Chapter 4: Thoracic Trauma

Objectives:

Upon completion of this topic, the physician will be able to identify and initiate treatment of life-threatening thoracic injuries.

Specifically, the physician will be able to:

A. Identify and manage the following immediately life-threatening chest injuries evidenced in the primary survey:

1. Airway obstruction
2. Tension pneumothorax
3. Open pneumothorax
4. Massive hemothorax
5. Flail chest
6. Cardiac tamponade.

B. Identify and initiate treatment of the following potentially life-threatening injuries assessed during the secondary survey:

1. Pulmonary contusion
2. Myocardial contusion
3. Aortic disruption
4. Traumatic diaphragmatic rupture
5. Tracheobronchial disruption

C. Explain the purpose of, define the complications of, and demonstrate the ability to perform needle thoracocentesis, chest tube insertion, and pericardiocentesis in a surgical skill practicum.
I. Introduction

A. Incidence

Chest injuries cause one of every four trauma deaths in North America. Many of these patients die after reaching the hospital. Many of these deaths can be prevented by prompt diagnosis and treatment coupled with an understanding of pathophysiologic factors associated with thoracic trauma.

Because most injuries occur at a distance from a trauma center, recognition of the features of thoracic injuries that require early intervention and influence transport is very important. Less than 10% of blunt chest injuries require an operation, and 15% to 30% of penetrating chest injuries require open thoracotomy. Most patients sustaining thoracic trauma may be managed by simple procedures within the capabilities of any physician taking this course. Therefore, the responsibility for the initial management of most chest-injury patients rests with the physician who first examines the patient, and not the trauma surgeon to whom the patient may be transferred.

B. Pathophysiology

Tissue hypoxia, hypercarbia, and acidosis often result from chest injuries. Tissue hypoxia results from inadequate delivery of oxygen to the tissues because of hypovolemia (blood loss), pulmonary ventilation/perfusion mismatch (contusion, hematoma, alveolar collapse, etc), and changes in intrathoracic pressure relationships (tension pneumothorax, open pneumothorax, etc). Hypercarbia implies hypoventilation. Acutely, hypoxia is more important. Respiratory acidosis is caused by inadequate ventilation, changes in intrathoracic pressure relationships, depressed level of consciousness, etc. Metabolic acidosis is caused by hypoperfusion of the tissues (shock).

C. Initial Assessment and Management

1. Patient management must consist of:

   a. Primary survey

   b. Resuscitation of vital functions

   c. Detailed secondary survey

   d. Definitive care.

2. Because hypoxia is the most serious feature of chest injury, early interventions are designed to ensure that an adequate amount of oxygen is delivered from the lung to the tissues.

3. Immediately life-threatening injuries are treated as quickly and as simply as possible.
4. Most life-threatening thoracic injuries are treated with an appropriately placed chest tube or needle.

5. The secondary survey is guided by a high index of suspicion for specific injuries.

II. Primary Survey of Life-threatening Injuries

A. Airway

1. Assess for airway patency and air exchange by listening for airway movement at the patient’s nose and mouth.

2. Assess for intercostal and supraclavicular muscle retractions.

3. Assess the oropharynx for foreign body obstruction, particularly in the unconscious patient.

B. Breathing

Expose the patient's chest completely and evaluate breathing. Assess respiratory movement and quality of respiration by observing, palpating, and listening.

The signs of chest injury or hypoxia that are particularly important and often subtle include an increased rate of breathing and a change in the breathing pattern, especially toward progressively more shallow respirations. Cyanosis is a late sign of hypoxia in the trauma patient. However, the absence of cyanosis does not indicate adequate tissue oxygenation or an adequate airway.

c. Circulation

1. Assess the patient’s pulse for quality, rate, and regularity. Remember, the radial and dorsalis pedis pulses may be absent in the hypovolemic patient.

