Thoracic Trauma

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PATHOPHYSIOLOGY

The most common mechanism of blunt thoracic trauma is an MVC, followed by falls, assaults, and crush injuries. Compressive forces directly injure the thoracic cage and underlying viscera and result in rib fractures and pulmonary contusion. Deceleration produces traction on fixed structures such as the isthmus of the aorta and the carina and results in traumatic aortic and tracheobronchial injuries. Blunt thoracic trauma causes penetrating thoracic trauma when rib or clavicle fractures impale thoracic or abdominal viscera.

Gunshot wounds and stab wounds are the most common mechanisms of penetrating thoracic trauma. Low-velocity stab wounds disrupt only the structures penetrated. Medium-velocity handguns and high-velocity military assault rifles produce temporary and permanent cavities of tissue damage. Missile injuries to the thorax often involve multiple anatomic regions, including the neck, diaphragm, abdomen, and retroperitoneum.

THORACIC CAGE INJURIES: RIB, STERNUM, AND SCAPULA FRACTURES

MVCs are the most common cause of rib and sternum fractures. Other mechanisms include pedestrian injury by a moving vehicle, falls, contact sports, and altercations. Fractures occur at the site of direct blows or at their posterior weak point as a result of compressive forces. Ribs 4 to 9 are the most commonly fractured.

Seat belts have increased the incidence of sternum fractures while reducing the number of lives lost in MVCs. Isolated nondisplaced sternum fractures are no longer considered markers of blunt cardiac injury. More complicated fracture patterns predict associated injuries. Fractures of the manubrium, manubrium-sternum synchondrosis, and proximal part of the sternum and severely displaced sternum fractures are associated with an increased incidence of spinal fractures. Displaced fractures of the body of the sternum are associated with a higher incidence of intrapulmonary and cardiac injuries.

EPIDEMIOLOGY

Head and thoracic injuries from moving vehicle collisions (MVCs) and firearms account for the majority of the more than 160,000 injury-related deaths in the United States each year. Most fatalities occur immediately as a result of massive cardiac or vascular injury. Rib fractures are the most common thoracic cage injury following blunt thoracic trauma. Isolated first and second rib, sternum, and scapula fractures are no longer considered markers of traumatic aortic injury. However, rib fractures must still be considered markers of significant injury. Most patients seen in trauma centers with rib fractures will have hemothorax, pneumothorax, or a pulmonary contusion. Three or more rib fractures at any anatomic site dramatically increases the risk for spleen and liver injury. Likewise, scapula fractures are uncommon yet signify a high-energy mechanism of injury, almost always with important associated injuries.

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**KEY POINTS**

- Emergency life-threatening conditions that need to be detected during the primary survey include airway obstruction, tension pneumothorax, open pneumothorax, massive hemothorax, flail chest, and pericardial tamponade (Table 78.1).
- Urgent life-threatening conditions to detect during the secondary survey include simple pneumothorax, hemothorax, pulmonary contusion, tracheobronchial injury, blunt cardiac injury, traumatic aortic injury, diaphragmatic injury, and esophageal injury.
- Common thoracic cage injuries are not always associated with serious injury, but some individuals, especially pediatric and elderly patients, may require admission for associated injuries and respiratory therapy.

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### PRESENTING SIGNS AND SYMPTOMS

Classically, rib fractures are accompanied by localized tenderness and pleuritic chest pain, as well as splinting, crepitus, and ecchymosis. Patients with a classic sternum fracture have localized pain and tenderness along with ventral compression, ecchymosis, and deformity. Pain at the site of thoracic cage injuries increases with cough and deep inspiration. Patients with scapular fractures typically have rib and extremity fractures that often mask the diagnosis of scapula fracture.

### DIFFERENTIAL DIAGNOSIS AND MEDICAL DECISION MAKING

The initial portable anteroposterior (AP) chest radiograph should be inspected to confirm the diagnosis of rib fracture and underlying pleura or lung injury. Upright posteroanterior (PA) and lateral radiographs should be obtained if a high clinical index of suspicion remains for fracture or underlying injury. The presence of an occult “clinical rib fracture” with tenderness over the rib should be assumed even in the absence of radiographic findings. Rib radiographs seldom add to the clinical evaluation and are not routinely indicated.

Sternum fractures are best detected on the lateral chest radiograph. Associated rib fractures and mediastinal abnormalities may be evident on the PA view. In experienced hands, bedside ultrasound may be more sensitive than radiographs for detection of both rib and sternum fractures, as well as associated hemothorax or pneumothorax. The electrocardiogram (ECG) should be examined for evidence of cardiac injury. Scapula fractures are often missed on the initial chest radiograph unless the scapular outline is specifically inspected. Shoulder radiographs can confirm suspected fractures (Fig. 78.1).

Helical computed tomographic (CT) angiography should be performed on hemodynamically stable patients when clinically significant underlying injury is suspected. An abdominal CT scan can rule out intraabdominal injury in patients with tenderness or fracture of the sixth rib or below, three or more rib fractures, hypotension noted in the field or emergency department (ED), abdominal or flank tenderness, pelvic or femoral fractures, or gross hematuria.

### TREATMENT

Adequate pain control should be provided to prevent atelectasis in patients with simple acute rib fractures. Patients should be instructed to perform incentive spirometry or take 10 deep breaths every hour. Binders and belts are not recommended because such devices promote hypoventilation, which results in atelectasis and pneumonia. Shoulder slings and pendular exercise should be prescribed for most scapular fractures. Displaced fractures, especially those involving the scapular spine and neck, often require consultation with an orthopedic surgeon for repair.

### FOLLOW-UP, NEXT STEPS IN CARE, AND PATIENT EDUCATION

Otherwise healthy patients with isolated rib fractures or sternum or scapula fractures may be discharged home. Elderly
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move inward during inspiration and outward during expiration. More commonly, splinting secondary to severe pain or mechanical ventilation masks the diagnosis. Forced expiration and coughing accent the paradox.

DIFFERENTIAL DIAGNOSIS AND MEDICAL DECISION MAKING

A chest radiograph can confirm the diagnosis and detect complications such as pneumothorax and hemothorax. A chest CT scan can further evaluate the underlying pulmonary contusion and assess for other underlying injuries such as traumatic aortic injury.

TREATMENT

Immediate chest tube placement is required for assessment and management of other injuries, including pneumothorax and hemothorax. Continuous positive airway pressure is the first-line treatment in awake and cooperative patients with worsening oxygenation or ventilation.\textsuperscript{10} Criteria for intubation include airway obstruction, respiratory distress, shock, closed head injury, and need for surgery. Endotracheal intubation should be performed only when necessary to avoid the increased mortality associated with nosocomial pneumonia.

