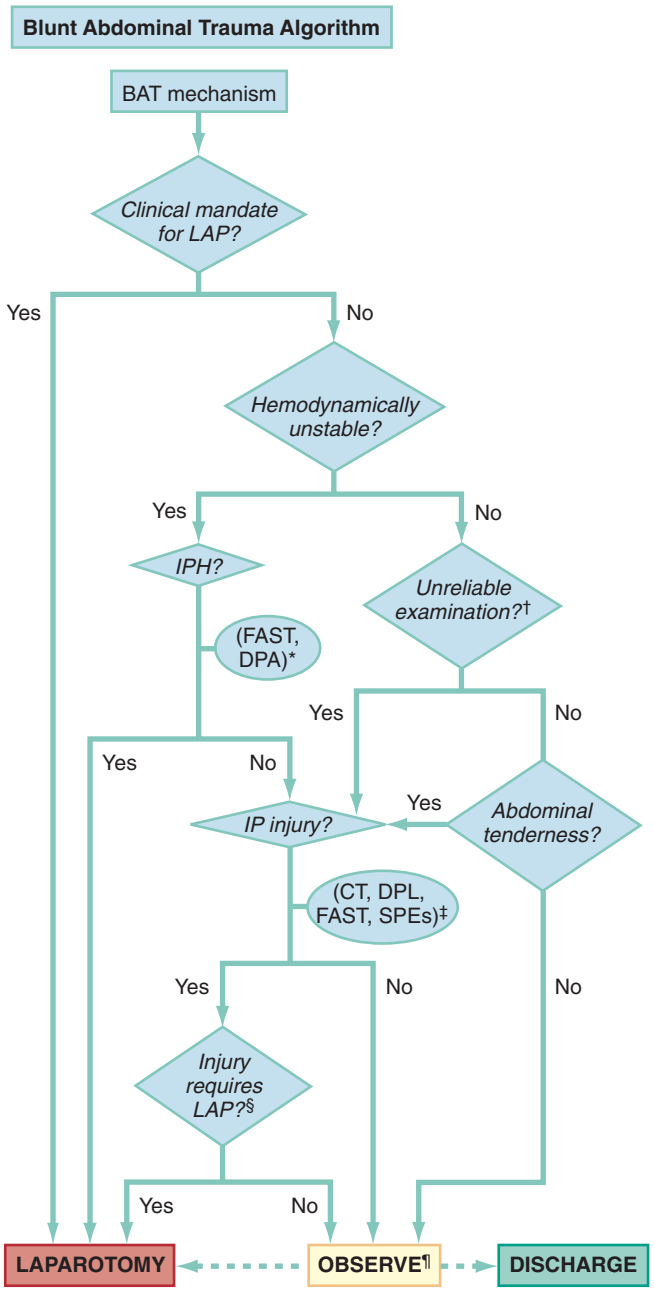

Fig. 39.8. Blunt abdominal trauma *(BAT)* algorithm. *CT,* Computed tomography; *DPL,* diagnostic peritoneal lavage; *FAST,* focused assessment with sonography in trauma; *IP,* intraperitoneal; *IPH,* intraperitoneal hemorrhage; *LAP,* laparotomy; *SPEs,* serial physical examinations. *Determined by unequivocal free intraperitoneal fluid on FAST or positive aspiration of blood on diagnostic peritoneal aspiration *(DPA).* †Can be unreliable because of closed head injury, intoxicants, distracting injury, or spinal cord injury. ‡One or more studies may be indicated. §Need for laparotomy is based on clinical scenario, diagnostic studies, and institutional resources. ¶Duration of observation should be 6 to 24 hours depending on whether diagnostic tests have been performed, the results of the tests, and clinical circumstances, including the absence of factors rendering the examination unreliable.

and, specifically, closed head trauma is most vulnerable to having delayed diagnosis of perforated intestinal injury because of delayed or impaired development of physical findings by abdominal examination. Second, expectant management may lead to increased use of blood products. Finally, this management approach will fail in those patients whose hemorrhage persists and is not amenable to therapeutic angiography and embolization. In such cases, the lag time from injury to operation may increase morbidity and mortality.

