9

Trauma

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OVERVIEW AND EPIDEMIOLOGY

leading cause of death in the United States for individuals aged 1 to 44 years

third cause of mortality after the first year of life.

It is estimated that there are over 30 million nonfatal injuries annually in America.

Some of the advances that have allowed for reduced morbidity and mortality rates include

computed tomography (CT)

magnetic resonance imaging (MRI),

minimally invasive surgical interventional techniques,

abbreviated operations

regionalization of trauma care.

Table 7-1

Immediately life-threatening injuries to be identified during the primary survey

Airway	
	Airway obstruction
	Airway injury
Breathing	
	Tension pneumothorax
	Open pneumothorax
	Massive air leak from tracheobronchial injury
	Flail chest with underlying pulmonary contusion
Circulation	
Hemorrhagic shock	
	Massive hemothorax
	Massive hemoperitoneum
	Mechanically unstable pelvis fracture with bleeding
	Extremity blood loss
Cardiogenic shock	
	Cardiac tamponade
Neurogenic shock	
Disability	
	Intracranial hemorrhage
	Cervical spine injury

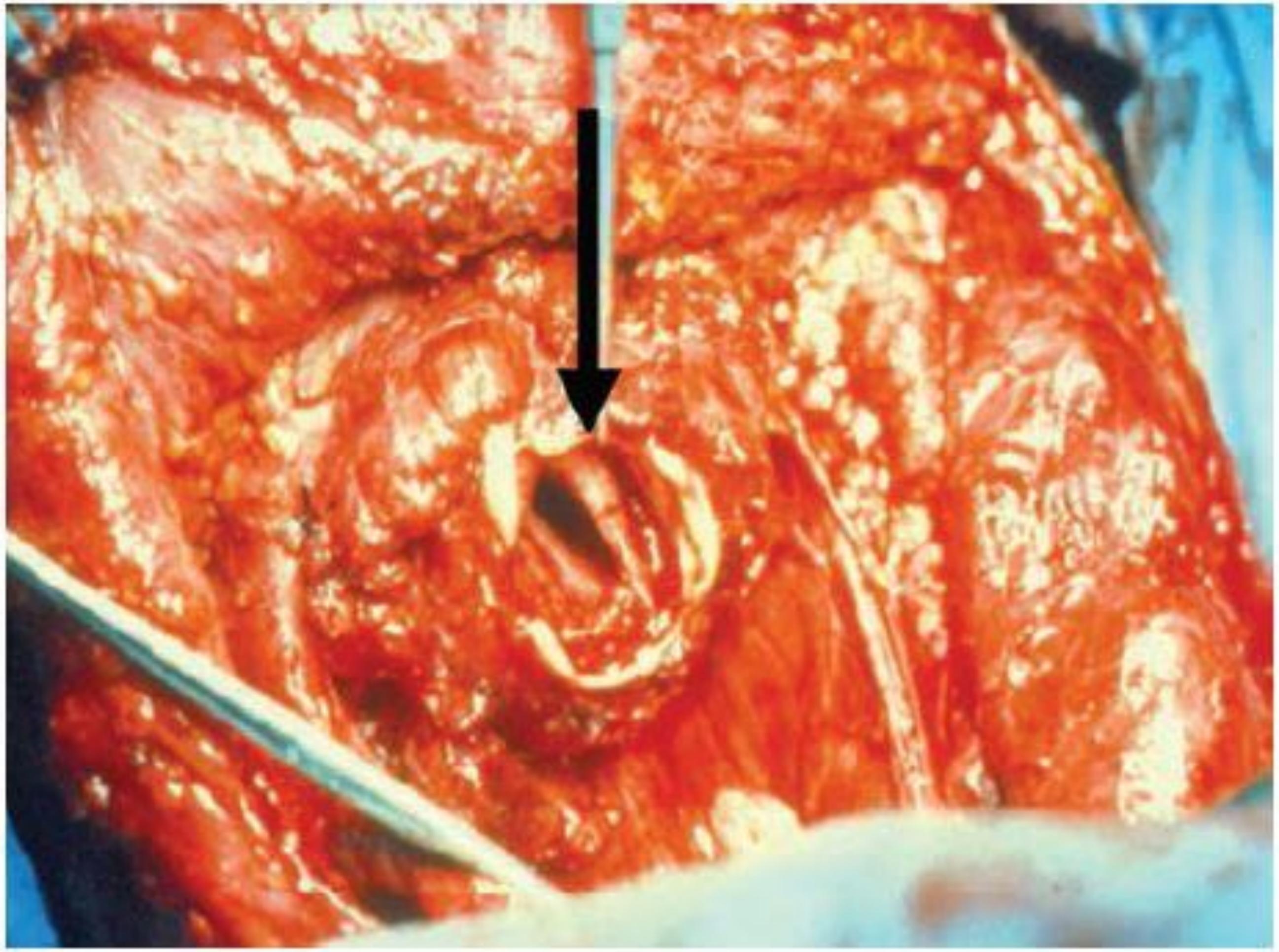
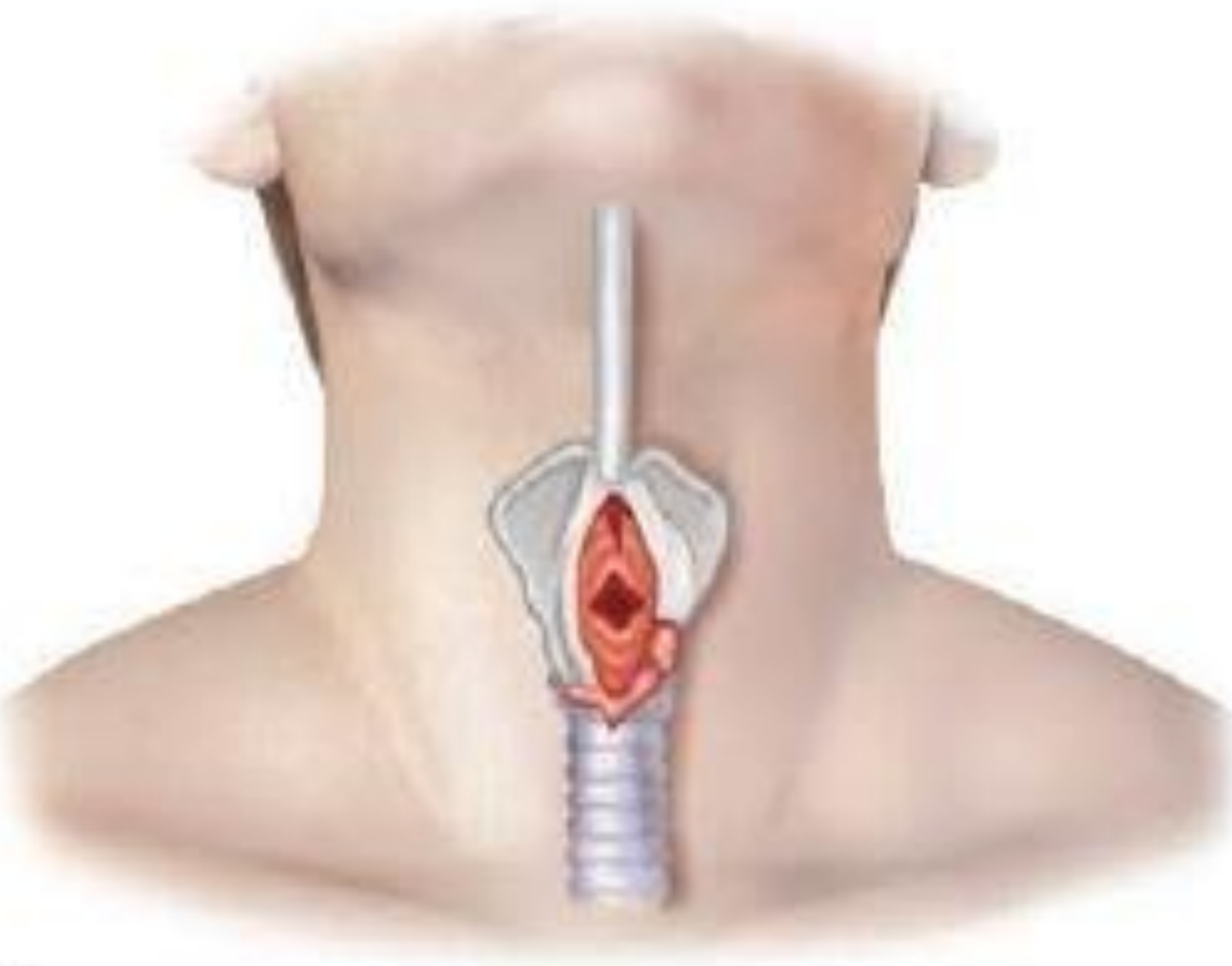


Figure 7-2. A "clothesline" injury can partially or completely transect the anterior neck structures, including the trachea. With complete tracheal transection, the endotracheal tube is placed directly into the distal aperture, with care taken not to push the trachea into the mediastinum.



A

INITIAL ASSESSMENT

The Advanced Trauma Life Support (ATLS) course teaches the gold standard for providing the initial care of injured patients. It offers an invaluable framework for prioritizing the management of the patient focusing on

(1) primary survey
(2) Resuscitation
(3) secondary survey
(4) definitive care

Primary Survey

The primary survey is focused on identification and immediate treatment of life-threatening injuries while initiating resuscitation.

It is described by the acronym ABCDE.

Airway

Breathing

Circulation

Disability

Exposure

Injuries identified at each step are treated before moving on to the next

Airway

If a patient lacks a patent airway, respiratory gas exchange cannot occur and death becomes imminent.

Airway patency can be simply assessed by asking the patient to speak.

Normal voice and speech indicate patent airway and intact cognition.

Stridor, hoarseness, and pain when speaking as well as cyanosis, agitation, and tachypnea are signs of possible airway injury.