Fluid replacement should be managed carefully to avoid overhydration and worsening of lung injury. Analgesia is titrated so that patients are more willing to make sufficient inspiratory effort, but excessive sedation should be avoided. Intercostal nerve blocks, epidural anesthesia, or even surgical fixation of the flail segment may be beneficial.\textsuperscript{11} Stabilization of the flail segment in the ED or prehospital setting has not been shown to be helpful, and aggressive stabilizing efforts impede overall thoracic mechanics.

FOLLOW-UP, NEXT STEPS IN CARE, AND PATIENT EDUCATION

Consultation and admission for trauma or cardiothoracic surgery is advised when flail chest is suspected. Overall mortality from flail chest, though dependent on other injuries, ranges up to 35%. All patients with flail chest should be admitted to the intensive care unit, preferably at a level I trauma center for close observation of respiratory mechanics and worsening of pulmonary contusion.

PNEUMOTHORAX AND HEMOTHORAX

A simple pneumothorax occurs when air accumulates in the pleural space without shifting the mediastinum or communicating with the atmosphere. Mechanisms include laceration of the pleura or lung by a fractured rib, alveolar rupture from compression of the chest against a closed glottis, or a penetrating wound in the thorax.

Tension pneumothorax occurs when injury to the chest wall acts as a one-way valve. Outside air enters the pleural space
During inspiration but cannot exit during expiration. Accumulating air increases intrapleural pressure, which eventually shifts the mediastinum, compresses the vena cava, reduces venous return, and ultimately decreases cardiac output. Open or communicating pneumothorax occurs when a significant thoracic wall defect causes the lung to collapse on inspiration and expand on expiration, with air being “sucked” into and out of the chest and thus preventing effective ventilation. Mechanisms include high-velocity assault rifle injuries and shotgun wounds.

Hemothorax occurs when blood accumulates in the pleural space, typically from minor lacerations in the lung parenchyma. Massive hemothorax is defined as greater than 1.5 L of blood in the initial chest tube drainage and is an indication for immediate surgery. Hemopneumothorax occurs when both air and blood fill the pleural space and commonly results from rib fractures or penetrating trauma.

**PRESENTING SIGNS AND SYMPTOMS**

Patients with a simple pneumothorax classically have chest pain, diminished breath sounds, crepitus, hyperresonance, and mild to moderate respiratory distress. Patients with tension pneumothorax are classically seen in extremis and exhibit jugular venous distention, tracheal deviation, unilaterally absent breath sounds, or tachycardia followed by hypotension immediately before death (or any combination thereof). Patients with open pneumothorax have chest wall wounds that produce sonorous sounds and are in severe respiratory distress. Typical symptoms of hemothorax are respiratory distress, chest pain, and diminished breath sounds with dullness to percussion.

Atypical manifestations are more common than classic ones. Respiratory distress may occur as a result of multiple other causes. Patients can have severe pain from distracting injuries. Breath sounds may be difficult to hear in a noisy environment. Physical examination in patients with penetrating thoracic trauma is unreliable for the detection of pneumothorax or hemothorax. Patients with simple pneumothorax may be minimally symptomatic or may be cyanotic and in severe respiratory distress. Tension pneumothorax most commonly occurs in intubated patients as a result of positive pressure ventilation, sometimes after overzealous bagging.

Clinical reassessment of ventilated patients with decreasing oxygen saturation and hypotension may allow faster detection and treatment, even before chest radiographic diagnosis. Open pneumothorax may be missed if the patient is not completely exposed and rolled during the primary survey.

**DIFFERENTIAL DIAGNOSIS AND MEDICAL DECISION MAKING**

The differential diagnosis for tension pneumothorax includes cardiac tamponade, massive hemothorax, and right mainstem intubation with left lung collapse. All will produce respiratory distress, hypotension, and tachycardia. Cardiac tamponade results in diminished heart sounds with normal breath sounds and a midline trachea. Massive hemothorax produces decreased or absent unilateral breath sounds and dullness to percussion. Chest tube insertion confirms the diagnosis. Right mainstem intubation results in jugular venous distention, tracheal deviation to the left, normal resonance, and diminished breath sounds on the left versus the right. In an intubated patient, the endotracheal tube should be checked and pulled back. In the field or resuscitation bay, bilateral needle thoracostomy should be performed when the patient is in distress, even if the diagnosis is uncertain. A rush of air confirms the diagnosis of tension pneumothorax. Chest tubes must be placed after needle decompression.

A chest radiograph can confirm the diagnosis of simple pneumothorax and hemothorax. A distance of 1 cm or one fingerbreadth between the chest wall and visceral pleural line correlates with a small, 10% to 15% pneumothorax. Anything larger requires immediate chest tube insertion. On a supine portable AP chest radiograph, a deep sulcus sign suggests pneumothorax. The affected costophrenic angle appears clearer and deep with depression of the hemidiaphragm as a result of localized air collection in a supine patient. In patients with a high index of clinical suspicion based on symptoms or penetrating injuries, some authorities advocate expiratory upright PA and lateral chest radiographs to make the lung volume smaller and the pneumothorax volume relatively larger and easier to visualize. Clinically significant pneumothorax should be evident on standard chest radiographs. The chest CT scan is more sensitive in visualizing pneumothorax; it often detects small occult pneumothoraces, which require close monitoring.

In an upright patient, a hemothorax appears as a fluid layer in the affected hemithorax. Early collections are noted to blunt the costophrenic angles on the AP and lateral radiographic views. Hemothorax often appears as only a diffuse hazy infiltrate in a supine trauma patient. Hemopneumothorax has a fluid layer with a flat superior border, in contrast to the round meniscus of an isolated hemothorax (Figs. 78.2 and 78.3). Decubitus views better demonstrate a small hemothorax.
An extended focused assessment with sonography for trauma (FAST) scan can diagnose pneumothorax and hemothorax with higher sensitivity than portable chest radiography can in experienced hands. An extended FAST scan is especially helpful when chest radiography is not immediately available and in mass casualty situations.14

TREATMENT

Tension pneumothorax and open pneumothorax are both clinical diagnoses that require immediate treatment with needle thoracostomy followed by tube thoracostomy, even when based on clinical evaluation, before radiographic confirmation. All suspicious open chest wounds should be covered with petrolatum gauze secured on three sides to prevent the entry of air during inspiration and allow the exit of air during expiration. Postprocedure radiographs should be obtained to confirm placement, drainage of air and blood, and reexpansion of lung. Prophylactic antibiotics with chest tube insertion do not reduce the risk for empyema or pneumonia.15

Operating room thoracotomy is indicated for patients with massive hemothorax (initial drainage of 1.5 to 2 L of blood), persistent bleeding of more than 200 mL/hr for 4 hours, and persistent hypotension or instability despite blood replacement. Autotransfusion should be performed in patients with massive hemothorax or persistent significant bleeding. It is prudent to prepare for autotransfusion early because most blood loss occurs at the time of initial chest tube insertion.