TABLE 39.3

Clinical Indications for Laparotomy After Blunt Trauma

MANIFESTATION	PITFALL
Unstable vital signs with strongly suspected abdominal injury	Alternate sources of shock
Unequivocal peritoneal irritation	Potentially unreliable
Pneumoperitoneum	Insensitive; may be caused by cardiopulmonary source or invasive procedures (diagnostic peritoneal lavage, laparoscopy)
Evidence of diaphragmatic injury	Nonspecific and insensitive, especially in penetrating trauma
Significant gastrointestinal bleeding	Uncommon, unknown accuracy

Pelvic Fracture

In the setting of pelvic fracture, the clinical triage determinant is the presence or absence of hemoperitoneum (Fig. 39.9). Although the sensitivity of E-FAST in patients with pelvic fractures may be decreased, it still serves as a tool to triage the patient to the next intervention. In an unstable patient, if the E-FAST is negative, then the patient should proceed to therapeutic angiography with the presumed diagnosis of a life-threatening retroperitoneal bleed. In all patients, early mechanical pelvic stabilization is advised (see Chapter 48), and CT scan followed by pelvic angiography and embolization are undertaken as early as possible in the context of the multiple injuries.

Multiple System Injury

It is not unusual to confront intraperitoneal hemorrhage in a patient with apparent closed head injury or suspected blunt aortic disruption or both. Repair of the abdomen is said to take precedence over that of the head and chest. However, these situations are highly complex, and decision-making is influenced by numerous and dynamic variables, and approaches to two of these situations are summarized in Figures 39.10 and 39.11. The key tenet is that a patient with known hemoperitoneum whose vital signs cannot be stabilized should undergo laparotomy to avoid exsanguination.

Bedside Procedures

Diagnostic Peritoneal Lavage

Once the mainstay of evaluation of the abdominal trauma patient to determine the presence of injury and the need for laparotomy, diagnostic peritoneal lavage now is largely of historic interest only. Its remaining role in trauma is limited to centers where ultrasound equipment is not available or the clinician is not trained to perform ultrasound.

Local Wound Exploration

LWE is used to determine whether an anterior stab wound has penetrated into the peritoneal cavity in a non-obese patient. The