2. Assess the blood pressure for pulse pressure.

3. Observe and palpate the skin for color and temperature to assess the peripheral circulation.

4. Check to see if the neck veins are distended. Remember, neck veins may not be distended in hypovolemic patients with cardiac tamponade.

5. A cardiac monitor should be attached to the patient. Patients sustaining thoracic trauma - especially in the area of the sternum or from a rapid deceleration injury - are susceptible to myocardial contusion and/or coronary artery spasm, which may lead to dysrhythmias. Hypoxia and/or acidosis enhance this possibility. Premature ventricular contractions, a common dysrhythmia, may require treatment with an immediate lidocaine bolus (1 mg/kg) followed by a lidocaine drip (2 to 4 mg/minute). Electromechanical dissociation (EMD) is manifest by an electrocardiogram (ECG) showing a rhythm while the
patient has no identifiable pulse. EMD may be present in cardiac tamponade, tension pneumothorax, profound hypovolemia, or even worse, cardiac rupture.

**D. Thoracotomy**

Closed heart massage for cardiac arrest or EMD is ineffective for a hypovolemic patient. Patients with exsanguinating, penetrating precordial injuries who arrive pulseless but with myocardial electrical activity may be candidates for emergency department thoracotomy. Assuming a surgeon is present, a left anterior thoracotomy, cross-clamping of the descending thoracic aorta, pericardiotomy, and open chest massage in conjunction with intravascular volume restoration may be initiated. Emergency department thoracotomy for patients with blunt thoracic injuries, in whom there is no electrical cardiac activity, is rarely effective.

**III. Life-threatening Chest Injuries Identified in the Primary Survey**

**A. Airway Obstruction**

Airway obstruction at the alveolar level is a potentially life-threatening injury that is assessed and managed during the secondary survey and definitive care phases. Chapter 2 deals with the management of life-threatening situations of the upper airway.

**B. Tension Pneumothorax**

A tension pneumothorax develops when a "one-way-valve" air leak occurs either from the lung or through the chest wall. Air is forced into the thoracic cavity without any means of escape, completely collapsing the affected lung. The mediastinum and trachea are displaced to the opposite side, decreasing venous return and compressing the opposite lung.

The most common causes of tension pneumothorax are mechanical ventilation with positive end-expiratory pressure, spontaneous pneumothorax in which ruptured emphysematous bullae have failed to seal, and blunt chest trauma in which a parenchymal lung injury has failed to seal. Occasionally traumatic defects in the chest wall may cause a tension pneumothorax. A significant incidence of pneumothorax is associated with subclavian or internal jugular venous catheter insertion.

**Tension pneumothorax is a clinical diagnosis and should not be made radiologically.** A tension pneumothorax is characterized by respiratory distress, tachycardia, hypotension, tracheal deviation, unilateral absence of breath sounds, neck vein distention, and cyanosis as a late manifestation. Because of the similarity in their symptomatology, a tension pneumothorax initially may be confused with cardiac tamponade. However, a tension pneumothorax is more common. Differentiation may be made by a hyperresonant percussion note over the ipsilateral chest.

Tension pneumothorax requires immediate decompression and is managed initially by rapidly inserting a needle into the second intercostal space in the midclavicular line of the affected hemithorax. This maneuver converts the injury to a simple pneumothorax. (Note: The possibility of subsequent pneumothorax as a result of the needle stick now exists.) Repeated reassessment is necessary. Definitive treatment usually requires only the insertion of a chest
tube into the fifth intercostal space (nipple level), anterior to the midaxillary line.

**C. Open Pneumothorax ("Sucking Chest Wound")**

Large defects of the chest wall, which remain open, result in an open pneumothorax or sucking chest wound. Equilibration between intrathoracic pressure and atmospheric pressure is immediate. If the opening in the chest wall is approximately two thirds the diameter of the trachea, air passes preferentially through the chest defect with each respiratory effort, because air tends to follow the path of least resistance through the large chest-wall defect. Effective ventilation is thereby impaired, leading to hypoxia.