Complex facial fractures

massive tissue disruption above the nipples,

oropharyngeal swelling

blood in the oropharynx

may quickly obstruct the airway and should prompt intervention to stabilize the airway

Tipping the chin upward (chin lift) or pulling the mandible anteriorly (jaw thrust) while maintaining c-spine immobilization are two simple maneuvers that may reopen the airway and assure oxygenation and ventilation.

In the obtunded patient, the tongue will partially or completely obstruct the glottis and insertion of a nasal or oral airway will promptly reestablish a patent airway.

Nasopharyngeal devices are better tolerated in the conscious patient but should not be used in the presence of midface injuries.

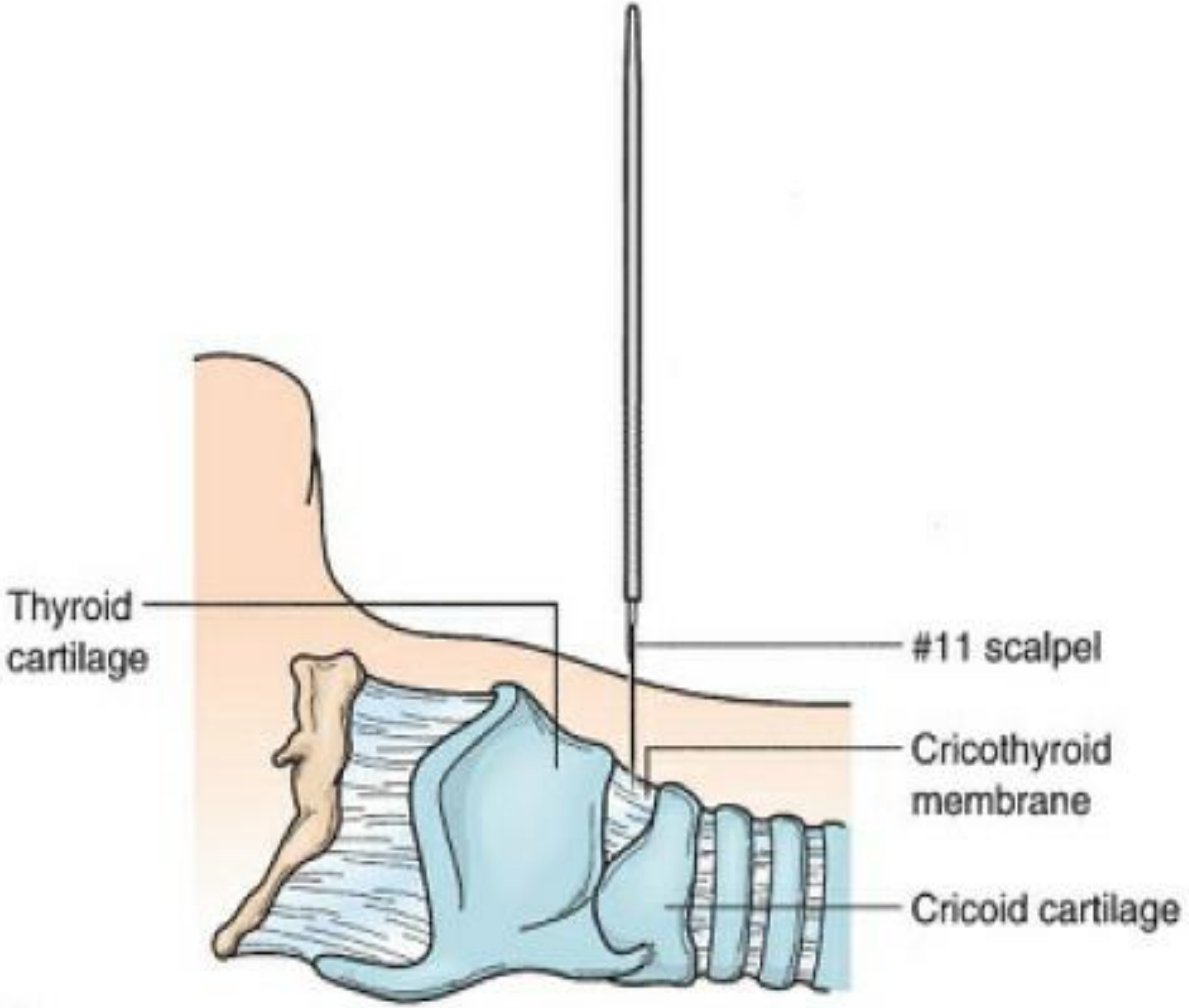
The most definitive way to secure the airway is with endotracheal intubation.

If the glottis cannot be intubated via the oral route, a surgical airway must be performed.

This can be achieved by placing a cricothyroidotomy or large-bore needle

Once the cricothyroid membrane is opened, a 6-French or smaller endotracheal tube is placed directly into the trachea.

The needle cricothyroidotomy is quicker to perform than the open approach. A large-bore (16 to 18 gauge) intravenous catheter is passed directly through the cricothyroid membrane.



Thyroid cartilage
#11 scalpel
Cricothyroid membrane
Cricoid cartilage

A

Jaw thrust

Chin lift

Breathing

Breathing is assessed by inspecting the chest for symmetric movement and auscultating for breath sounds.

Cyanosis and poor oxygen saturation despite the presence of an airway may indicate poor ventilation.

A tension pneumothorax results from a lung injury. Air from the lung enters the pleural space, and the intrapleural pressure increases with each respiration. As the pressure rises, the mediastinal structures shift to the contralateral side and impede venous blood return to the heart. This results in a decrease in cardiac output and shock.

The diagnosis of a tension pneumothorax is made on physical examination.

The triad of absent breath sounds, shock, and muffled heart sounds confirm the diagnosis.

Immediate treatment is directed at decompressing the intrapleural hypertension.

This is accomplished by either placing a large-bore angiocath into the second intercostal space at the midclavicular line or inserting a chest tube at the anterior axillary line in the fourth or fifth intercostal space.

Circulation

The evaluation of the circulation focuses on prompt recognition and reversal of shock through intervention and resuscitation.

Shock is defined as inadequate tissue perfusion resulting in anaerobic metabolism, and prolonged tissue hypoxia causes organ dysfunction, irreversible tissue damage, and eventually death.

Tachycardia

Tachypnea

Hypotension

mental status change

Agitation

Anxiety

oliguria

are common signs and symptoms of shock.

Additional signs include cool, clammy, or cyanotic skin, and diminished peripheral pulses.

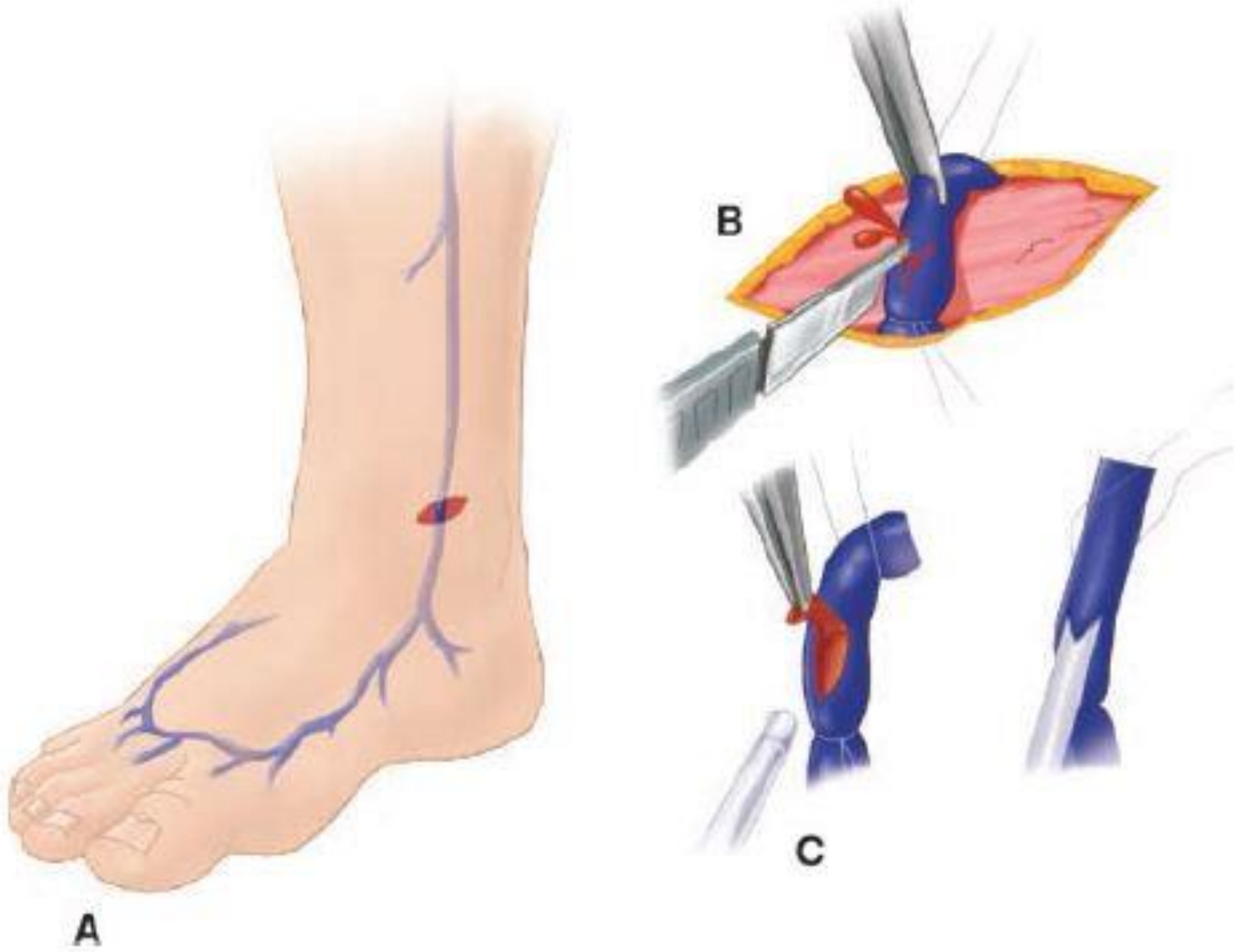


Figure 7-7. Saphenous vein cutdowns are excellent sites for fluid resuscitation access. **A.** The vein is consistently found 1 cm anterior and 1 cm superior to the medial malleolus. **B.** Proximal and distal traction sutures are placed with the distal suture ligated. **C.** A 14-gauge IV catheter is introduced and secured with sutures and tape to prevent dislodgment.