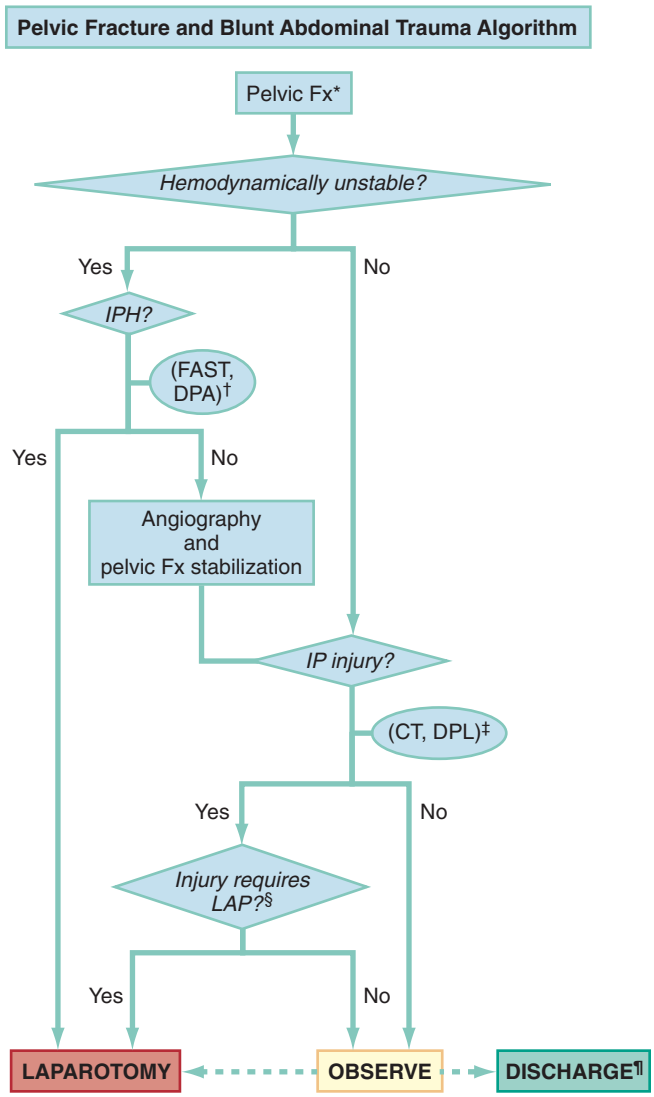

Fig. 39.9. Pelvic fracture *(Fx)* and blunt abdominal trauma algorithm. *CT,* Computed tomography; *DPL,* diagnostic peritoneal lavage; *FAST,* focused assessment with sonography in trauma; *IP,* intraperitoneal; *IPH,* intraperitoneal hemorrhage; *LAP,* laparotomy. *Certain pelvic fractures are more likely to cause pelvic vascular disruption and subsequent retroperitoneal hemorrhage. †Determined by unequivocal free intraperitoneal fluid on FAST or positive peritoneal aspiration on diagnostic peritoneal aspiration *(DPA).* ‡One or more studies may be indicated. Serial physical examinations are generally considered unreliable owing to the presence of pelvic fracture. §Need for laparotomy is based on clinical scenario, diagnostic studies, and institutional resources. ¶Discharge from the perspective of need for further consideration for laparotomy.