PULMONARY CONTUSION

Pulmonary contusion is the most common parenchymal lung injury in victims of blunt chest trauma. Though typically described in the setting of flail chest, pulmonary contusion can occur with less significant chest wall fractures and occasionally even in the absence of overlying injury.

Pulmonary contusion occurs with blunt, blast, or high-energy penetrating injuries. MVCs and falls are the most commonly reported mechanisms. Injury to the lung parenchyma causes hemorrhage and edema of the alveoli and interstitium, which results in ventilation-perfusion mismatching and ultimately hypoxia and hypercapnia. Hemorrhage worsens over the first 24 to 48 hours and then typically resolves over the next 7 days. Acute respiratory distress syndrome and pneumonia are the most frequent complications, both with significant morbidity and mortality.

PRESENTING SIGNS AND SYMPTOMS

Patients with pulmonary contusion typically have significant chest wall injury accompanied by dyspnea and tachypnea and progressing to hemoptysis, cyanosis, and hypotension. Inspection often reveals an obvious flail chest or ecchymosis overlying rib fractures. Auscultation reveals rhonchi, wheezes, rales, or minimal breath sounds. Blast injuries may result in significant pulmonary contusion with minimal chest wall injury. Delayed manifestations of pulmonary contusion can occur in initially well-appearing patients. Because the hemorrhage and edema will worsen, patients with even mild initial symptoms must be observed closely with continuous monitoring. The clinical findings usually progress over the initial hours through the first 2 days.

DIFFERENTIAL DIAGNOSIS AND MEDICAL DECISION MAKING

The differential diagnosis in a trauma patient with respiratory distress and infiltrates on initial chest radiographs includes pulmonary contusion, congestive heart failure, aspiration pneumonia, and acute respiratory distress syndrome. Symptomatic congestive heart failure may predispose patients to blunt trauma, result from blunt myocardial injury, or develop during fluid resuscitation. Aspiration pneumonia leads to even with positive pressure ventilation.16 Any prolonged surgery, diagnostic testing, or transport preventing immediate tube thoracostomy requires prophylactic placement.

In patients with penetrating injuries and a negative initial chest radiograph, upright PA and lateral chest radiographs should be repeated in 3 to 4 hours.17 Patients with normal findings on repeated radiographs and no significant associated injuries are discharged with wound care and follow-up instruction. Patients with asymptomatic blunt chest trauma and normal findings on the initial chest radiographs do not require repeated films before discharge. All patients with chest tubes are admitted to the trauma, cardiothoracic, or general surgery service in the care of personnel experienced in managing chest tube equipment.
higher in patients with larger areas of contusion, flail chest, acute respiratory distress syndrome, and pneumonia.

**TRACHEOBRONCHIAL INJURY**

Tracheobronchial injuries are infrequent but present unique challenges to the emergency physician (EP). Emergency airway management is often both required and complicated by these devastating injuries.

Penetrating tracheobronchial injuries are more common than blunt injuries. Penetrating injuries to the relatively exposed cervical trachea occur more frequently than injuries to the protected thoracic trachea. Gunshot wounds involving the thoracic trachea occur more often than stab wounds. Blunt injuries to the cervical trachea occur with rapid deceleration and result in shear stress at the junction of the larynx and trachea; examples of these types of injury include hyperextension injury, direct dashboard strikes, and "clothesline" injuries in snowmobile and motorcycle accidents.

Blunt injuries to the thoracic trachea are typically caused by high-energy MVCs, crush injuries, and falls. Rapid deceleration produces a shearing force with injury typically within 2 cm of the fixed carina. Injuries to the esophagus and spine are the most common associated injuries. Head, vascular, nerve, and intrathoracic injuries also occur frequently with both blunt and penetrating tracheobronchial injuries (Box 78.1).

**PRESENTING SIGNS AND SYMPTOMS**

Patients with tracheobronchial injuries typically have dramatic but nonspecific symptoms, including hoarseness, dysphagia, hemoptysis, and dyspnea. Careful inspection for penetrating wounds should be made, and the trajectory and proximity of the injury to the trachea should be estimated. Findings on physical examination include escape of air from wounds, subcutaneous emphysema in the neck and supraclavicular region, hypoxia, stridor, pneumothorax, and pneumomediastinum. Patients with blunt trauma often have few signs of external injury. Persistent air leaks despite a functioning chest tube suggest tracheobronchial injury. Rarely, patients with tracheobronchial injuries without communication with the pleural space maintain respiration with minimal symptoms until granulation tissue obstructs the airway and results in delayed lobar atelectasis.

**DIFFERENTIAL DIAGNOSIS AND MEDICAL DECISION MAKING**

Chest radiographs may have subtle evidence of tracheobronchial injuries such as high rib fractures, the fallen lung sign, pneumomediastinum, deep cervical emphysema, peribronchial air, abnormal location of the endotracheal tube, and a spherical shape of the normally oval endotracheal tube balloon. The fallen lung sign occurs when the apical segments of the lung have collapsed and fallen to the level of the hilum. Flexible fiberoptic bronchoscopy usually confirms the injury. Helical CT angiography is particularly effective in diagnosing blunt laryngeal injury and often provides additional informa-
Blunt Trauma
High-energy mechanisms: Falls greater than 3 m or motor vehicle collisions at more than 30 mph
All injuries: CXR and pulse oximetry. If pneumothorax or hemothorax, insert a chest tube
Traumatic aortic injury: A mechanism with chest wall tenderness or abnormal CXR evidence requires helical CT angiography; if negative, evaluate for traumatic aortic injury; if findings indeterminate, obtain an aortogram; if positive, transfer the patient to the operating room
Blunt cardiac injury: With abnormal ECG, hypotension, or dysrhythmia, cardiac monitoring and hospitalization for 24 hours with repeated ECGs every 8 hours; with hypotension or symptomatic dysrhythmia, formal echocardiography