The most common cause of shock after injury is hemorrhage.

Treatment involves restoration of circulating blood volume, initially with an isotonic crystalloid solution such as lactated Ringer's normal saline or plasmalyte.

In severe shock, transfusion of blood products in a 1:1:1 ratio including packed red blood cells, plasma, and platelets (massive transfusion protocol) should be initiated. The severity of hemorrhagic shock is classified according to the percentage of circulating blood volume loss (Table 9-1).

TABLE 9-1 Classification of Hemorrhage

	Class I	Class II	Class III	Class IV
Blood loss (mL) 70-kg person	<750	750–1,500	1,500–2,000	>2,000
Blood volume loss (%)	<15	15–30	30–40	>40
Heart rate (beats/min)	<100	>100	>120	>140
Blood pressure	Normal	Normal	Decreased	Decreased
Pulse pressure	Normal	Decreased	Decreased	Decreased
Respiratory rate (breaths/min)	14–20	20–30	30–40	>35
Urine output (mL/hr)	>30	20–30	5–15	Negligible
Capillary refill(s)	Normal	>2	>2	>2
Mental status	Slight anxiety	Mild anxiety	Anxious/confused	Confused/lethargic
Fluid management	Crystalloid	Crystalloid	Crystalloid and blood	Crystalloid and blood

- Although most external bleeding from traumatic wounds can be controlled temporarily with direct pressure or a tourniquet, intrathoracic or intra-abdominal hemorrhage may require more invasive measures such as tube thoracostomy, surgical intervention, or angiography with embolization.
- Other less common causes of shock include cardiogenic (tension pneumothorax and cardiac tamponade), obstructive, and neurogenic (spinal cord injury).

Disability

A quick assessment of neurologic function provides a measure of disability. The Glasgow Coma Scale (GCS) score, based on the patient's best verbal, motor, and eye-opening response, is calculated and can help guide subsequent evaluation and treatment

TABLE 9-2 Glasgow Coma Scale

Assessment Area	Score
Eye Opening (E)	
Spontaneous	4
To speech	3
To pain	2
None	1

Motor Response (M)

Obeys commands	6
Localizes pain	5
Withdraws to pain	4
Decorticate posturing (abnormal flexion)	3
Decerebrate posturing (abnormal extension)	2
None (flaccid)	1

Verbal Response (V)

Oriented	5
Confused conversation	4
Inappropriate words	3
Incomprehensible sounds	2
None	1

GCS score = E + M + V; best = 15, worst = 3.

Exposure

The last step in the primary survey is removal of all clothing to allow a complete head-to-toe examination for injury or bleeding.

Removing wet and contaminated clothing is also important to prevent hypothermia and toxicity.

Once completed, the patient should be covered with warm linens and/or heating devices to prevent hypothermia, which will exacerbate coagulopathy and worsen acidosis

Secondary Survey

The purpose of the secondary survey is to identify and treat additional injuries not recognized during the primary survey; it includes a

comprehensive physical examination

where possible, a medical history including allergies, last meal, tetanus immunization status, and medications.

A nasogastric tube (NG) should be placed to relieve gastric distension.

The tube should not be placed:

when there is a basilar skull fracture or extensive facial fractures.

A urinary catheter is a useful adjunct to monitor urine output.

Blood at the penile meatus or a disruption of the pubic symphysis, which is seen with an open book pelvic fracture, are signs of urethral transection.

If present, retrograde urethrography (RUG) should be performed to assess the integrity of the urethra. In the event of a urethral disruption, suprapubic catheterization should be performed

Adjunctive Studies and Definitive Care

The results of the primary and secondary surveys determine the need for further diagnostic studies.

Radiographs of the chest, cervical spine, and pelvis during the secondary survey assist with the identification of potentially life-threatening injuries.

Ultrasonography is typically performed as an adjunct to the primary survey in an effort to detect hemorrhage in the abdomen and pericardium.

In the hemodynamically stable patient, CT scans of various body regions are more sensitive and specific for identification of other injuries.

THORACIC INJURY

Thoracic trauma accounts for approximately 25% of trauma-related deaths and follows traumatic brain injury as the second most common cause of death after injury.

Life-threatening chest injuries may be fatal if not promptly diagnosed and treated. They include

tension pneumothorax

open pneumothorax

Cardiac tamponade

massive hemothorax

flail chest

The majority of thoracic injuries can be treated by relatively simple maneuvers such as establishment of a definitive airway or tube thoracostomy.

Thus, only 10% to 15% of thoracic injuries require formal operative intervention by median sternotomy or thoracotomy.

Life-Threatening Injuries Detected during Primary Survey

Tension pneumothorax

results when gas builds up under pressure within the pleural cavity. It may occur after either blunt or penetrating thoracic trauma.

Open pneumothorax

occurs in the setting of a penetrating injury to the thorax when the chest wall wound remains patent. This allows air to preferentially enter through the chest wall defect rather than the trachea, resulting in collapse of the underlying lung.

Clinically, the passage of air through the chest wound results in an audible “sucking” sound.

Respiratory failure may occur as the work of breathing increases because air flow via the wound may prevent generation of adequate negative inspiratory force to entrain air via the tracheobronchial tree.

Open pneumothorax should be promptly treated by placing a partially occlusive dressing over the thoracic wound and securing it to the skin with tape on three sides. This creates a one-way valve that allows egress of accumulated pleural gas during exhalation, but prevents inflow from the atmosphere during inhalation.

The result is an improvement in gas exchange. In effect, this maneuver converts an open pneumothorax into a simple pneumothorax.

Once the patient’s condition is stabilized, a chest tube should be inserted through a separate incision to allow for complete reexpansion of the lung.

Operative surgical debridement and closure of the thoracic wound may be required

Cardiac tamponade

an immediately life-threatening event that may occur in the setting of penetrating or blunt precordial injury.

The most common scenario is a stab wound left of the sternal border with a laceration of the right ventricle. Blood escaping from the heart accumulates within the nondistensible pericardial space, resulting in compromise of right ventricular relaxation during diastole and tamponade.

The clinical picture:

muffled heart sounds, jugular venous distension, and hypotension (Beck's triad) in a patient with a penetrating wound to the precordium is the classic presentation for cardiac tamponade.

Kussmaul's sign (increasing jugular venous distension with inspiration)

Pulsus paradoxus (drop in systolic blood pressure ≥10 mm Hg during inspiration).

Diagnosis is confirmed by ultrasound, usually bedside focused assessment with sonography in trauma (FAST), which is the diagnostic test for hemopericardium and tamponade

Treatment of tamponade is based on judicious volume resuscitation to increase cardiac output, and immediate surgical decompression to release the tamponade and repair the underlying cardiac injury.

In patients with cardiac tamponade who deteriorate or experience cardiac arrest in the resuscitation area, prompt emergency department (ED) resuscitative thoracotomy should be performed.

Pericardiocentesis should only be considered in situations where resuscitative thoracotomy is not an option because of lack of experienced surgeons or equipment though salvage rates are extremely low using this temporizing intervention.

- Massive hemothorax

defined as the loss of 1,500 mL or more of blood into a pleural space during the first hour after injury, or ongoing thoracic blood loss at least 200 mL/hour of blood over 4 hours.

Clinical diagnosis may be made by the presence of diminished breath sounds and dullness to percussion.

These physical findings may be difficult to determine in a loud emergency room.

Chest x-ray may confirm the presence of hemothorax.

Treatment involves tube thoracostomy and volume resuscitation to restore euvolemia.

Thoracotomy for control of hemorrhage is indicated for either of the above criteria.

Autotransfusion of shed blood may be a useful adjunct to decrease utilization of banked blood products.

The source of bleeding is most frequently intercostal vessels but lacerated lung parenchyma, lacerated intercostal

muscles, great vessels, or the atrial injuries have also been reported as causes

- Flail chest

occurs when two or more adjacent ribs are fractured in two or more places.

A commonly associated injury that results from the fail segment is contusion to the underlying lung.

The contusion results in a ventilation–perfusion mismatch and is the primary cause of the hypoxia and hypercarbia seen with flail chest.

Pulmonary contusion, coupled with pain from the fractured ribs, impairs respiratory function.

Treatment involves aggressive pain control measures, as well as tube thoracostomy for an associated pneumothorax or hemothorax.

Intubation with mechanical ventilation is used in patients who develop respiratory failure.

Intravenous fluids should be administered judiciously because aggressive hydration is associated with sequestering of fluid in the contused lung, which will increase the ventilation–perfusion mismatch and exacerbation of hypoxia and hypercarbia.

Operative stabilization of the flail segment in select patients reduces morbidity.

Potentially Severe Injuries Detected during Secondary Survey

- Simple pneumothorax

Occurs when gas enters the pleural space, causing collapse of the ipsilateral lung.

Gas may be introduced from the atmosphere in a penetrating injury, or it may emanate from an injury to the lung parenchyma or tracheobronchial tree.

Physical examination typically reveals diminished breath sounds on the affected side, though this finding is variable in the noisy environment of the trauma resuscitation area.

Hyper resonance to percussion may be present.

Diagnosis is made by plain radiography of the chest or bedside ultrasound.

Posttraumatic pneumothorax visible on plain radiography of the chest should be treated by tube thoracostomy for reexpansion of the lung.

Pneumothorax not seen on plain film but noted on CT of the chest requires observation but may not need a chest tube.

Positive pressure ventilation results in tension pneumothorax more frequently with small CT-diagnosed pneumothoraces than spontaneous respiration, so a chest tube should be considered early in the treatment phase to minimize this risk

- Hemothorax

results when blood or clot accumulates within the pleural space.

The source of hemorrhage is most commonly from the chest wall or pulmonary parenchyma.

Lacerated intercostal vessels, both venous and arterial, may bleed significantly.