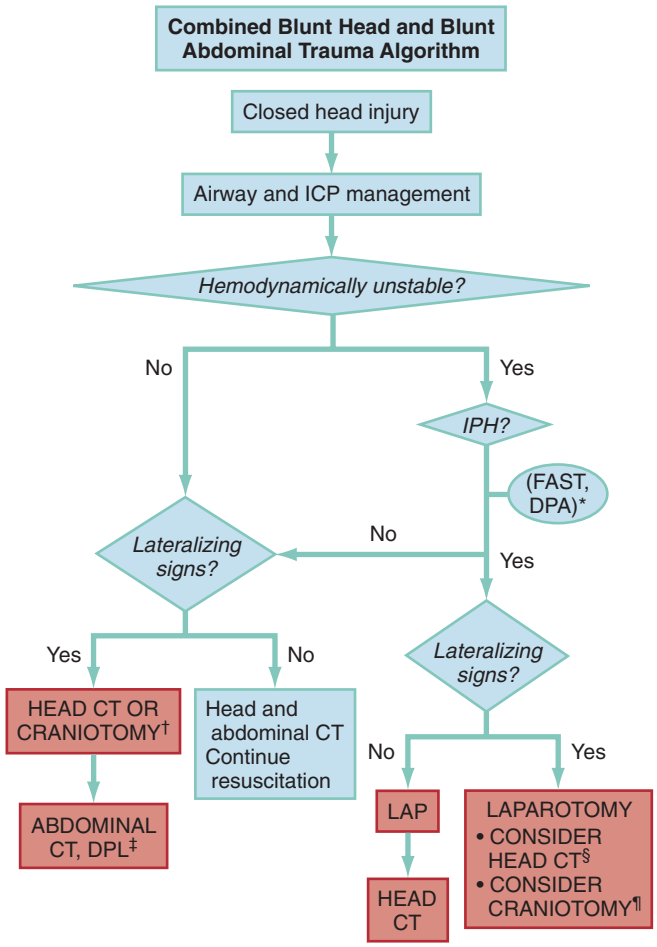

Fig. 39.10. Combined blunt head and blunt abdominal trauma algorithm. *CT,* Computed tomography; *ICP,* intracranial pressure; *IPH,* intraperitoneal hemorrhage. *Determined by unequivocal free intraperitoneal fluid on focused assessment with sonography in trauma *(FAST)* or positive peritoneal aspiration on diagnostic peritoneal aspiration *(DPA).* †Craniotomy or burr holes based on clinical picture and unavailability of computed tomography (CT). ‡Diagnostic peritoneal lavage *(DPL)* can be complementary to CT in determining hollow viscus injury. §Consider prelaparotomy *(LAP)* head CT based on clinical picture and availability of CT. ¶Consider craniotomy or burr holes simultaneous with laparotomy.

wound is infiltrated with a local anesthetic containing epinephrine then carefully visualized through each successive layer of tissue. Blind probing with digits, instruments, or cotton-tipped swabs is inaccurate, unless the peritoneal cavity is obviously freely entered. If LWE indicates that the peritoneum is not violated, the E-FAST is negative, and the patient is otherwise uninjured, the injury can be treated as a local abdominal wall injury, and the patient is treated and discharged. Indication of entry into the peritoneal cavity or inability to locate the end of the wound tract are indications for ongoing observation or abdominal CT scan (see Management).[3]

Wound explorations in patients with multiple entrances are not economical and require extensive effort, and it may be wiser to assume peritoneal penetration. Deep exploration over the thoracic cage is precluded by attendant complications to neurovascular structures and pleura. However, careful inspection of superficial chest wounds (eg, slash wound) is safe and can provide valuable data.

Therapeutic Angioembolization

Therapeutic angiography, a time-consuming procedure, is usually reserved for the unstable patient with blunt trauma and pelvic fracture in whom it can be used to embolize bleeding vessels (Fig. 39.12). Laparotomy and angioembolization for pelvic fractures with hemoperitoneum have shown no significant difference in regards to in-hospital mortality regardless of hemodynamic status.[20] It can also be a means of staunching solid visceral hemorrhage from blunt trauma, notably of the spleen. Nonoperative management has become standard in management of splenic injuries but is associated with increasing failure rates with increasing grades of injury, up to 44% with the highest-grade injuries. Successful nonoperative management increases significantly with the use of angioembolization, although higher-grade injuries are still more likely to fail nonoperative management than