Manage an open pneumothorax by promptly closing the defect with a sterile occlusive dressing, large enough to overlap the wound's edges, and taped securely on three sides. Taping the occlusive dressing on three sides provides a flutter-type valve effect. As the patient breathes in, the dressing is occlusively sucked over the wound, preventing air from entering. When the patient exhales, the open end of the dressing allows air to escape. A chest tube should be placed remote from the wound as soon as possible. Securely taping all edges of the dressing can cause air to accumulate in the thoracic cavity resulting in a tension pneumothorax unless a chest tube is in place. Any occlusive dressing (plastic wrap, petrolatum gauze, etc) may be used as a stopgap so rapid assessment can continue. Definitive surgical closure of the defect is usually required.

**D. Massive Hemothorax**

Massive hemothorax results from a rapid accumulation of more than 1500 mL of blood in the chest cavity. It is most commonly caused by a penetrating wound that disrupts the systemic or hilar vessels. It may also be the result of blunt trauma. The blood loss is complicated by hypoxia. The neck veins may be flat secondary to severe hypovolemia or may be distended because of the mechanical effect of intrathoracic blood. This condition is discovered when shock is associated with the absence of breath sounds and/or dullness to percussion on one side of the chest.

Massive hemothorax is initially managed by the simultaneous restoration of blood volume and decompression of the chest cavity. Large-caliber intravenous lines and rapid crystalloid infusion are begun and type-specific blood is administered as soon as possible. If an auto-transfusion device is available, it may be used. A single chest tube (#38 French) is inserted at the nipple level, anterior to the midaxillary line, and rapid restoration of volume continues as decompression of the chest cavity is completed. When massive hemothorax is suspected, prepare for autotransfusion. If 1500 mL is immediately evacuated, it is highly likely that the patient will require an early thoracotomy.

Some patients who have an initial volume output of less than 1500 mL, but continue to bleed, may require a thoracotomy. This decision is based on the rate of continuing blood loss (200 mL/hour). During patient resuscitation, the volume of blood initially drained from the chest tube and the rate of continuing blood loss must be factored into the amount of intravenous fluid replacement. The color of the blood (arterial or venous) is a poor indicator of the necessity for thoracotomy.
Penetrating anterior chest wounds medial to the nipple line and posterior wounds medial to the scapula should alert the physician to the possible need for thoracotomy, because of possible damage to the great vessels, hilar structures, and the heart, with the associated potential for cardiac tamponade. **Thoracotomy is not indicated unless a surgeon is present and the procedure is performed by a physician qualified by training and experience.**

**E. Flail Chest**

A flail chest occurs when a segment of the chest wall does not have bony continuity with the rest of the thoracic cage. This condition usually results from trauma associated with multiple rib fractures. The presence of a flail chest segment results in severe disruption of normal chest wall movement. If the injury to the underlying lung is significant, serious hypoxia may result. The major difficulty in flail chest stems from the injury to the underlying lung. Although chest wall instability leads to paradoxical motion of the chest wall with inspiration and expiration, this defect alone does not cause hypoxia. Associated pain with restricted chest wall movement and underlying lung injury contribute to the patient's hypoxia.

Flail chest may not be apparent initially because of splinting of the chest wall. The patient moves air poorly, and movement of the thorax is asymmetrical and uncoordinated. Palpation of abnormal respiratory motion and crepitus of rib or cartilage fractures aids diagnosis. A satisfactory chest roentgenogram may suggest multiple rib fractures, but may not show costochondral separation. Arterial blood gases, suggesting respiratory failure with hypoxia, also may aid in diagnosing a flail chest.

Initial therapy includes adequate ventilation, administration of humidified oxygen, and fluid resuscitation. **In absence of systemic hypotension**, the administration of crystalloid intravenous solutions should be carefully controlled to prevent overhydration. The injured lung in a flail chest is sensitive to both underresuscitation of shock and fluid overload. Specific measures to optimize fluid measurement must be taken for the patient with flail chest.