On physical examination, decreased breath sounds and dullness to percussion are typical findings.

Chest x-ray will confirm the diagnosis in a stable patient.

Treatment involves placement of a large-bore (36-French) chest tube

Postprocedure x-rays should be obtained to confirm satisfactory evacuation of the hemothorax and tube location.

Retained hemothorax should be treated by early thoracoscopic evacuation, usually within 5 days, as the risk of infection (empyema) or entrapped lung increases significantly after this time frame.

Rib fractures

the most common injury of the chest after blunt trauma.

Fractured ribs are diagnosed on physical examination by noting point tenderness along a rib. They may or may not be seen on plain radiographs of the chest.

CT of the thorax is quite sensitive for diagnosing rib fractures but is seldom indicated to make the diagnosis of a fracture.

The location of fractured ribs helps associated injuries. As mentioned previously, fracture of the first three ribs is associated with aortic or great vessel injury.

Fractures of the midthoracic ribs are frequently associated with pulmonary contusion and/or hemopneumothorax.

Lower rib fractures have an association with diaphragmatic, liver, and spleen injuries.

The management of fractured ribs is directed at the provision of adequate analgesia to allow for oxygenation, ventilation, and clearance of secretions.

Otherwise, healthy young patients with one or two rib fractures may be safely managed with oral narcotic analgesics and discharged from the ED.

Older patients, or those with multiple rib fractures, generally require inpatient admission.

Intravenous patient-controlled analgesia and thoracic epidural catheterization are options that provide effective analgesia and avoid intubation.

The goal of treatment is to avoid splinting from pain, which impairs secretion clearance and which may result in atelectasis and subsequent pneumonia.

Elderly patients with multiple rib fractures fare worse than their younger counterparts.

Table 7-2

Current indications and contraindications for emergency department thoracotomy

Indications	
Salvageable postinjury cardiac arrest:	
Patients sustaining witnessed penetrating trauma to the torso with <15 min of prehospital CPR	
Patients sustaining witnessed blunt trauma with <10 min of prehospital CPR	
Patients sustaining witnessed penetrating trauma to the neck or extremities with <5 min of prehospital CPR	
Persistent severe postinjury hypotension (SBP ≤60 mmHg) due to:	
Cardiac tamponade	
Hemorrhage—intrathoracic, intra-abdominal, extremity, cervical	
Air embolism	
Contraindications	
Penetrating trauma: CPR >15 min and no signs of life (pupillary response, respiratory effort, motor activity)	
Blunt trauma: CPR >10 min and no signs of life or asystole without associated tamponade	

CPR = cardiopulmonary resuscitation; SBP = systolic blood pressure.

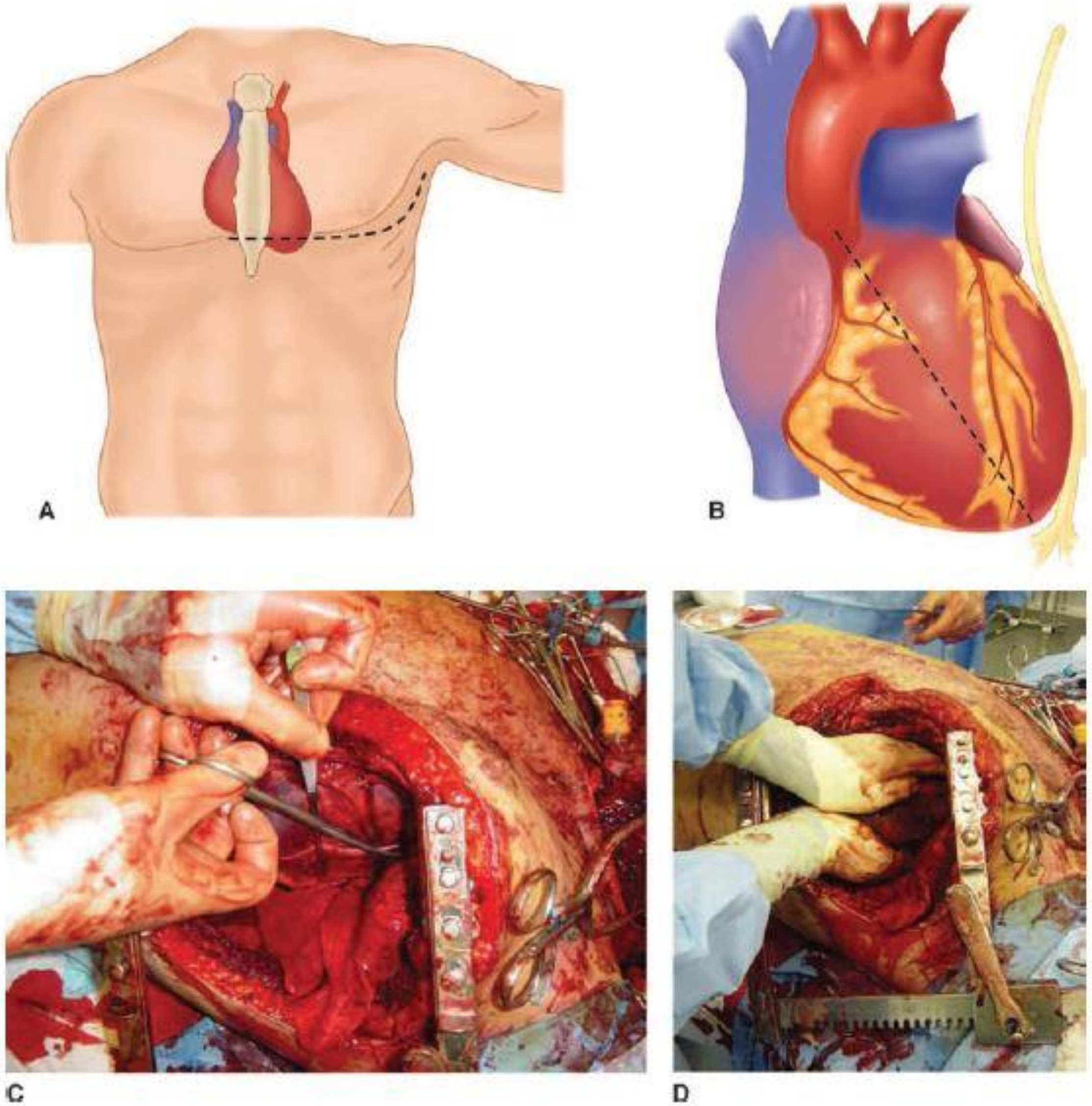


Figure 7-12. A. Resuscitative thoracotomy (RT) is performed through the fifth intercostal space using the anterolateral approach. **B** and **C.** The pericardium is opened anterior to the phrenic nerve, and the heart is rotated out for evaluation. **D.** Open cardiac massage should be performed with a hinged, clapping motion of the hands, with sequential closing from palms to fingers. The two-handed technique is strongly recommended because the one-handed massage technique poses the risk of myocardial perforation with the thumb.

ED Thoracotomy

Patients presenting to the ED in profound shock or in pulseless electrical activity may not respond to cardiopulmonary resuscitation (CPR) and volume resuscitation.

In selected cases, resuscitative left thoracotomy may be beneficial and should be considered as a life-saving maneuver.

Resuscitative thoracotomy allows several goals to be accomplished quickly.

These include pericardiotomy for release of cardiac tamponade, open cardiac massage (which is superior to closed chest compression to restore perfusion, particularly in hypovolemia), cross-clamping of the descending aorta at the diaphragm, increasing BP,

intracardiac administration of resuscitative drugs, direct control of intrathoracic hemorrhage, and potential relief of air embolism.

This procedure should be considered in

penetrating trauma victims who lose vital signs <15 minutes before arrival or in the ED.

Patients with pericardial tamponade who are too unstable for transport to the operating room are candidates for ED thoracotomy as well.

In contrast, prolonged cardiac arrest after penetrating injury, massive blunt trauma with prehospital cardiac arrest or pulseless electrical

activity do not benefit from ED thoracotomy.

Resuscitative thoracotomy should not be performed unless a surgeon capable of managing complex truncal injuries is immediately available.

ABDOMINAL INJURY

Background

Abdominal trauma results from either penetrating wounds or blunt force.

Penetrating injuries occur with lowenergy stab wounds and high-energy gunshot wounds.

Blunt traumatic injury occurs after falls, assaults, crush injuries, and motor vehicle crashes.

Unexplained hypotension in an injured patient requires immediate consideration of intra-abdominal injury.

Life-threatening intra-abdominal hemorrhage is a common source of shock that must be considered during the primary survey.

Rapid diagnosis and treatment of intra-abdominal hemorrhage is critical.

- **Anatomic Considerations**

The torso is divided into several regions

The flank is defined as the region between the anterior and posterior axillary lines, the lower ribs, and the iliac crest.

The back is bounded by the spinous processes, the posterior axillary line, the lower ribs, and the iliac bone. Injuries to any of these areas can involve the peritoneal cavity and/or retroperitoneum.