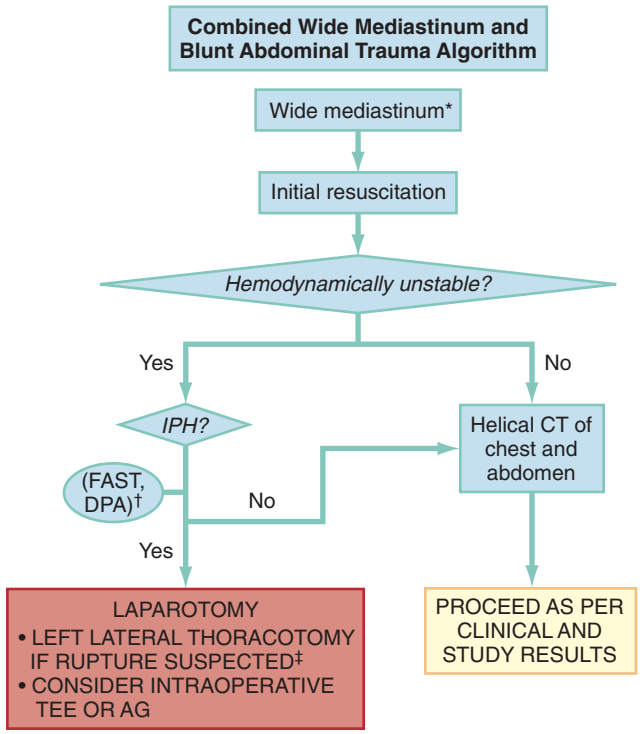

Fig. 39.11. Combined wide mediastinum and blunt abdominal trauma algorithm. *AG,* Aortogram; *CT,* computed tomography; *FAST,* focused assessment with sonography in trauma; *IPH,* intraperitoneal hemorrhage; *TEE,* transesophageal echocardiogram. *Preferably based on upright posteroanterior film and mechanism of injury; other radiographic signs or mechanism alone may signal need for evaluation. †Determined by unequivocal free intraperitoneal fluid on FAST or positive finding on diagnostic peritoneal aspiration *(DPA).* ‡Allows surgical access to majority of aortic disruption sites.

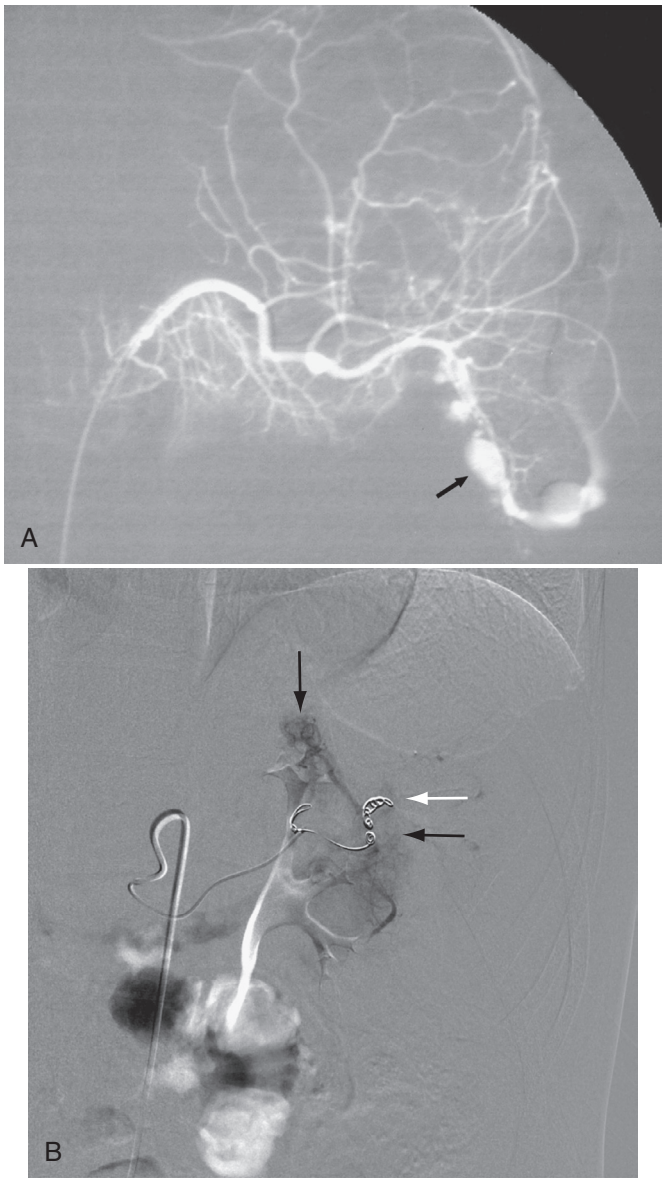

Fig. 39.12. **A,** Angiography of splenic laceration. Note the blush representing active hemorrhage *(arrow).* **B,** Angioembolization of renal laceration. Note coil in the splenic artery *(white arrow)* and blush representing active hemorrhage stemming from two branches *(black arrows).* (**A,** From Mauro MA: Image guided interventions, Philadelphia, 2008, Elsevier, p 835.)

lower-grade injuries. Angioembolization may have the added benefit over splenectomy of preserved splenic immunity in many cases, although further data are needed. Finally, angioembolization also has been used rarely for intraperitoneal and retroperitoneal hemorrhage after trauma by a penetrating mechanism.