Penetrating Injuries
All injuries: Continuous pulse oximetry and PA and lateral CXR at 0 and 6 hours
Anterior cardiac box: FAST examination to evaluate for pericardial fluid
Posterior box and transmediastinal gunshot wounds: Angiography for great-vessel injury; with signs and symptoms of injury, esophagography or esophagoscopy and bronchoscopy
Posterior box stab wounds: If abnormal mediastinum on CXR, angiography for great-vessel injury; with signs and symptoms of injury, esophagography or esophagoscopy and bronchoscopy
Thoracoabdominal: DPL with a red blood cell count of 10,000 cells/µL, laparoscopy/thoracoscopy or laparotomy to evaluate for diaphragmatic injury

CT, Computed tomography; CXR, chest radiograph; DPL, diagnostic peritoneal lavage; ECG, electrocardiogram; FAST, focused assessment with sonography for trauma; PA, posteroanterior.
*Protocols and approach may vary depending on institutional experience and availability.

TREATMENT

Patients with tracheobronchial injuries who are in respiratory distress require immediate intubation and mechanical ventilation. Fiberoptic bronchoscopy is the best diagnostic and management option for patients with cervical and intrathoracic tracheal injuries. When not available and immediate airway intervention is required, some authorities recommend orotracheal intubation without paralysis to prevent loss of paratracheal muscle support of the injured trachea. The benefits must be weighed against the suboptimal intubating conditions in a nonparalyzed patient. If paralysis is required, prior preparation for a surgical airway and right-sided thoracotomy is necessary.

During orotracheal intubation, a smaller-size endotracheal tube should be inserted and placed past the injury if possible. To prevent worsening of the injury, force should be avoided during placement of the endotracheal tube. When orotracheal intubation is not possible, the endotracheal tube should be placed through the anterior neck wound into the trachea. The EP must be careful to avoid pushing a transected trachea deeper into the thorax. In patients with complete transection and retraction of the trachea, major intervention is required. A right-sided thoracotomy should be performed (to avoid the aortic arch on the left), and the EP should attempt to visualize the injured trachea, support it, and establish an airway. Extension to a left-sided thoracotomy may be needed for complex distal injuries. Tube thoracostomy is required, often with multiple tubes to drain the resulting pneumothorax and reexpand the affected lung.

FOLLOW-UP, NEXT STEPS IN CARE, AND PATIENT EDUCATION

Stable patients with tracheobronchial injuries and a maintained airway are best transported to the operating room immediately for fiberoptic bronchoscopy, intubation, and possible thoracotomy. Definitive surgical repair is necessary to prevent acute and late complications. Acute complications include persistent air leak, pneumothorax, empyema, and mediastinitis. Delayed complications include granulation of partial injuries with resultant atelectasis and significant loss of pulmonary function. Penetrating and blunt injuries are typically managed early by exploration and repair.

BLUNT CARDIAC INJURY

The pathologic spectrum of blunt cardiac injury begins with cardiac concussion; includes myocardial contusion, coronary artery injury, and valve and septal injury; and ends with myocardial rupture. Myocardial contusion remains the most common clinical challenge to the EP. A definitive diagnosis can be made only at autopsy, and complications are rare but life-threatening.

Blunt cardiac injury typically results from MVCs but may occur after falls, crush injuries, blast injuries, direct blows, and chest compression. Low-speed deceleration injuries occasionally result in significant injury. Proposed mechanisms include compression of the heart between the sternum and vertebral bodies and sudden striking of the heart against the sternum in deceleration injuries.

Cardiac concussion, or commotio cordis, occurs when a blow to the chest briefly “stuns” the heart; it results in dysrhythmia, hypotension, syncope, and often sudden death but without permanent cellular damage. Commotio cordis may result from an anterior chest wall impact at a moment when the myocardium is refractory to depolarization and can result in fatal arrhythmia, also known as the R-on-T phenomenon.

Myocardial contusion occurs when injury to the anterior wall, formed by the right ventricle, results in well-defined areas of red blood cell extravasation and eventually in subendocardial and transmural necrosis. Infrequent delayed complications include mural thrombus, pericardial effusions,
constrictive pericarditis, and ventricular aneurysms. Direct injury to already atherosclerotic coronary arteries or severely contused myocardium can result in myocardial infarction. The rare blunt cardiac rupture is typically immediately fatal except when limited to the low-pressure right side of the heart or to small, self-sealing ventricular injuries.

**PRESENTING SIGNS AND SYMPTOMS**

Blunt cardiac injury typically occurs in patients with multiple blunt trauma injuries. Patients with commotio cordis generally experience immediate dysrhythmia and loss of consciousness. Though usually fatal, the survival rate is increasing as a result of increased public awareness, immediate cardiopulmonary resuscitation, and increased availability of automatic external defibrillators.21

Patients with myocardial contusion typically complain of angina-type chest pain unrelieved by nitroglycerin, pleuritic pain, or pain from associated injuries. Evidence of external trauma is usually but not always present. Information about the scene of the injury often provides the only evidence of blunt cardiac injury.

Initial and vital sign trends should be carefully noted, including mental status, color, jugular venous distention, and the presence of chest wall ecchymosis or tenderness, gallop rhythms, and friction rubs. Persistent unexplained tachycardia, hypotension, or dysrhythmia suggests blunt cardiac injury. Patients with valve dysfunction typically have a loud murmur, acute heart failure, and jugular venous distention. The rare patient with cardiac rupture who survives to arrive at the ED generally exhibits signs of cardiac tamponade or overt cardiogenic shock.

**DIFFERENTIAL DIAGNOSIS AND MEDICAL DECISION MAKING**

An ECG should be recorded in all patients with suspected blunt cardiac injury. Traditionally, stable patients with normal results on the initial ECG were considered to be at low risk for complications and safe for discharge. However, more recent literature suggests that patients may still be at risk for complications of blunt cardiac injury, including lethal dysrhythmias up to 12 hours after trauma and non–life-threatening dysrhythmias up to 72 hours later.22 New findings on the ECG suggestive of myocardial contusion include unexplained tachycardia, ST- and T-wave changes, conduction abnormalities, and dysrhythmias.