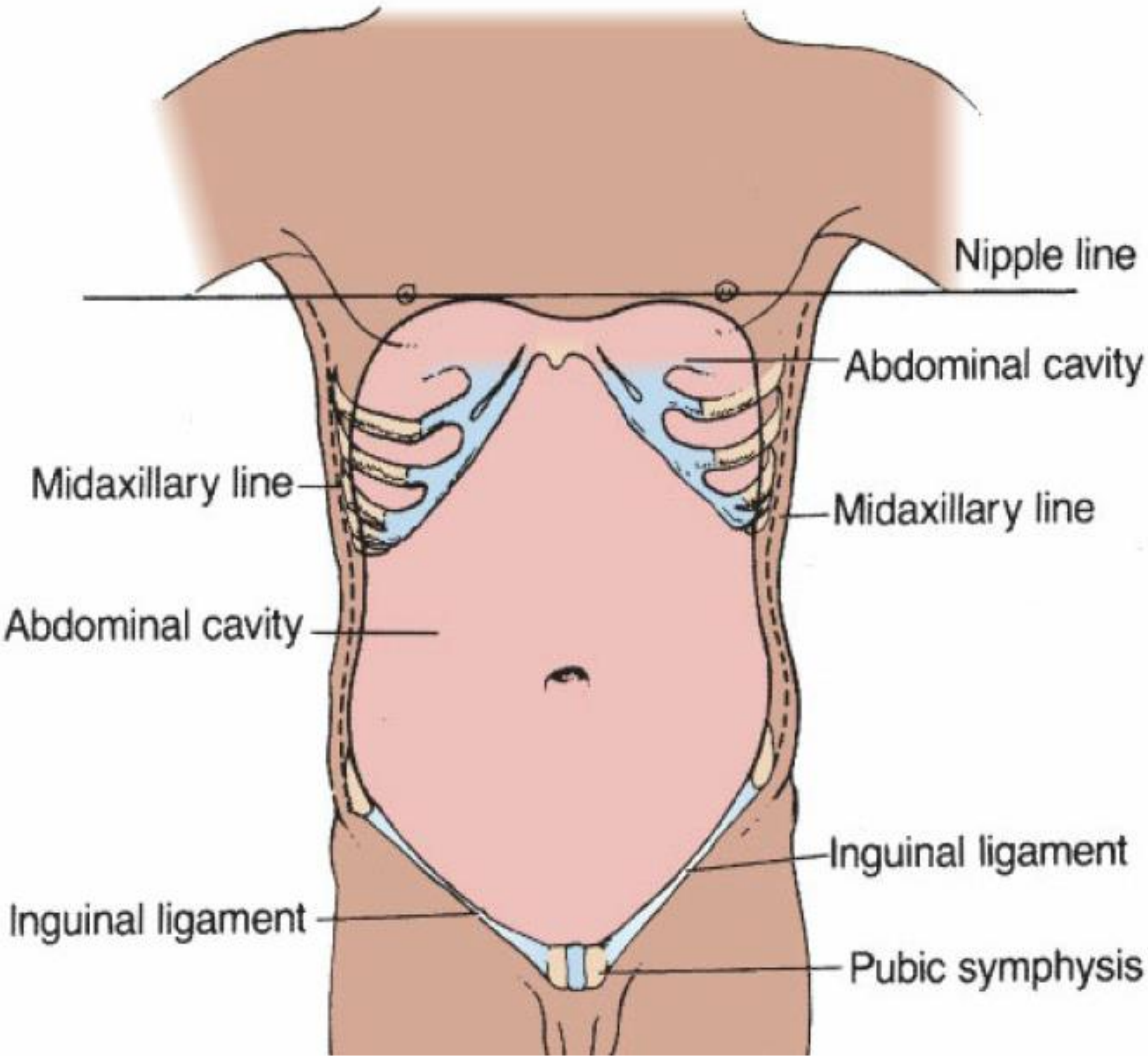
The abdominal contents are partially protected by the rib cage, the pelvis, and the lumbar spine as well as the abdominal wall musculature.

The pancreas, kidneys, bladder, aorta, inferior vena cava, duodenum, ascending and descending colons, and rectum reside in the retroperitoneum

The location, volume, and size of these organs affects injury patterns observed with both blunt and penetrating trauma. For example, penetrating wounds in the third trimester of pregnancy can involve the uterus and/or fetus.

The small bowel and mesentery are the most frequently injured organs with penetrating wounds.

During rapid deceleration that occurs during a motor vehicle crash, the spleen and liver are more mobile relative to hollow viscus organs resulting in a higher frequency of injury.


Nipple line
Abdominal cavity
Midaxillary line
Midaxillary line
Abdominal cavity
Inguinal ligament
Inguinal ligament
Pubic symphysis

- **Initial Evaluation**

The history and mechanism of a traumatic injury

The exam starts with complete exposure and thorough examination of the abdomen, flanks, and back. Identification of old scars, bruising, puncture wounds, lacerations, asymmetry, and

distension all provide insights into what may be injured.

Palpation of the abdomen in trauma patients is essential but may be unreliable due to altered mental status

from alcohol, drug use, head injury, or shock.

Palpation may reveal focal or diffuse tenderness, signs of peritoneal irritation, distension due to intra-abdominal hemorrhage, and fascial and muscular defects in the abdominal wall.

Examination of the pelvis should be performed, looking for pelvic bony instability or pain.

Serial abdominal exams should be performed to minimize the risk of missed injury.

Digital rectal examination should be performed in cases of suspected intra-abdominal trauma and when pelvic fracture is suspected

Adjunctive Diagnostic Tools

If there is no evidence of urethral injury or a high-riding prostate on rectal examination, insertion of a urinary catheter can help guide fluid resuscitation and reveal hematuria from renal or bladder injuries.

A supine abdominal x-ray of the abdomen and pelvis may be useful to determine the presence and location of bullets or other foreign bodies

The FAST abdominal ultrasound exam is quick and easy to perform and has supplanted diagnostic peritoneal lavage to assess for intraperitoneal bleeding. FAST evaluates for free fluid in the abdomen or pericardium using ultrasonographic views of the right and left upper quadrants, pericardium, and pelvis

CT scanning has dramatically changed the evaluation of the abdomen for injury and is the gold standard for diagnosing injury to any of the intraperitoneal or retroperitoneal organs in the hemodynamically stable patient.

Operative Care

A hypotensive victim of blunt abdominal trauma who does not respond to volume resuscitation is considered

to have an intra-abdominal source of bleeding until proven otherwise.

Spinal cord or neurologic injury can cause hypotension, but uncontrolled intra-abdominal hemorrhage occurs far more frequently.

The most common source of hemorrhage is the spleen and/or liver.

Rapid surgical management to secure hemostasis is required in this situation.

Penetrating wounds with peritonitis require prompt laparotomy, as the incidence of visceral injury is extremely high. Bullets may ricochet and fragment, and one should never assume that skin wounds from penetrating injury connect in a straight line.

Hemodynamically stable patients with a penetrating wound in the right upper quadrant or right thoracoabdominal region should be managed nonoperatively when the only organ injured is the liver.

In addition, stable patients without peritonitis may have wounds that are limited to the abdominal wall.

CT scans can help avoid a nontherapeutic laparotomy.

Low-velocity injury to the abdomen from sharp objects should also undergo local wound exploration to determine if the fascia and/or peritoneum has been violated. When there is violation, laparotomy is indicated to manage injuries

Penetrating flank wounds and back wounds from firearms are managed like abdominal wounds, but contrast-enhanced CT scan with both oral and rectal contrast allows for accurate identification of injuries in stable patients.

Penetrating trauma to these regions causes retroperitoneal organ injury more frequently.

Any hypotensive patient with a penetrating wound in the abdomen, flank, or back should undergo emergent exploratory laparotomy to control the bleeding

INJURY TO SPECIFIC ORGANS

- **Liver**

Blunt liver injuries are graded from I to VI in severity, with grade I injuries represented by small capsular hematomas or parenchymal lacerations less than 1 cm in depth, and grade VI injuries resulting from avulsion of the liver from its vascular pedicles (Table 9-4).

Most liver injuries are self-limiting in nature.

CT scan is the diagnostic modality of choice, providing anatomic detail and accurate grading of the injury (Figure 9-12) In the hemodynamically normal patient.

Ongoing bleeding such as contrast extravasation may require embolization to control the hemorrhage.

Higher-grade liver injuries, including those involving the hepatic veins or retrohepatic vena cava, may result in massive hemorrhage, requiring urgent operative intervention and damage control surgical techniques, as outlined in a subsequent section

TABLE 9-4 Liver Injury Scale

Grade[a]		Injury Description
I	Hematoma	Subcapsular, nonexpanding, <10% surface area
	Laceration	Capsular tear, nonbleeding, <1 cm in depth
II	Hematoma	Subcapsular, nonexpanding, 10%–50% surface area
		Intraparenchymal, nonexpanding, <10 cm in diameter
	Laceration	Capsular tear, active bleeding; 1–3 cm parenchymal depth, <10 cm in length
III	Hematoma	Subcapsular, >50% surface area or expanding; ruptured subcapsular hematoma with active bleeding; intraparenchymal hematoma >10 cm or expanding
	Laceration	>3 cm parenchymal depth
IV	Hematoma	Ruptured intraparenchymal hematoma with active bleeding
	Laceration	Parenchymal disruption involving 25%–75% of hepatic lobe or 1–3 segments within a single lobe
V	Laceration	Parenchymal disruption involving >75% of hepatic lobe or >3 segments within a single lobe.
	Vascular	Juxtahepatic venous injuries (i.e., retrohepatic vena cava/central major hepatic veins)
VI	Vascular	Hepatic avulsion

[a] *Advance one grade for multiple injuries up to grade III.*

- **Spleen**

The spleen is frequently injured in blunt abdominal trauma.

Splenic salvage is preferred but must be balanced with the risk of bleeding and death.

CT scan allows for accurate assessment of the degree of splenic injury and also assesses for concomitant injuries.

Nonoperative management is used for hemodynamically stable patients, particularly with low-grade splenic injuries

Recurrent hemorrhage or development of peritonitis signals failure of nonoperative management and should be followed by expeditious laparotomy or embolization.

Splenic injury with active bleeding and hypotension requires either total splenectomy or splenorrhaphy.