DISPOSITION

Disposition will vary according to findings from the evaluation and the patient's clinical course. Stable patients without any identified injuries sustaining stab wounds (see Fig. 39.6) or blunt abdominal trauma (see Fig. 39.8) may be discharged home according to the algorithms provided. Patients sustaining penetrating wounds into the peritoneal cavity should either be admitted and followed with serial examinations or taken immediately to the operating room (see Figs. 39.6 and 39.7). Patients sustaining blunt abdominal trauma should be taken to the operating room or angioembolization suite (see Figs. 39.8, 39.9, 39.10, and 39.11), whereas stable patients with identified injuries can either be admitted for serial examinations or taken to the operating room, as necessary.

Consultation

Trauma is a multi-disciplinary condition. Early consultation with a general or trauma surgeon, or their involvement as part of a team response to severe trauma is a hallmark of an effective trauma hospital. Emergency clinicians provide care to the majority of abdominal trauma patients, and initial evaluation and resuscitation to an even greater proportion, but many injuries, as outlined earlier, require operative intervention or prolonged observation on an experienced service. Similarly, consultation with a radiologist may help to prioritize studies, avoid unnecessary studies, or obtain the vital information with the minimum exposure of the patient to ionizing radiation or contrast material.

Transfer

Patients with significant abdominal trauma whether blunt or penetrating should be transferred to a level I, II, or III trauma center as soon as possible after the threatening injury is identified, and without delay for time-consuming imaging studies that will not alter the need for transfer. Trauma patients in non-trauma hospitals with significant transfer times may require a stabilizing damage control laparotomy by a general surgeon before being transferred to a trauma center for definitive care.

KEY CONCEPTS

- The accuracy of physical examination is limited in cases of abdominal trauma. It is rendered less reliable by distracting injury, altered sensorium (eg, head trauma, alcohol or drug intoxication, developmental delay, psychiatric illness), and spinal cord injury.
- Stab and gunshot wounds frequently violate the lung parenchyma, diaphragm, mediastinum, intraperitoneal cavity, and retroperitoneum in some combination.
- Physical examination with E-FAST, followed by CT scan when indicated, provides accurate diagnosis for the majority of blunt and penetrating abdominal trauma patients.
- Emergent laparotomy is indicated for patients sustaining a stab wound in the setting of hemodynamic compromise, peritoneal signs, evisceration, or left-sided diaphragmatic injury. Patients not meeting these criteria undergo a combination of LWE, CT scan, serial examination and E-FAST, depending on the location of the wound
- Emergent laparotomy is indicated for patients sustaining a gunshot wound in the setting of hemodynamic compromise, peritoneal signs, or peritoneal violation. Patients not meeting these criteria undergo a combination of LWE, CT scan, serial examination and E-FAST, depending on the location of the wound.
- The critical determinant in hemodynamically unstable patients with pelvic fracture is the existence of active intraperitoneal hemorrhage. Discovery of this by E-FAST, CT scan, or peritoneal aspiration is an indication for laparotomy, whereas its absence prompts diagnostic and potentially therapeutic angiography.

The references for this chapter can be found online by accessing the accompanying Expert Consult website.

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CHAPTER 39: QUESTIONS & ANSWERS

39.1. The focused assessment with sonography in trauma (FAST) scan of a patient with blunt abdominal trauma shows a hypoechoic stripe in the pouch of Douglas. Which of the following is correct?

A. In the presence of hemodynamic instability, this indicates a need for laparotomy.
B. The patient needs to go for emergent laparotomy.
C. The patient requires repeat abdominal examinations and FAST examinations in the emergency department (ED).
D. There is at least 50 mL free fluid in the abdomen.
E. This indicates a ruptured bladder.

Answer: A. The pouch of Douglas is one of the areas of ultrasound inspection for a FAST examination. If free fluid is present and the patient is hemodynamically unstable, the patient should forego computed tomography (CT) scanning for the operating room. FAST examinations are effective in detecting as little as 100 mL of free fluid in the abdominal cavity.