The definitive treatment is to re-expand the lung, ensure oxygenation as completely as possible, administer fluids judiciously, and provide analgesia to improve ventilation. Some patients can be managed without the use of a ventilator. However, prevention of hypoxia is of paramount importance for the trauma patient, and a short period of intubation and ventilation may be necessary until the diagnosis of the entire injury pattern is complete. A careful assessment of the respiratory rate, arterial oxygen tension, and an estimate of the work of breathing will indicate appropriate timing for intubation and ventilation. Not all patients with a flail chest require immediate endotracheal intubation.

**F. Cardiac Tamponade**

Cardiac tamponade most commonly results from penetrating injuries. Blunt injury also may cause the pericardium to fill with blood from the heart, great vessels, or pericardial vessels. The human pericardial sac is a fixed fibrous structure, and only a relatively small amount of blood is required to restrict cardiac activity and interfere with cardiac filling. Removal of small amounts of blood or fluid, often as little as 15 mL to 20 mL, by pericardiocentesis may result in immediate hemodynamic improvement.
The classic Beck's triad consists of venous pressure elevation, decline in arterial pressure, and muffled heart sounds. However, muffled heart tones are difficult to assess in the noisy emergency department. Distended neck veins, caused by the elevate central venous pressure, may be absent due to hypovolemia. Pulsus paradoxus, a decrease in systolic pressure during inspiration in excess of 10 mm Hg, also may be absent in some patients or difficult to detect in some emergency settings. In addition, tension pneumothorax - particularly on the left side - may mimic cardiac tamponade. Kussmaul's sign (a rise in venous pressure with inspiration when breathing spontaneously) is a true paradoxical venous pressure abnormality associated with tamponade. Electromechanical dissociation in the absence of hypovolemia and tension pneumothorax suggests cardiac tamponade.

Pericardiocentesis is indicated for patients who do not respond to the usual measures of resuscitation for hemorrhagic shock and who have the potential for cardiac tamponade. Insertion of a central venous line may aid diagnosis. Life-saving pericardiocentesis should not be delayed for this diagnostic adjunct. A high index of suspicion coupled with a patient who is unresponsive to resuscitative efforts are all that is necessary to initiate pericardiocentesis by the subxyphoid method.

Even though cardiac tamponade is strongly suspected, the initial administration of intravenous fluid will raise the venous pressure and improve cardiac output transiently while preparations are made for pericardiocentesis via the subxyphoid route. The use of a plastic-sheathed needle is preferable, but the urgent priority is to aspirate blood from the pericardial sac. Electrocardiographic monitoring may identify current of injury and needle-induced dysrhythmias. Because of the self-sealing qualities of the myocardium, aspiration of pericardial blood alone may relieve symptoms temporarily. However, all patients with positive pericardiocentesis due to trauma will require open thoracotomy and inspection of the heart. Pericardiocentesis may not be diagnostic or therapeutic because the blood in the pericardial sac is clotted. Preparations for transfer of these patients to the appropriate facility is necessary. Open pericardiotomy may be life-saving but is indicated only when a qualified surgeon is available.

Once these injuries and other immediate, life-threatening injuries have been treated, attention may be directed to the secondary survey and definitive care phase of potential, life-threatening thoracic injuries.

**IV. Potentially Lethal Chest Injuries Identified in the Secondary Survey**

The secondary survey requires further in-depth physical examination, an upright chest roentgenogram if the patient's condition permits, arterial blood gases, and an electrocardiogram. In addition to lung expansion and the presence of fluid, the chest film should be examined for widening of the mediastinum, a shift of the midline, or loss of anatomic detail. Multiple rib fractures and fractures of the first and/or second rib(s) are evidence of severe force delivered to the chest and underlying tissues.
Six potentially lethal injuries are considered herein:

1. Pulmonary contusion
2. Myocardial contusion
3. Aortic disruption
4. Traumatic diaphragmatic rupture
5. Tracheobronchial disruption

Unlike immediately life-threatening conditions, these injuries are not obvious on initial physical examination. Diagnosis requires a high index of suspicion. All are more often missed than diagnosed during the initial posttraumatic period. However, if these injuries are overlooked, lives may be lost.