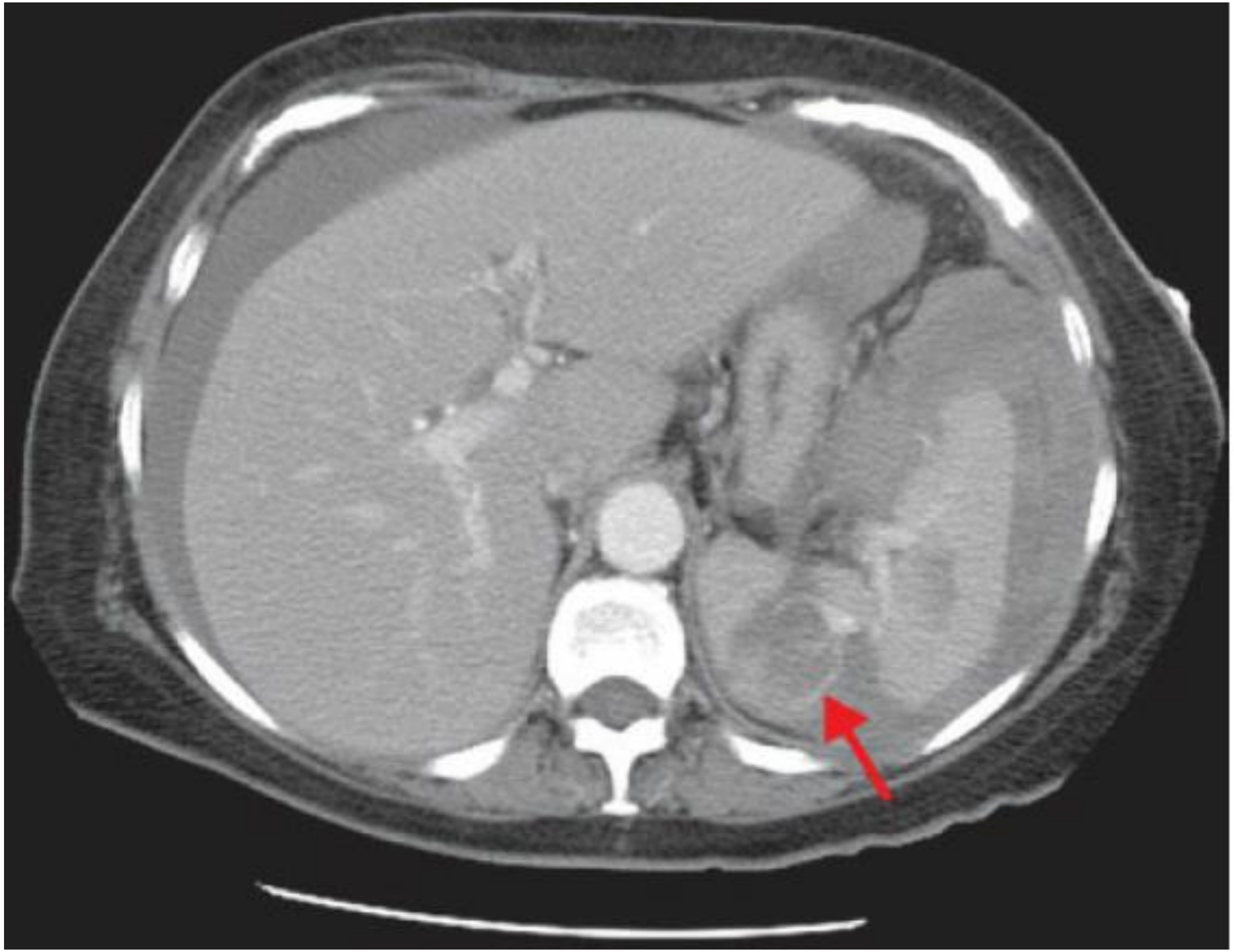
Hemodynamically stable patients with IV contrast extravasation on dynamic CT scan can be managed by angioembolization for splenic salvage

Splenectomized patients should undergo postoperative vaccination for encapsulated organisms such as pneumococcus

and meningococcus to reduce the risk for the rare but potentially fatal complication of overwhelming postsplenectomy infection

TABLE 9-5 Splenic Injury Scale

Grade[a]		Injury Description
I	Hematoma	Subcapsular, nonexpanding, <10% surface area
	Laceration	Capsular tear, nonbleeding, <1 cm in depth
II	Hematoma	Subcapsular, nonexpanding, 10%–50% surface area
		Intraparenchymal, nonexpanding, <5 cm in diameter
	Laceration	Capsular tear, active bleeding; 1–3 cm parenchymal depth that does not involve a trabecular vessel
III	Hematoma	Subcapsular, >50% surface area or expanding; ruptured subcapsular hematoma with active bleeding; intraparenchymal hematoma >5 cm or expanding
	Laceration	>3 cm parenchymal depth or involving trabecular vessels
IV	Hematoma	Ruptured intraparenchymal hematoma with active bleeding
	Laceration	Laceration involving segmental or hilar vessels producing major devascularization (>25% of spleen)
V	Laceration	Completely shattered spleen
	Vascular	Hilar vascular injury, which devascularizes spleen



- **Pancreas**

Injury to the pancreas is uncommon due to its protected retroperitoneal location.

This location makes diagnosis by physical examination difficult.

Transection of the body of the pancreas may occur by compression against the vertebral column.

When the fracture in the parenchyma is to the left of the superior mesenteric artery, distal pancreatectomy with or without splenic salvage is the optimal management.

Injuries of the pancreatic head can be challenging. Initial management is usually at controlling hemorrhage and drainage of the disrupted pancreatic tissue.

Small injuries of the pancreas not involving the main pancreatic duct may be managed with drainage.

Stab wounds to the back can injure pancreatic parenchyma and ducts.

Evaluation may include CT scanning, magnetic resonance cholangiopancreatography (MRCP), and endoscopic retrograde cholangiopancreatography (ERCP).

- **Diaphragm**

Blunt rupture of the diaphragm usually extends from the gastroesophageal (GE) junction into the tendinous portion of the central diaphragm.

Rarely, blunt injury may result in complete avulsion of the posterior muscular insertion from the ribs

Repair is done with interrupted or running permanent suture to minimize the risk of recurrence.

Care should be taken to avoid injury to the branches of the phrenic nerve when possible

Low-velocity penetrating injury to the diaphragm can occur without pneumothorax or evidence of

peritoneal injury.

Left-sided diaphragmatic injuries are particularly concerning because of the risk of development of diaphragmatic hernia and visceral incarceration if not repaired.

In addition, left-sided diaphragmatic wounds are commonly associated with injuries of the stomach, colon, spleen, and small intestine.

Unfortunately, small penetrating injuries of the diaphragm are not readily diagnosed by CT.

For these reasons, there should be a low threshold for diagnostic laparoscopy or thoracoscopic evaluation of the

left diaphragm for penetrating injury to the left thoracoabdominal region.

Small injuries of the right diaphragm may be managed without surgical repair because the liver is protective against herniation

- **Kidneys**

The kidneys, like the pancreas, are relatively protected from injury because of their retroperitoneal location, as well as encasement within Gerota’s fascia.

Blunt renal trauma rarely requires operative intervention unless:

ureteral injury

disruption of the renal pelvis

Nephrectomy may be necessary for massive destruction of the parenchyma (grade IV or higher) or injury involving the hilum.

Penetrating injuries are selflimiting under most circumstances unless the vessels are involved.

Foley catheter drainage should be maintained for 7 to 10 days, or until hematuria resolves

- **Small Intestine and Mesentery**

Blunt perforation of the small intestine may occur as the result of compression and resultant blowout, or by avulsion of the mesenteric blood supply.

Contusion to bowel wall may result in a delayed perforate.

An abdominal "seatbelt sign" increases the risk for bowel injury.

Mesenteric tears with hemorrhage from the arcade vessels can occur in deceleration injury and should be suspected when CT scan shows fluid without a solid organ injury.

The small bowel and mesentery are frequently injured by knife and gunshot wounds.

Repair is generally straightforward and involves closure with absorbable or nonabsorbable suture.

Stapled repair or resection with anastomosis is appropriate for injuries involving the mesentery

- **Colon**

Injury to the large intestine from low- and high-velocity projectiles can often be repaired primarily.

More extensive wounds that involve the mesentery may be managed by resection with primary reanastomosis.

Colostomy is seldom required in colonic trauma.

Injuries to the extraperitoneal rectum should be considered for fecal diversion to avoid perineal sepsis while the wound heals.

Patients with colonic trauma and multiple other injuries or profound shock may also be considered candidates for temporary diverting colostomy because of their increased risk for anastomotic breakdown

- **Damage Control**

Patients presenting with shock and ongoing hypotension benefit from an abbreviated laparotomy that controls hemorrhage and/or contamination. This is commonly referred to as a damage control laparotomy.

The "lethal triad" of

hypothermia

acidosis

coagulopathy

Damage control surgery usually takes 60 to 90 minutes, with expedient transfer of the patient to the intensive care unit for ongoing resuscitation, rewarming, and correction of coagulopathy.

Once stabilized, usually 12 to 48 hours after initial presentation, the patient is returned to the operating room for staged removal of hemostatic packing, reconstruction of the gastrointestinal tract, and definitive repair of other injuries

- **Abdominal Compartment Syndrome**

Aggressive crystalloid volume resuscitation can result in sequestering of fluids in the retroperitoneum and peritoneal cavity (third spacing).

When the intraperitoneal pressure is greater than 25 mm Hg and there is organ dysfunction, there should be concern for the development of abdominal compartment syndrome (ACS).

ACS compromises blood flow to the abdominal and retroperitoneal viscera. Diaphragmatic excursion is reduced and evident by increased airway pressure, reduced tidal volumes, hypoxia, and eventually hypercapnia.

When left untreated or when there is a delay in diagnosis, ACS results in multiple organ dysfunction syndrome (MODS) and is commonly fatal.

The clinical triad of decreased urine output, increased airway pressures, and elevated abdominal pressure constitutes ACS.

Diagnosis is facilitated by measuring the bladder pressure, which indirectly represents the intraperitoneal pressure.

Treatment is prompt decompression by making a midline laparotomy incision.

This allows prompt decompression and restoration of pulmonary function.

Renal perfusion is restored, and urinary output increases.

The abdominal cavity and fascia can often be closed after swelling of the viscera has subsided, but occasionally prolonged wound care, skin grafting, or complex closure techniques are required

PELVIC FRACTURES

The fracture patterns are typically classified by the mechanism of injury:

- anterior–posterior (AP) compression
- lateral compression (LC)
- vertical shear

the LC mechanism is the most common and the most stable because it is less likely to lead to ligamentous disruption of the sacroiliac joint.

The AP compression fracture pattern is also known as the open book pelvic fracture. The symphysis pubis is disrupted and the iliac wings open, leading to variable amounts of sacroiliac ligamentous disruption.