39.2. An 18-year-old man presents after a moderate-velocity front-end vehicle collision. He has a blood pressure of 110/70 mm Hg, heart rate of 120 beats per minute, respiratory rate of 17 breaths per minute, and a Glasgow Coma Score (GCS) of 13. On physical examination, he has a tender abdomen and an unstable pelvis. A FAST examination is positive for free fluid in the abdomen. What should be the next step in this patient's management?

A. Admission to the trauma service for observation
B. Diagnostic peritoneal lavage (DPL) followed by laparotomy if 5 mL blood is aspirated
C. DPL followed by laparotomy if 10 mL of grossly bloody aspirate is obtained
D. Emergency laparotomy
E. ED observation for 12 hours with repeat FAST examinations

Answer: C. Although the sensitivity of FAST examinations for identifying intra-abdominal injuries requiring surgical intervention is not high, it still serves as a tool to triage patients to the next intervention. In an unstable patient, a positive FAST ultrasound scan is followed by a supraumbilical peritoneal aspirate. If this reveals 10 mL or more of blood, then the patient should expeditiously move to laparotomy.

39.3. Which of the following is *not* an advantage of CT scanning over diagnostic peritoneal lavage (DPL) in assessing patients with blunt abdominal trauma?

A. Identification of hemorrhage
B. Evaluation of genitourinary injury
C. Evaluation of retroperitoneum
D. Evaluation of unstable trauma patients
E. Quantification of hemorrhage

Answer: D. In most situations, CT scanning has supplanted DPL because of its higher predictive ability for operative lesions and the fact that it is noninvasive. CT scanning can define the injured organ and the extent of the injury. It is most accurate for solid visceral lesions and accurately discerns the presence, source, and approximate quantity of intraperitoneal hemorrhage. It can demonstrate active bleeding from the liver or spleen, and it can be used to determine whether therapeutic angiographic embolization is indicated. CT scanning also evaluates the retroperitoneum. In cases of blunt trauma, DPL's primary remaining use is the triage of the patient who is hemodynamically unstable and has multiple injuries with an equivocal FAST examination.

39.4. Which of the following statements regarding radiation exposure from CT scans in the setting of blunt abdominal trauma is false?

A. A single CT scan may increase the lifetime risk of cancer.
B. CT scans are never indicated in pregnancy, given the risk of radiation to the fetus.
C. Institutions should follow as low as reasonably achievable (ALARA) principles to mitigate radiation exposure.
D. Medical radiation may be responsible for 0.4 to 1% of all cancers in the United States.
E. Patients transferred to another facility should have attempts made to convey the images to the receiving facility as long as it does not negatively impact the patient's care.

Answer: B. Although there is a risk to the fetus with radiation, there may be situations where the risk of missed injury or exploratory laparotomy outweighs the risk of radiation to both mother and fetus. Patients being transferred to another facility should have attempts made to provide CT scans either in hard copy or digitally, to minimize repeat radiation exposure to the patient. Current estimates suggest at least 0.4% of all cancers in the United States are secondary to medical radiation, and a single CT scan may increase the lifetime risk of cancer. Facilities can minimize this risk by adopting ALARA principles.

39.5. A 27-year-old male presents 4 hours after an isolated stab wound to the anterior abdomen. His vital signs are heart rate 84 beats per minute and blood pressure 115/64, and the lactate level is 0.9 mg/dL. His focused assessment with sonography in trauma (FAST) examination is negative for free fluid. He denies alcohol and drug use and appears clinically sober. Which of the following statements regarding this patient's subsequent management is true?

A. A diagnostic peritoneal lavage (DPL) with 250,000 red blood cells per mm^3 indicates the need for admission and serial abdominal examinations.

B. A local wound exploration (LWE) that fails to demonstrate peritoneal violation means that the patient can be discharged from the emergency department (ED).