A. Pulmonary Contusion With or Without Flail Chest

Pulmonary contusion is the most common potentially lethal chest injury seen in North America. The respiratory failure may be subtle and develops over time rather than occurring instantaneously. The plan for definitive management may change with time warranting careful monitoring and re-evaluation of the patient.

Some patients with stable conditions may be managed selectively without endotracheal intubation or mechanical ventilation. Patients with significant hypoxia should be intubated and ventilated within the first hour after injury. Associated medical conditions, eg, chronic pulmonary disease and renal failure, predispose to the need for early intubation and mechanical ventilation.

If the patient cannot maintain satisfactory oxygenation or has any of the above complicating features, intubation and mechanical ventilation should be considered. Pulse oximetry, ABG determination, ECG monitoring, and appropriate ventilatory equipment are necessary for optimal management. Any patient with the aforementioned pre-existing conditions and who is to be transferred should be intubated and ventilated.

B. Myocardial Contusion

Myocardial contusion, although difficult to diagnose, is another potentially lethal injury from blunt chest trauma. The patient's reported complaints of discomfort are often bypassed as being associated with chest wall contusion or fractures of the sternum and/or ribs. The diagnosis of myocardial contusion is established by abnormalities on the electrocardiogram, two-dimensional echocardiography, and associated history of injury. The electrocardiographic changes are variable and may even indicate frank myocardial infarction. Multiple premature ventricular contractions, unexplained sinus tachycardia, atrial fibrillation, bundle branch block (usually right), and ST segment changes are the most common electrocardiographic findings.
Elevated central venous pressure in the absence of obvious cause may indicate right ventricular dysfunction secondary to contusion.

Patients with myocardial contusion are at risk for sudden dysrhythmias. They should be admitted to the critical care unit for close observation and cardiac monitoring.

C. Traumatic Aortic Rupture

Traumatic aortic rupture is a common cause of sudden death after an automobile collision or a fall from a great height. Tears of the aorta and major pulmonary arteries, most of which result from blunt trauma, are usually fatal at the scene. For survivors, salvage is frequently possible, if aortic rupture is identified and treated early.

Patients with aortic rupture, who are potentially salvageable, tend to have a laceration near the ligamentum arteriosum of the aorta. Continuity maintained by an intact adventitial layer prevents immediate death. Many of the surviving patients die in the hospital if left untreated. Some blood may escape into the mediastinum, but one characteristic shared by all survivors is that this is a contained hematoma. Other than the initial pressure drop associated with the loss of 500 mL to 1000 mL of blood, hypotension responds to intravascular infusion. Persistent or recurrent hypotension is usually due to an unidentified bleeding site. Although free rupture of a transected aorta into the left chest does occur and causes hypotension, it is usually fatal unless the patient is operated on within a few minutes.

Specific signs and symptoms are frequently absent. A high index of suspicion triggered by a history of decelerating force and characteristic radiologic findings, followed by arteriography, are the means of making the diagnosis. Angiography should be performed liberally because the findings of the chest roentgenogram, especially the supine view, are unreliable. Approximately 10% of the aortograms will be positive for aortic rupture if liberal indications for using angiography are employed for all patients with widened mediastinum. Adjunctive radiologic signs, which may or may not be present, indicate the likelihood of major vascular injury in the chest. They include:

1. Widened mediastinum.
2. Fractures of the first and second ribs.
3. Obliteration of the aortic knob.
4. Deviation of the trachea to the right.
5. Presence of a pleural cap.
6. Elevation and rightward shift of the right mainstem bronchus.
7. Depression of the left mainstem bronchus.
8. Obliteration of space between the pulmonary artery and the aorta.
9. Deviation of the esophagus (nasogastric tube) to the right.