The appearance of the pelvis on radiologic imaging does not necessarily indicate the full extent of the distraction of the pelvic bones that occurred on initial impact.

The least common pelvic ring disruption but most unstable is the vertical shear injury pattern, which is caused by a severe vertical force that may disrupt the hemipelvis from the spine, or create a fracture through the iliac wing.

This fracture pattern is often associated with other abdominal, pelvic, or vascular injuries

Pelvic fractures may be suspected on the basis of history and physical findings.

If the patient is conscious, pain is usually present, particularly with palpation.

There may be bruising to the lower abdomen, hips, buttocks, or lower back.

The bony pelvis should be manually palpated gently to illicit tenderness, deformity (such as a widened symphysis pubis), or movement with gentle compression.

Examination should also include inspection of the perineum for open wounds, which would signify an open pelvic fracture.

The lower extremities should be examined for alignment, length discrepancy, and pelvic pain with movement.

In symptomatic patients, a plain x-ray of the pelvis is indicated to evaluate for a pelvic fracture.

Dynamic helical CT scan of the pelvis offers a means of evaluating the integrity of the bony pelvis, as well as the internal pelvic structures.

Extravasation of intravenous contrast is a sign of ongoing hemorrhage and should prompt consideration for early angioembolization.

CT scan also allows for evaluation of the lower genitourinary tract.

Hemorrhage associated with a pelvic fracture is related to the fracture edges, presacral venous plexus, or, in approximately 10% of patients, an arterial source.

Because of the high kinetic energy necessary to disrupt the pelvic ring, rapid assessment for other sources of blood loss should be performed.

Bleeding from the fracture edges or small veins can be minimized by stabilizing the pelvis

There are several simple methods to achieve this, ranging from wrapping a sheet tightly around the pelvis to applying a pelvic binder or external fixator.

These methods work best for AP compression injuries to restore the alignment of the pelvic bones.

Ongoing bleeding from an arterial source requires intervention.

As a general rule, surgical exploration is not the best option to control pelvic hemorrhage.

Surgical exploration by opening the peritoneum releases the tamponading of the retroperitoneal venous bleeding.

If the patient is taken to surgery for other injuries, such as a ruptured spleen, the pelvic hematoma can be packed with laparotomy pads.

The preferred method to control arterial hemorrhage is catheter-directed embolization.

Blunt mechanisms produce two types of bladder injury, namely, intraperitoneal and extraperitoneal lacerations.

Extraperitoneal injury results from the ligamentous attachments, which secure the bladder to the pelvic bones, tearing the bladder wall.

The diagnosis is made by a cystogram demonstrating extravasation into the retroperitoneum.

Treatment is decompression of the bladder with a Foley catheter until the laceration heals, typically 7 to 10 days.

Blunt force to the lower abdominal wall when the bladder is distended results in a disruption of the dome of the bladder, which is intraperitoneal.

This injury may or may not be associated with pelvic fractures.

The diagnosis is made by CT cystogram revealing contrast extravasation into the peritoneal cavity.

Intraperitoneal bladder injury requires surgical exploration and repair.

Typical signs associated with urethral injury are scrotal hematoma, blood at the urethral meatus, and a high-riding or nonpalpable prostate gland on rectal exam.

A retrograde urethrogram should be done to evaluate for injury before passage of a Foley catheter in these cases.

Blind passage of a catheter in a patient with a partial urethral tear can lead to worsening of the injury or complete transection.

Inability to pass a catheter or identification of a urethral injury will require urologic consultation for definitive management.

The urethra can also be injured directly with penetrating trauma or blunt force mechanisms such as straddle injuries

PENETRATING NECK TRAUMA

The neck is a highly complex anatomic region with critical vascular, neurologic, and aerodigestive structures concentrated within a very small area.

Any wound that violates the platysma muscle carries a risk of injury to the great vessels, trachea, esophagus, and spinal cord, and therefore requires further assessment.

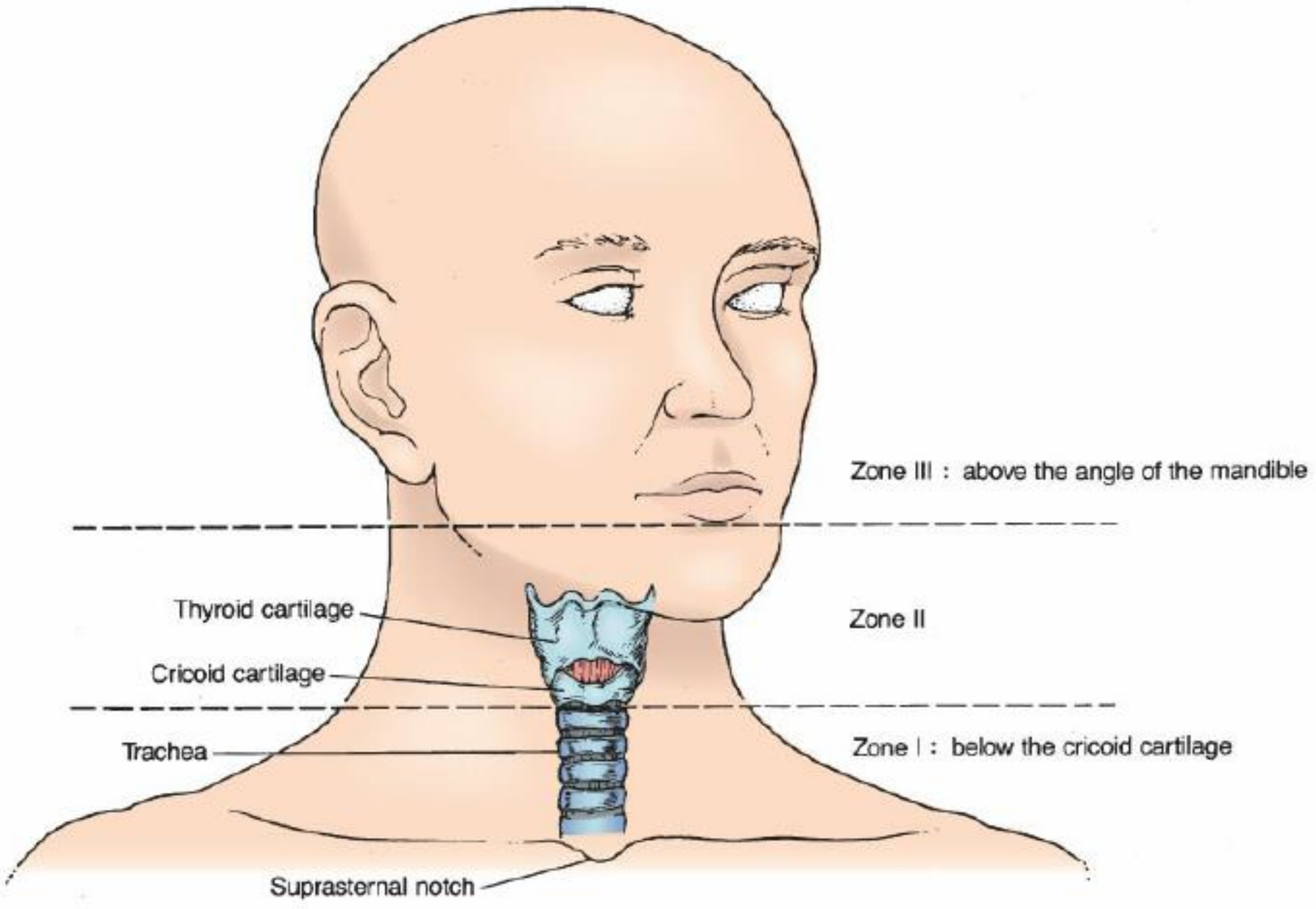


Figure 9-17 Zones of the neck.

Initial evaluation :

Shock or hard signs of injury to any of the vital structures in zones I and II mandate immediate operative exploration to control hemorrhage.

In the hemodynamically stable patient, a more selective approach is taken for injuries to both zone I and zone III because of the difficulty in examining and operatively exposing structures in these areas.

Controversy continues to center around hemodynamically stable patients with an injury located in zone II and no signs or symptoms suggestive of a major injury.

Traditional evaluation includes angiography, bronchoscopy, and esophagoscopy in conjunction with esophagography

There is a growing body of literature to support the use of contrast-enhanced CT for evaluation of penetrating neck injury.

Several prospective studies evaluating the use of CT angiography in penetrating neck trauma have demonstrated

a sensitivity approaching 100% and a negative predictive value over 90%.

- **Aerodigestive Tract Injury**

Aerodigestive tract injuries are seen in 10% of penetrating trauma to the neck. Airway management is paramount. The need for a surgical airway (cricothyroidotomy) should always be considered in any patient who might have a tenuous or compromised airway.

The preferred method of evaluating for an injury to the larynx and trachea involves a combination of direct laryngoscopy and bronchoscopy.

Laryngeal injuries are classified as supraglottic, glottic, and subglottic.

Supraglottic injuries typically result in a depression of the superior notch of the thyroid cartilage and are associated with a vertical fracture of the thyroid cartilage.

Disruption of the thyroid cartilage results in a glottic injury.

An injury to the subglottic region usually involves the lower thyroid and cricoid cartilage.

Early definitive repair for any laryngeal injury should be the goal because of the higher incidence of stricture formation with delayed repair.

Subglottic injury to the trachea should be repaired in one layer with absorbable suture.

When there is an associated esophageal or arterial injury, the risk of fistulization between the two repairs is reduced by interposing a vascularized pedicle of omohyoid or sternocleidomastoid muscle.

Operative management of cervical esophageal injuries requires meticulous debridement, a two-layer closure of the wound, and closed suction drainage.

Injuries limited to the hypopharyngeal region can be safely managed conservatively including a nasogastric tube for feeding and an empiric course of parenteral antibiotics

- **Vascular Injury**

The approach to evaluation of a vascular injury in the neck is dictated by the patient’s hemodynamic status and neurologic assessment.

Observation or expectant management is advocated for patients who are comatose.