C. A negative computed tomography (CT) scan rules out the need for further evaluation.

D. The negative FAST examination rules out intra-abdominal injury requiring operative intervention.

E. The patient meets criteria for emergent laparotomy.

Answer: B. Simple anterior abdominal stab wounds that do not violate the peritoneum can be discharged from the ED after appropriate wound care (see Fig. 39-6). Not all anterior stab wounds meet indication for laparotomy, even in the presence of peritoneal penetration. A DPL of greater than 100,000 red blood cells (RBCs)/mm^3 is an indication for laparotomy in abdominal stab wounds. A negative FAST examination does not rule out significant intra-abdominal injury or even small-volume hemoperitoneum in either penetrating or blunt abdominal trauma. CT scans poorly visualize both the small bowel and diaphragm and cannot be used in isolation to rule out injury in penetrating abdominal trauma.

39.6. A 67-year-old female who is taking warfarin (Coumadin) for atrial fibrillation presents after a high-mechanism motor vehicle collision. Her heart rate is 142 beats per minute and blood pressure is 84/40 after 1 L of normal saline. Her Glasgow Coma Score (GCS) is 6, and her left pupil is 6 mm versus 3 mm on the right. Her physical examination is notable for a seat belt sign on the abdomen. Which of the following is *not* an acceptable approach to her initial assessment and treatment?

A. Perform a focused assessment with sonography in trauma (FAST) examination to evaluate for the presence of intra-abdominal fluid.

B. Perform chest and pelvic radiographs in the resuscitation bay.

C. Perform empirical craniotomy concurrently with laparotomy in the operating room after a positive diagnostic peritoneal aspiration.

D. Perform endotracheal intubation and begin mild hyperventilation.

E. Proceed to radiology for an emergent abdominal CT scan.

Answer: E. The patient is hemodynamically unstable, with suspected intra-abdominal injuries in conjunction with signs of herniation. CT scanning of the abdomen would be inappropriate in this patient. Several concurrent management options to stabilize the patient and determine the source of her hypotension are desirable (see Fig. 39.10). Endotracheal intubation allows airway control and possible hyperventilation to delay impending herniation. Chest and pelvic radiographs rule out other sources of ongoing hemorrhage and may support emergent laparotomy. A FAST examination can confirm the presence of intra-abdominal free fluid, which in the setting of hemodynamic instability is an indication for laparotomy. Finally, after confirmation of intra-abdominal blood by either digital pulse analyzer (DPA) or FAST, proceeding to the operating room, with or without emergent CT scanning of the head, are management options. If the head CT is foregone because of instability, empirical craniotomy is an acceptable management option.

39.7. Which of the following statements regarding splenic injuries in blunt abdominal trauma is false?

A. A CT scan with a grade IV splenic laceration indicates the need for laparotomy.

B. Angiographic embolization may preserve some of the immune function of the spleen, even in the setting of a grade V laceration.

C. Bedside focused assessment with sonography in trauma (FAST), although sensitive for intra-abdominal fluid, is a relatively poor test for the evaluation of solid organ injury.

D. CT scanning followed by serial abdominal examinations and hematocrits is a reasonable management option at experienced centers.

E. Mononucleosis increases the risk of splenic laceration from seemingly minor blunt abdominal trauma.

Answer: A. High-grade splenic lacerations, although having a higher rate of failed nonoperative or angiographic embolization management, do not represent a definitive indication for laparotomy. Mononucleosis does increase the risk of splenic laceration. Trauma can be so minor that the patient may have little recollection of the remote trauma responsible. Serial abdominal examinations, laboratory tests, and/or repeat FAST examinations are reasonable management options at experienced centers. Limited studies have suggested that angiographic embolization does preserve some of the immune function of the spleen compared with splenectomy. The FAST examination does not visualize solid organ injury effectively enough to eliminate the need for further evaluation with CT scanning in this case, especially because laparotomy is not necessarily indicated.