False-positive and false-negative findings occur with each roentgenographic sign. Therefore, no single finding reliably predicts or excludes significant injury. A widened mediastinum is the most consistent finding. The slightest suspicion of aortic injury should be evaluated angiographically, which is considered the gold standard. Transesophageal ultrasonography may be a useful diagnostic tool. Computed tomography (CT) is time consuming and may not provide a definitive diagnosis.

The treatment is either direct repair of the aorta or resection of the injured area and grafting. A qualified surgeon should treat such a patient.

D. Traumatic Diaphragmatic Rupture

A traumatic diaphragmatic rupture is more commonly diagnosed on the left side because the liver obliterates the defect on the right side, while the appearance of bowel, stomach, or nasogastric tube is more easily detected in the left chest. Blunt trauma produces large radial tears that lead to herniation. Penetrating trauma produces small perforations that often take some time, even years, to develop into diaphragmatic hernias.

These injuries are missed initially if the chest film is misinterpreted as showing an elevated left diaphragm, acute gastric dilatation, a loculated pneumohemothorax, or subpulmonary hematoma. If a laceration of the left diaphragm is suspected, a gastric tube should be inserted. When the gastric tube appears in the thoracic cavity on the chest film, the need for special contrast studies is eliminated. Occasionally, the diagnosis is not identified on the initial roentgenogram or after chest tube evacuation of the left thorax. An upper gastrointestinal contrast study should be performed if the diagnosis is not clear. The appearance of peritoneal lavage fluid in the chest tube drainage also confirms the diagnosis.

Right diaphragmatic ruptures are rarely diagnosed in the early postinjury period. The liver often prevents herniation of other abdominal organs into the chest. The appearance of an elevated right diaphragm on chest roentgenogram may be the only finding. Operation for other abdominal injuries often reveals diaphragmatic tears. The treatment is direct repair.

E. Tracheobronchial Tree Injuries

1. larynx

Fracture of the larynx is a rare injury, and is indicated by the following triad:

a. Hoarseness

b. Subcutaneous emphysema

c. Palpable fracture crepitus.

If the patient's airway is totally obstructed or the patient is in severe respiratory distress, an attempt at intubation is warranted. If intubation is unsuccessful, a tracheostomy
(not surgical cricothyroidotomy) is indicated, followed by operative repair. If the patient has sustained blunt trauma to the larynx, exhibits subtle symptoms, and a fracture is suspected, computed tomography may be helpful in identifying a fracture of the larynx.

2. Trachea

Direct trauma to the trachea, including the larynx, can be either penetrating or blunt. Blunt injuries may be subtle, and history is all-important.

Penetrating trauma is overt and requires immediate surgical repair. Penetrating injuries are often associated with esophageal, carotid artery, and jugular vein trauma. Because of the blast effect, penetrating injuries caused by missiles are often associated with extensive tissue destruction surrounding the area of penetration.

Noisy breathing indicates partial airway obstruction that suddenly may become complete. Absence of breathing suggests that complete obstruction already exists. When the level of consciousness is depressed, detection of significant airway obstruction is more subtle. Observations of labored respiratory effort may be the only clue to airway obstruction and tracheobronchial injury. Endoscopic procedures and CT scanning aid the diagnosis.

3. Bronchus

Injury to a major bronchus is an unusual and fatal injury that is frequently overlooked. The majority of such injuries result from blunt trauma and occur within one inch of the carina. Although most patients with this injury die at the scene, those who reach the hospital alive have a 30% mortality, often due to associated injuries.