Simple ligation of an artery is an option for those patients presenting with exsanguination or when a temporary shunt cannot be placed.

The carotid artery should be repaired when the patient has an intact or alternating neurologic examination. Repair may be performed by a direct operative approach or using endovascular techniques in the stable patient.

Angiographic intervention is particularly applicable in zone III injuries to the internal carotid artery located at the base of the skull because of the difficulty in accessing this area.

The most common vascular injury with penetrating wounds is the internal jugular vein.

In the hemodynamically unstable patient, any venous injury should be managed by simple ligation.

Otherwise, an injury to the internal jugular vein should be repaired by lateral venorrhaphy or patch venoplasty.

Despite the method of repair, subsequent thrombosis is common

TRAUMA IN PREGNANCY

The leading causes of injury among pregnant women are transportation related, falls, and assault.

Motor vehicle collision is the most common mechanism resulting in fetal death, followed by firearms, and then falls.

It is estimated that 10% to 30% of women are physically abused during pregnancy, and of these 5% are severe enough to result in fetal death.

Thus, it is mandatory for all members of the health care team to be versed in recognizing the signs and symptoms of physical abuse

The priorities for treatment of the pregnant patient are the same as those for the nonpregnant patient.

Prevention of hypotension when the patient is supine is accomplished by repositioning to displace the uterus off the vena cava and aorta while maintaining alignment of the spine.

This can be accomplished by three simple maneuvers:

left lateral decubitus position, the right lateral decubitus position, or the knee–chest position when supine.

Alternatively, the uterus can be manually displaced to the patient’s left side.

A urine pregnancy test should be obtained in all injured

women of childbearing age, and, when positive, early obstetrical consultation is recommended

Abdominal examination may reveal evidence of uterine rupture because fetal parts may be palpable in this circumstance.

A speculum examination should be performed followed by the bimanual examination only if there is no evidence of vaginal bleeding.

The examination focuses on the following: vaginal blood, ruptured amniotic membranes, active contractions, a bulging perineum, and an abnormal fetal heart rate or rhythm.

Drainage of cloudy white or green fluid from the cervical *os* is indicative of ruptured membranes. This is an obstetrical emergency requiring urgent cesarean section.

Bloody amniotic fluid is indicative of either placental abruption or placenta previa. When this occurs during the first trimester, there is a great risk of spontaneous abortion.

Rh typing is essential in the pregnant trauma patient. The Rh antigen is well developed by 6 weeks of gestation, and as little as 0.001 mL of fetal blood can cause sensitization of the Rh-negative mother.

Therefore, all Rh-negative women should receive Rho (D) immune globulin, unless the injury is minor and remote from the uterus.

PEDIATRIC TRAUMA

Pediatric trauma is the number one cause of death of children, as well as the number one cause of permanent disability in those under 14 years of age.

In children over 1 year and under 14 years of age, motor vehicle collisions cause 47% of all pediatric deaths related to injury.

Drowning is the second most frequent cause of injury-related death in children, followed by thermal injury.

Although the resuscitation priorities (ABCDE algorithm) are the same for children as for adults, anatomic and physiologic differences require modifications to the approach.

The Broselow Pediatric Resuscitation Measuring Tape has become the standard for determining height, weight, and the appropriate size for resuscitative equipment and medication dosing in children.

This device is placed on the bed next to the child, and the height measurement allows estimation of weight for dosing of medications and other therapeutic maneuvers.

A child's blood volume is approximately 8% of body weight, or 80 mL/kg.

Clinical signs of decreased organ perfusion in conjunction with altered mentation are the classic findings of hemorrhagic shock.

Initial resuscitation is begun with 20 mL/kg of an isotonic crystalloid solution, such as 0.9% normal saline, or lactated Ringer's solution.

If there is no improvement in perfusion after a second bolus of crystalloid, then a 10 mL/kg bolus of either crossmatched or O-negative packed red blood cells should be administered

Hypothermia is common in the injured child and may occur at any time of the year.

The response to hypothermia includes:

catecholamine release, with an increase in oxygen consumption and metabolic acidosis.

Hypothermia and acidosis may then contribute to posttraumatic coagulopathy. The rate of cooling and subsequent hypothermia can be reduced by warming the room (>37°C), using warmed intravenous fluids and blood (39°C), heated air-warming blankets, and external warmed blankets during the initial resuscitation.

In addition to physical examination, adjunctive tests include FAST and CT scan. CT imaging of the head, chest, abdomen, and pelvis are the accepted diagnostic radiologic studies of choice in the hemodynamically stable children.

In the hemodynamically normal children, the vast majority of solid organ injuries can be managed without surgical intervention.

As in adults, hollow viscus perforation should be managed by prompt surgical repair.

TRAUMA IN THE ELDERLY

The elderly population (age ≥ 65 years) is the fastest growing age group in the United States.

Injury is the fifth leading cause of death in the elderly.

Within this group, 42% reported some type of long-lasting condition or a disability. Of those aged 65 to 74, a third reported at least one disability; that number climbs to 72% in people 85 years of age and older.

Common injury mechanisms in the geriatric population include falls, motor vehicle collisions, automobile versus pedestrian collisions, assaults, and burns.

Motor vehicle collision victims over the age of 85 have a fatality rate that is seven to nine times higher than that of younger adults.

Adult pedestrian injuries are more common in lower socioeconomic groups who are more likely to travel by walking.

Elderly trauma patients have higher injury-related mortality when compared with younger patients.

Much of this is due to reduced function in all organs that occurs with aging and also the increased incidence of comorbid conditions.

The most frequent comorbidities in the elderly involve the cardiovascular system.

These diseases compromise the older trauma patient's ability to respond to hypovolemia.

Rather than mounting a tachycardia and increase in cardiac output, there is an increase in systemic vascular resistance resulting in a falsely reassuring BP.

In fact, a normal BP in an elderly trauma victim frequently corresponds to profound shock when perfusion is assessed using systemic markers such as serum lactate and base deficit.

Cardiac physiology is also affected by medications prescribed for hypertension and arrhythmias

Aging also affects pulmonary function.:

decrease in the alveolar surface area that reduces the surface tension and thus gas exchange and forced expiratory flow.

Gross anatomic changes in the thorax of the elderly include the development of kyphosis, which results in a reduction of the transverse thoracic diameter.

The loss of bone density is associated with an increased rigidity of the chest wall.

Chest wall compliance decreases with age, resulting in increased work of breathing.

In elderly women, osteoporosis increases the risk for rib fractures and pulmonary contusion.

Age has been shown to be the strongest predictor of outcome and is directly proportional to mortality in patients with multiple rib fractures.

In the geriatric patient, the initial GCS score may be less reliable and more reflective of chronic disease of the central nervous system or systemic disease.

A significant traumatic brain injury can result from apparently minor trauma because of the changes with aging of the meninges and a reduction in brain volume.

Thus, any elderly patient with a change in mental status should prompt a thorough evaluation for traumatic brain injury, including a noncontrast CT scan of the head.

In addition, many elderly patients are prescribed anticoagulants.

Otherwise minor head injuries may become devastating intracranial hemorrhages in the anticoagulated patient.

Morbidity and mortality are reduced by prompt correction of coagulopathy

Renal function begins to deteriorate at the age of 30.

The number of functioning nephrons decreases by 10% per decade, whereas the remaining functional units hypertrophy.

Glomerular filtration rate begins to decrease at 50, declining by 0.75 to 1 mL/minute/year.

Traumatic injury in the elderly is more likely to produce bowel and mesenteric infarction.

Gastrointestinal tract wounds are associated with a 3- to 4-fold increase in mortality when compared with younger cohorts.

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1. A 43-year-old woman unbelted driver was involved in a motor vehicle collision into a tree. She was noted to have extensive facial injuries including fractures to the midface and mandible with bleeding in the airway. She does not open her eyes, she moans to deep stimulation, and she has extensor flexion of her extremities on noxious stimulation. Her oxygen saturation is 90% to 92%. The optimal management of her airway is

A. nasotracheal airway.
B. orotracheal airway.
C. fiberoptic nasal intubation.
D. endotracheal intubation.
E. surgical cricothyroidotomy.

2. A 65-year-old man is struck by a car while riding a moped. On arrival, his respiratory rate is 18/minute, his heart rate is 95 beats/minute, and his BP is 78/54 mm Hg. His oxygen saturation is 93%. He complains of chest pain and shortness of breath, and he has right chest wall tenderness and decreased breath sounds. He moves all his extremities to command. The most likely cause of his hemodynamic instability is

A. neurogenic shock.
B. cardiogenic shock.
C. hemorrhagic shock.
D. distributive shock.
E. obstructive shock.

3. A 23-year-old man is brought in by EMS after a fall off his roof. He presents unresponsive, with a heart rate of 40 beats/minute and a BP of 165/90. His GCS is 3. His physical exam shows a laceration to his right scalp, bruising of his chest wall, a nontender, nondistended abdomen, and deformity of his right forearm. His FAST exam is positive. The next step of his management should be

A. endotracheal intubation.
B. administration of an antihypertensive agent.
C. resuscitative thoracotomy.
D. CT scan of his head.
E. exploratory laparotomy.

4. A 70-year-old woman is brought in after a fall down a flight of stairs. She is disoriented to time and place, is somnolent, and complains of neck and back pain. She cannot feel or move her lower extremities. She localizes to pain her upper extremities. Her heart rate is 46 beats/minute, and her BP is 75/34 mm Hg. This patient most likely has

A. high cervical spine injury.
B. low cervical spine injury.
C. high thoracic spine injury.
D. low thoracic spine injury.

5. A 38-year-old unbelted male driver is involved in a head-on motor vehicle collision and is brought in to the ED, with a heart rate of 95 beats/minute and BP of 65/28 mm Hg. He is awake and anxious, complaining of shortness of breath and chest wall tenderness. He has decreased breath sounds on the right, bruising across his chest, and chest wall tenderness. The next step should be

A. orotracheal intubation.

B. nasotracheal intubation.

C. ED thoracotomy.

D. chest tube placement.

E. needle thoracostomy.