Evaluation of cardiac markers is not routinely indicated in patients with blunt cardiac injury. The exception is serial troponin I measurement in patients with an ischemic pattern on the initial ECG and in patients in whom cardiac ischemia may have precipitated the trauma. However, a recent metaanalysis supports the use of troponin I as a sensitive test for myocardial contusion when determined at admission and 4 to 6 hours later.23

Emergency bedside echocardiography is recommended for unstable patients with suspected blunt cardiac injury or with evidence of myocardial infarction on the ECG. Pericardial effusions are easily identified on the initial subxiphoid view of the FAST scan. Formal echocardiography with parasternal and apical views will better identify small effusions, valve dysfunction, and wall motion abnormalities. Transesophageal echocardiography is more sensitive than transthoracic echocardiography and provides additional imaging of the aorta in unstable patients. Routine echocardiography does not predict complications in stable patients with suspected blunt cardiac injury.

**TREATMENT**

Unstable patients with blunt cardiac injury require definitive airway control to ensure optimal oxygenation and ventilation. A large-bore internal jugular catheter should be inserted for fluid resuscitation, monitoring of central venous pressure, and placement of a Swan-Ganz catheter. Cardiogenic shock secondary to myocardial contusion or cardiac rupture typically requires careful fluid replacement and inotropic support. Refractory cases may require temporary stabilization with an aortic balloon pump after an aortic injury has been ruled out. Cardiac catheterization is necessary in patients with myocardial infarction because antithrombotic therapy is contraindicated after trauma.

**FOLLOW-UP, NEXT STEPS IN CARE, AND PATIENT EDUCATION**

Stable patients with a normal initial ECG and without significant associated injuries can be safely discharged from the ED. Stable patients with changes on the ECG suggestive of myocardial contusion require observation with continuous monitoring for 24 hours and electrocardiography repeated every 8 hours for 24 hours. Brief dysrhythmias seldom require treatment, and prophylactic antidysrhythmic therapy is not indicated.

Unstable patients with ventricular dysrhythmias, atrial fibrillation, sinus bradycardia, and bundle branch block require intensive care unit admission. In patients with abnormal findings on the initial ECG, the complication rate is low, with complications predominantly occurring in older patients with multiple injuries. Wall motion abnormalities and rhythm disturbances typically resolve within hours. Most patients with myocardial contusion require only supportive care and aggressive management of complicating injuries. Morbidity and mortality are directly related to the presence of other injuries.

**PENETRATING CARDIAC INJURY, CARDIAC TAMponade, AND EMERGENCY DEPARTMENT THORACOTOMY**

Penetrating cardiac injuries most commonly result from gunshot wounds, followed by stab wounds. Any gunshot wound involving the torso can result in penetrating cardiac injury. Survival is better in patients with stab wounds, single-chamber involvement, and low-pressure right heart injuries.
Cardiac tamponade most commonly results from stab wounds to the chest or upper part of the abdomen, followed by gunshot wounds and infrequently by blunt chest trauma.

Penetrating injuries to the heart result in either death at the scene or tamponade, which allows transport to the ED. Tamponade is more likely to occur with smaller injuries from stab wounds. The tough fibrous sac surrounding the heart prevents immediate exsanguination. As blood accumulates, cardiac filling and eventually output are impaired, which often results in rapid decompensation after arrival at the ED. Acutely accumulated pericardial blood may be difficult to visualize on cardiac ultrasonography. The right ventricle is the most commonly injured structure, followed by the left ventricle. Approximately three of four patients will die of the injury.

**PRESENTING SIGNS AND SYMPTOMS**

Patients with pericardial tamponade classically but uncommonly exhibit the Beck triad of hypotension, jugular venous distention, and muffled heart sounds. Most patients will have at least one of these signs, with all three appearing only briefly before cardiac arrest. More frequently, patients either appear relatively stable or are in extremis. Stable-appearing patients have small wounds in the pericardium that allow intermittent decompression of the accumulated blood. Patients with more rapid accumulation are panic-stricken, appear to be in severe respiratory distress, and often have needle thoracostomy performed for presumed tension pneumothorax. In these patients, agitation, tachycardia, and hypotension predominate before progressing to obtundation, bradycardia, and pulseless electrical activity.

**DIFFERENTIAL DIAGNOSIS AND MEDICAL DECISION MAKING**

An ultrasonographic subxiphoid view (Fig. 78.5) may detect pericardial fluid in patients with suspected cardiac injury. Pericardial fluid with diastolic collapse of the right atrium and ventricle is diagnostic of pericardial tamponade. Any pericardial effusion in unstable trauma patients with equal bilateral breath sounds signals tamponade requiring immediate operative intervention. Although the sensitivity of FAST scans approaches 100% for hemopericardium, false-negative results may occur when blood drains rapidly into the thorax. The possibility should be considered in patients with small anterior stab wounds and persistent left hemothorax despite tube thoracostomy.

An initial ECG should be obtained to evaluate for findings suggestive of pericardial tamponade and other cardiac injury. Electrical alternans, low voltage, and PR-segment depression are specific but not sensitive for the diagnosis of pericardial effusion. A chronic pericardial effusion is more likely to reveal such findings. Acute traumatic pericardial effusion resulting in tamponade does not change the size of the heart on the chest radiograph. However, a chest radiograph can be useful in identifying other injuries and the presence of retained foreign bodies. It is important to remember that normal findings on the ECG and chest radiograph do not rule out traumatic pericardial effusion or tamponade.

**TREATMENT**

A central venous line should be placed for volume infusion and monitoring of central venous pressure. The injured hemithorax is preferred for central line placement to avoid iatrogenic complications in the uninjured side. The exception is a patient with obvious injury to the clavicle and suspected injury to the subclavian vein.

Aggressive fluid resuscitation is mandatory for patients with suspected pericardial tamponade to maximize cardiac filling pressure and cardiac output. Elevated central venous pressure in persistently hypotensive and tachycardic trauma patients suggests impending tamponade. Pericardiocentesis with catheter placement should be performed in patients with deteriorating vital signs. Pericardiocentesis may serve as a diagnostic and temporizing measure but is never a replacement for thoracotomy and definitive repair of the injury. Ultrasonography or ECG-guided pericardiocentesis is preferred, if available. Nonclotting blood traditionally signifies pericardial blood, but aspiration may be unsuccessful because of needle placement, continuous brisk pericardial bleeding, or other reasons. However, removal of even a small amount of pericardial blood can restore vital signs and aid survival until surgical intervention is available.