If suspicion of a bronchial injury exists, immediate surgical consultation is warranted. A patient with a bronchial injury frequently presents with hemoptysis, subcutaneous emphysema, or tension pneumothorax with a mediastinal shift. A pneumothorax associated with a persistent large air leak after tube thoracotomy suggests a bronchial injury. More than one chest tube may be necessary to overcome a very large leak. Bronchoscopy confirms the diagnosis of the injury.

Treatment of tracheobronchial injuries may require only airway maintenance until the acute inflammatory and edema processes resolve. Major deviation or compression of the trachea by extrinsic masses, ie, hematomas, must be treated. Intubation frequently may be unsuccessful because of the anatomic distortion from paratracheal hematoma, major laryngotracheal injury, and associated injuries. For such patients, operative intervention is indicated. Patients surviving with bronchial injuries may require direct surgical intervention by thoracotomy.

F. Esophageal Trauma

Esophageal trauma is most commonly penetrating. Blunt esophageal trauma, although very rare, may be lethal if unrecognized. Blunt injury of the esophagus is caused by a forceful expulsion of gastric contents into the esophagus from a severe blow to the upper abdomen. This forceful ejection produces a linear tear in the lower esophagus, allowing leakage into the
mediastinum. The resulting mediastinitis and immediate or delayed rupture into the pleural space cause empyema. Esophageal trauma may be caused by mishaps of instrumentation (nasogastric tubes, endoscopes, dilators, etc).

The clinical picture is identical to that of postemetic esophageal rupture. Esophageal injury should be considered for any patient who (1) has a left pneumothorax or hemothorax without a rib fracture, (2) has received a severe blow to the lower sternum or epigastrium and is in pain or shock out of proportion to the apparent injury, or (3) has particulate matter in their chest tube after the blood begins to clear. Presence of mediastinal air also suggests the diagnosis, which often can be confirmed by contrast studies and/or esophagoscopy.

Wide drainage of the pleural space and mediastinum with direct repair of the injury via thoracotomy is the treatment if feasible. If the repair is tenuous or not feasible, esophageal diversion in the neck and gastrostomy of the lower and upper gastric segments usually is carried out, thereby avoiding continued soiling of the mediastinum and pleura by gastric and esophageal contents.

V. Other Manifestations of Chest Injuries

A. Subcutaneous Emphysema

Subcutaneous emphysema may result from airway injury, lung injury, or rarely, blast injury. Although it does not require treatment, the underlying injury must be addressed.

B. Crushing Injury to the Chest (Traumatic Asphyxia)

Findings associated with a crush injury to the chest include upper torso, facial, and arm plethora with petechiae secondary to superior vena cava compression. Massive swelling and even cerebral edema may be present. Underlying injuries must be treated.

C. Simple Pneumothorax

Pneumothorax results from air entering the potential space between the visceral and parietal pleura. Both penetrating and nonpenetrating trauma may cause this injury. Lung laceration with air leakage is the most common cause of pneumothorax resulting from blunt trauma.

The thorax is normally completely filled by the lung, held to the chest wall by surface tension between the pleural surfaces. Air in the pleural space collapses lung tissue. This collapsed lung does not participate in oxygen exchange. A ventilation/perfusion defect occurs because the blood circulated to the nonventilated area is not oxygenated.

When a pneumothorax is present, breath sounds are decreased on the affected side. Percussion demonstrates hyperresonance. An upright, expiratory roentgenogram of the chest aids the diagnosis.

A pneumothorax is best treated with a chest tube in the fourth or fifth intercostal space, anterior to the midaxillary line. Observation and/or aspiration of any pneumothorax is
risky. Once a chest tube has been inserted and connected to an underwater seal apparatus with or without suction, a chest roentgenogram is necessary to confirm re-expansion of the lung. General anesthesia should never be administered for definitive care of injuries in patients who have sustained traumatic pneumothorax or who are at risk for unexpected intraoperative pneumothorax, until a chest tube has been inserted. The chest also should be decompressed before transporting the patient with a pneumothorax via air ambulance.