Thoracotomy is reserved for patients with cardiac tamponade who are in cardiac arrest or impending arrest. The likelihood of functional survival after ED thoracotomy is greatest for victims of stab wounds with isolated cardiac injury who have signs of life on ED arrival. At the trauma center, thoracotomy is performed on victims of penetrating trauma who experienced cardiac arrest in the ED or within 10 minutes of arrival at the ED and on blunt trauma patients who experienced cardiac arrest in the ED. In the ED without surgical support, thoracotomy is best performed by a skilled EP only on patients with thoracic stab wounds or isolated gunshot wounds.
wounds who lost signs of life in the ED or within 10 minutes of arrival in the ED. In all other cases, ED thoracotomy should be performed only if a qualified surgeon is present or immediately available (Table 78.2).25-28

FOLLOW-UP, NEXT STEPS IN CARE, AND PATIENT EDUCATION

Immediate operative repair is indicated for all penetrating injuries of the heart to relieve tamponade and repair the initial injury. Identification and initial management of all associated injuries ensure optimal outcomes, but operative intervention must not be delayed. Diagnostic peritoneal lavage should be performed in the operating room to identify intraperitoneal bleeding and assess the need for laparotomy.

GREAT VESSEL INJURY

Great vessel injury is a significant cause of morbidity and mortality with both blunt and penetrating thoracic trauma. Traumatic aortic injury is the second most common cause of blunt traumatic death. Eighty percent of victims of traumatic aortic injury die immediately. The majority of survivors can be saved with prompt ED diagnosis, blood pressure control, and operative repair. Five percent of patients will be unstable on arrival and have a mortality rate of up to 98%. The remaining 15% will be hemodynamically stable, which often contributes to a delay in diagnosis and a mortality rate as high as 25%.29

The descending aorta is fixed within the thorax by the ligamentum arteriosum and the intercostal arteries. Sudden deceleration causes the aortic arch to swing forward and produces a shearing force with resultant injury just distal to the takeoff of the left subclavian artery. Traditionally, traumatic aortic injuries have been considered only in patients with “major mechanisms of injury,” including high-speed MVCs with frontal or side impact and motorcycle crashes. However, the injury has been reported with less impressive mechanisms such as pedestrian-versus-auto collisions, falls, and crush injuries. Use of restraint systems does not protect persons from traumatic aortic injuries.30,31 Penetrating injuries to the great vessels typically result from both gunshot penetration and stabbing.

PRESENTING SIGNS AND SYMPTOMS

Signs and symptoms of traumatic aortic injury are often not present or are masked by other injuries. Up to one half of all patients have no signs of chest wall injury. Common signs and symptoms include interscapular or retrosternal pain, decreased blood pressure in the left arm, upper extremity hypertension with absent femoral pulses, bruit, and a harsh systolic murmur heard over the precordium or interscapular area. Uncommon findings include extremity pain from distal ischemia, dysphagia from concomitant esophageal injury, and hoarseness as a result of compression of the laryngeal nerve.

Evidence of penetrating injury to the great vessels depends on the mechanism and location of the injury. High-energy proximal arterial injury typically results in immediate exanguination or hemorrhagic shock with massive hemothorax. Contained mediastinal hematoma can occasionally impair superior vena cava return and produce engorgement of the soft tissues of the neck, face, and airway. Distal injuries may result in diminished pulses, expanding hematomas, and limb ischemia. Careful palpation for pulse symmetry and measurement of blood pressure in both arms are advisable.

Stab wounds should be inspected carefully to help determine the general trajectory. Deep probing of wounds should be avoided to prevent iatrogenic worsening of the initial injury, dislodgment of clot and massive hemorrhage, and infection. Chest tube output should be closely monitored. The chest tube should be clamped when the patient is being transported to the operating room; when massive hemothorax and heavy, continuous bleeding are present, temporary tamponade within the pleural cavity may be required for this short time.

DIFFERENTIAL DIAGNOSIS AND MEDICAL DECISION MAKING

The initial chest radiograph should show evidence of traumatic aortic injury (Fig. 78.6, A). The most sensitive criterion is mediastinal widening, usually larger than 8 cm on an AP view; however, a subjective interpretation of mediastinal widening is more reliable. Other mediastinal abnormalities suggesting mediastinal hematoma secondary to traumatic aortic injury are an obscured aortic knob, loss of the AP window, a displaced nasogastric tube, widened paratracheal stripe, widened paraspinal interface, depression of the left mainstem bronchus, left hemothorax, left apical pleural cap, deviation of the trachea to the right, and multiple rib fractures. The more abnormalities seen on the chest radiograph, the higher the sensitivity in identifying an aortic injury. A normal chest radiograph, however, does not rule out a traumatic aortic injury.

With sensitivity near 100%, a normal CT scan rules out traumatic aortic injury.32 If the results are indeterminate, aortography should be performed. Rarely, a positive helical CT angiogram in a stable patient is followed by aortography for further localization of the injury and identification of other injuries, such as a pseudoaneurysm (see Fig. 78.6, B). Advantages of helical CT angiography over aortography are that it is faster, is noninvasive, requires a smaller volume of contrast agent, and provides information about other thoracic injuries. A high index of suspicion and low threshold for performing screening helical CT angiography are required.

Table 78.2 Indications for ED Thoracotomy

<table>
<thead>
<tr>
<th>SETTING</th>
<th>PENETRATING INJURIES</th>
<th>BLUNT TRAUMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trauma center</td>
<td>Cardiac arrest in the ED or within 10 min of ED arrival</td>
<td>Cardiac arrest in the ED</td>
</tr>
<tr>
<td>Community ED without emergency</td>
<td>Patients with thoracic stab wounds or isolated gunshot</td>
<td>All other ED thoracotomies should be performed</td>
</tr>
<tr>
<td>surgical backup</td>
<td>wounds who lose signs of life in the ED or within 10 min of ED arrival</td>
<td>only when a surgeon is available within 10 min</td>
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</tbody>
</table>

ED, Emergency department.
to save patients with traumatic aortic injury who survive to arrive at the ED.

Transthoracic echocardiography should be performed in unstable patients with suspected traumatic aortic injury but is contraindicated in patients with esophageal injuries. Very high sensitivity and specificity approaching 100% have been reported, but it varies widely depending on operator experience.

Aortography remains the “gold standard” for the diagnosis of traumatic aortic injury. False-positive and false-negative results are rare but do occur. Better sensitivity with helical CT angiography has been reported. Aortography offers improved localization of injury before surgical repair. Newer techniques such as intravenous digital subtraction angiography have improved the speed while reducing the cost of aortography (see Fig. 78.6, C).

A chest radiograph should be obtained in all patients with suspected penetrating great vessel injury, and all wounds should be noted and marked. The examination should be focused specifically on evidence of mediastinal hematoma, hemothorax, foreign bodies near vessels or in the trajectory of a missile, “fuzzy” missiles created by arterial pulsations, and the absence of a missile in patients with a gunshot wound to the chest, which suggests distal embolization. An angiogram should be obtained to further assess the injuries and plan an operative approach in the rare stable patient. With the added benefit of evaluating nearby structures, helical CT angiography will probably replace aortography in the evaluation of stable patients with transmediastinal penetrating injury.33

**TREATMENT**

Early orotracheal intubation is required because hematoma expansion can make both orotracheal intubation and creation of a surgical airway impossible. Tracheostomy is contraindicated in patients with great vessel injury involving the upper mediastinum or zone I of the neck because major bleeding can result.

Patients with penetrating great vessel injuries often require ED thoracotomy or immediate thoracotomy in the operating room. In patients with penetrating wounds involving the subclavian vessels, traditional left lateral thoracotomy will often not provide adequate exposure.

Before operative repair of traumatic aortic injury, blood pressure must be controlled, with systolic pressure maintained at 100 to 120 mm Hg to decrease shear stress and progression of the injury. Patients with isolated aortic injuries may be hypertensive and will require short-acting titratable agents such as nitroprusside and esmolol.

**FOLLOW-UP, NEXT STEPS IN CARE, AND PATIENT EDUCATION**

Surgical repair of traumatic aortic injury is performed after stabilization of other life-threatening intracranial or intraabdominal injuries. Delayed surgical repair is frequently indicated in elderly patients with multiple comorbid conditions. The mortality rate during surgery is approximately 10%,
and such mortality is primarily related to the extent of the injury and condition of the patient.

**ESOPHAGEAL INJURY**

Esophageal injuries occur infrequently with both blunt and penetrating trauma. More immediate life-threatening injuries often mask the clinical findings, and esophageal leakage can progress to fatal mediastinitis. Esophageal evaluation is indicated in patients with a significant penetrating injury to the neck. The majority of esophageal perforations result from medical endoscopic procedures, not from traumatic injuries.

Penetrating esophageal injury must be considered in any patient with injury near or trajectory through the esophagus. Common mechanisms of penetrating injury include laceration, missile penetration, iatrogenic perforation, and ingested foreign body. Stab wounds to the neck often directly injure the esophagus. High-velocity gunshot result in direct esophageal perforation, as well as delayed necrosis. The majority of penetrating injuries occur at the proximal or distal end of the esophagus during routine endoscopy.

Blunt esophageal injuries are much less common than penetrating injuries. Common mechanisms include crush injuries to the cervical esophagus and barotrauma. Blunt laryngotracheal trauma and cervical spine fractures are associated with injuries to the upper part of the esophagus. Blunt injuries to the lower third of the esophagus occur with sudden increases in intraabdominal pressure against a closed upper esophageal sphincter, analogous to Boerhaave syndrome. The initial rupture typically originates from an inherent weakness in the left posterior aspect of the distal end of the esophagus.

Both cardiopulmonary resuscitation and the Heimlich maneuver have been associated with perforation of the thoracic esophagus. Blast injury can result in primary esophageal injury as a result of the pressure wave, in secondary injury from impact of the patient against fixed structures, and in tertiary injury from blast projectiles.

**PRESENTING SIGNS AND SYMPTOMS**

Typical symptoms of esophageal injury include pleuritic chest pain anywhere along the course of the esophagus, dyspnea, odynophagia, dysphagia, hoarseness, and pain with flexion or extension of the neck. The physical examination should include palpation for subcutaneous emphysema and auscultation for a systolic Hamman crunch produced by mediastinal air.

Commonly, patients have emergency life-threatening injuries that obscure the clinical findings, which can lead to delayed recognition and management. Fever, tachycardia, hypotension, and progressive dyspnea are noted as mediastinitis develops.

**DIFFERENTIAL DIAGNOSIS AND MEDICAL DECISION MAKING**

AP or PA chest radiographs should be examined for evidence of mediastinal air, subcutaneous emphysema, left-sided pleural effusion, pneumothorax, and a widened mediastinum. A lateral neck radiograph may reveal prevertebral air displacing the tracheal air column forward. Early in the course of a perforation, radiographic evidence is often minimal. Later CT scans of the chest may demonstrate collections of air or fluid as infection develops, but CT scans are not usually performed for esophageal injury.

Esophagography and esophagoscopy should be performed in all patients with suspected esophageal injury, although neither modality alone is sensitive enough to rule out esophageal injury. The initial esophagography is done with Gastrografin to avoid mediastinal irritation from leakage of barium. Incidentally, a CT scan after barium ingestion may detect small esophageal perforations and small metallic foreign bodies better than plain radiographs. Negative findings on an esophagogram with Gastrografin enhancement should be followed by the more sensitive barium-enhanced esophagography. Neither contrast agent prevents the use of endoscopy. If findings on both esophagograms are negative, flexible endoscopy can be used to exclude subtle injuries.

**TREATMENT**

Chest tube drainage is often necessary for associated pneumothorax. Persistent air leak is suggestive of esophageal injury. Food particles in the chest tube confirm major injury. Patients should be kept on nothing-by-mouth status. Fluid resuscitation is mandatory. Broad-spectrum antibiotics that cover oral anaerobes should be administered. Placement of a nasogastric tube is controversial because of the risk for mediastinitis and should be done in consultation with trauma or general surgery services.

**FOLLOW-UP, NEXT STEPS IN CARE, AND PATIENT EDUCATION**

Management can be operative or nonoperative. Small, minimally symptomatic or chronic perforations, particularly those involving the cervical esophagus secondary to instrumentation, are most amenable to a nonsurgical approach. Consultation with trauma or general surgery specialists for primary surgical repair dramatically improves outcomes.

**DIAPHRAGMATIC INJURIES**

Diaphragmatic injuries are a diagnostic challenge and are associated with significant delayed complications. Complications often develop weeks to years after the initial trauma and consist of symptoms of visceral herniation. Both blunt and penetrating trauma can cause diaphragmatic injuries, but with very different injury patterns. The most common mechanisms for blunt diaphragmatic injuries are MVCs and falls, followed by pedestrian-versus-vehicle collisions, motorcycle accidents, and crush injuries. Penetrating injuries result from gunshot or stab wounds. When detected initially, diaphragmatic injury signals that other severe injuries are probably present.
Gunshot and stab wounds result in injuries to the diaphragm with nearly equal incidence. Stab wounds with a trajectory reaching the 4th intercostal space superiorly or the 12th intercostal space inferiorly must be considered to have perforated the diaphragm and require prudent evaluation. Stab wounds outside this area may also penetrate the diaphragm, depending on the length and angle of the blade. Gunshot wounds anywhere in the neck, chest, abdomen, or pelvis can penetrate the diaphragm. Blunt force to the chest or abdomen often results in large tears in the diaphragm. Left-sided injuries are more common in survivors, whereas an equal incidence of right- and left-sided injuries is noted at autopsy. The negative pressure of inspiration prevents closure and promotes herniation through the wound into the chest cavity. If not detected initially, diaphragm injuries frequently result in visceral herniation months to years later.

**PRESENTING SIGNS AND SYMPTOMS**

Three phases of injury have been described. The acute phase begins with the injury and ends with the initial recovery. A patient with acute diaphragmatic rupture will typically complain of chest pain, abdominal pain, and dyspnea. Findings on physical examination include diminished breath sounds in the lung bases, respiratory distress, bowel sounds in the chest, peritoneal signs, and palpation of viscera during chest tube placement. Large left-sided blunt injuries are more obvious than smaller penetrating and right-sided injuries. Acute diaphragmatic injuries are often overshadowed by other injuries. Frequently, no abdominal tenderness is noted.

In the second, or latent, phase, intermittent herniation of abdominal viscera results in mild and vague symptoms suggesting biliary, gastric, coronary artery, or pulmonary disease. Patients with latent manifestations often appear to have other gastrointestinal or cardiovascular diseases and complain of vague abdominal pain relieved when upright or cough and vague chest pain.

In the last, or obstructive, phase, incarceration, strangulation, and ischemia develop. Additionally, the compressive effects of the intrathoracic bowel on the heart and lung can result in tension enterotherax or viscerotherax. In this phase, symptoms of visceral obstruction, ischemia, and ultimately visceral infarction develop. Rarely, tension viscerotherax also develops. Herniation should be considered in any patient with vague complaints of chest or abdominal pain and a history of thoracoabdominal trauma.

**DIFFERENTIAL DIAGNOSIS AND MEDICAL DECISION MAKING**

The initial chest radiograph should be inspected for the classic diagnostic finding, which is a nasogastric tube or viscera in the left hemithorax. Other important but more subtle signs include an indistinct or elevated left hemidiaphragm and left lower lobe atelectasis. Hemopneumothorax is present in 50% of patients with penetrating injury. Up to 25% of patients with penetrating diaphragmatic injuries have normal chest radiographic findings and no abdominal tenderness. CT scanning is 100% specific but only 66% sensitive for the diagnosis of blunt diaphragmatic injury.

In the latent phase of injury, the chest radiograph is typically abnormal. Findings can be subtle, such as a unilaterally elevated hemidiaphragm, unilateral pleural thickening, or basilar atelectasis, or can be significant, such as a shift of the mediastinum or viscera evident above the diaphragm. In cases of delayed herniation, upper or lower gastrointestinal contrast-enhanced studies may be needed to demonstrate herniation (Fig. 78.7).

FAST can also be used in the diagnosis of diaphragmatic rupture. The sonographic features of a ruptured diaphragm include nonvisualization of the spleen or heart, poor diaphragmatic movement, elevated diaphragm, liver sliding sign, pleural effusion, subphrenic effusion, or viscera visualized in the thorax. Traditionally, a diagnostic peritoneal lavage count of less than 10,000 red blood cells/µL is used to rule out a diaphragmatic injury in patients with penetrating thoracoabdominal trauma. Laparoscopy or thoracoscopy is the diagnostic study of choice in patients with high clinical suspicion for diaphragmatic injury not otherwise needing surgery.

**TREATMENT**

A nasogastric tube should be placed carefully in obstructed patients to avoid further trauma to a herniated gastroesophageal
junction. In cases of tension viscerothorax, a chest tube should be placed into the thoracic cavity while taking care to avoid the viscera. The EP should palpate for viscera and diaphragmatic injuries before insertion of a chest tube.

**FOLLOW-UP, NEXT STEPS IN CARE, AND PATIENT EDUCATION**

Consultation and admission to trauma or general surgery services is recommended for early surgical repair to prevent delayed complications. Patients with suspected diaphragmatic injuries typically have multiple injuries requiring treatment and hospitalization. An asymptomatic patient with a mechanism for diaphragmatic injury but a negative work-up should be instructed about the need for immediate evaluation if signs of delayed herniation and obstruction develop, such as abdominal discomfort, chest discomfort, shortness of breath, or vomiting.

**DOCUMENTATION**

Careful documentation helps ensure identification and evaluation of all significant injuries. The documentation chart should reflect the following thought processes and actions:
- Primary survey assessment and management
- Secondary survey findings: Use a figure or drawing of the patient to describe the injuries
- Ample history
- Initial laboratory and imaging findings
- Definitive testing
- Results of consultations
- Main assessment and plan: Patient, mechanism, and list of injuries with a plan for each.
- Tertiary survey or reassessment before discharge:
  - Follow-up provided
  - Patient education provided

**RED FLAGS**

**Subtle Life-Threatening Emergencies in the Secondary Survey**

**Traumatic Aortic Injury**

Patients may have no external sign of trauma. Never say “She looks too good to have a traumatic aortic injury,” “It was only a lateral impact,” or “He was wearing a belt and the airbag went off.” The patient will look good until the aorta ruptures; with lateral impact in a moving vehicle collision, there may be increased risk for traumatic aortic injury, and restraints alone do not reduce the risk for traumatic aortic injury.

**Esophageal Injury**

For any injury near the esophagus, esophagography and esophagoscopy should be performed. Injuries are often subtle until fatal mediastinitis develops.

**Diaphragmatic Injury**

Penetrating injury anywhere near the diaphragm requires chest radiography, computed tomography, and in some cases, diagnostic peritoneal lavage.

**Tracheobronchial Injury**

Persistent air leaks despite a functioning chest tube indicate a tracheobronchial injury until proved otherwise. Bronchoscopy must be performed to prevent delayed infection, atelectasis, and loss of lung function.

**Liver and Splenic Injuries**

Three or more rib fractures or any fracture or tenderness of the sixth rib or below is an indication for abdominal computed tomography to rule out liver and splenic injury.

**SUGGESTED READINGS**


**REFERENCES**

References can be found on Expert Consult @ www.expertconsult.com.