D. Hemothorax

The primary cause of hemothorax is lung laceration or laceration of an intercostal vessel or internal mammary artery due to either penetrating or blunt trauma. In the vast majority of cases this bleeding is self-limiting and does not require operative intervention.

Hemothorax, sufficient to appear on chest roentgenogram, is usually treated with a large-caliber chest tube. The chest tube evacuates blood, reduces the risk of a clotted hemothorax, and provides a method for monitoring blood loss. Although many factors are involved in the decision to operate on a patient with a hemothorax, the amount of blood drainage from the chest tube is a major factor. If a liter of blood is obtained through the chest tube, surgical consultation is warranted. Persistent drainage of more than 200 mL per hour for four hours may indicate the need for thoracotomy.

E. Scapular and Rib Fractures

The ribs are the most commonly injured component of the thoracic cage. Injuries to the ribs are often significant. Pain on motion results in splinting of the thorax, which impairs ventilation. Tracheobronchial secretions cannot be eliminated easily. The incidence of atelectasis and pneumonia rises strongly with pre-existing lung disease.

The upper ribs (1 to 3) are protected by the bony framework of the upper limb. The scapula, humerus, and clavicle, along with their muscular attachments, provide a barrier to rib and scapular injury. Fractures of the scapula, and first or second ribs often indicate major injury to the head, neck, spinal cord, lungs, and the great vessels. Because of the severity of the associated injuries, mortality can be as high as 50%. Surgical consultation is warranted.

The middle ribs (4 to 9) sustain the majority of blunt trauma. Anteroposterior compression of the thoracic cage will bow the ribs outward with a fracture in the midshaft. Direct force applied to the ribs tends to fracture them and drive the ends of the bones into the thorax with more potential for intrathoracic injury, such as pneumothorax. As a general rule, a young patient with a more flexible chest wall is less likely to sustain rib fractures. Therefore, the presence of multiple rib fractures in young patients implies a greater transfer of force than in older patients. Fractures of the lower ribs (10 to 12) should increase suspicion for hepatosplenic injury.

Localized pain, tenderness on palpation, and crepitus are present in rib injury patients. A palpable or visible deformity suggests rib fractures. A chest roentgenogram should be obtained primarily to exclude other intrathoracic injuries and not just to identify rib fractures. Fractures of anterior cartilages or separation of costochondral junctions have the same implications as rib fractures, but will not be seen on the roentgenographic examinations.
Special rib technique roentgenograms are expensive, may not detect all rib injuries, add nothing to treatment, require painful positioning of the patient, and are not useful. Taping, rib belts, and external splints are contraindicated. Relief of pain is important to enable adequate ventilation. Intercostal block, epidural anesthesia, and systemic analgesics may be necessary.

F. Other Indications for Chest Tube Insertion

1. Selected patients with suspected severe lung injury, especially those being transferred by air or ground vehicle.

2. Individuals undergoing general anesthesia for treatment of other injuries (eg, cranial or extremity), who have suspected significant lung injury.

3. Individuals requiring positive pressure ventilation who are suspected of having substantial chest injury.

VI. Summary

Thoracic trauma is common in the multiple-injured patient and can be associated with life-threatening problems. These patients can usually be treated or their conditions temporarily relieved by relatively simple measures such as intubation, ventilation, tube thoracostomy, and needle pericardiocentesis. The ability to recognize these important injuries and the skill to perform the necessary procedures can be life-saving.
Skill Station VI: Roentgenographic Identification of Thoracic Injuries

Resources and Equipment

This list is the recommended equipment to conduct this skill session in accordance with the stated objectives for and intent of the procedures outlined. Additional equipment may be used providing it does not detract from the stated objectives and intent of this skill or from performing the procedure in a safe manner as described and recommended by the ACS Committee on Trauma.

1. Thoracic roentgenograms (available from the ACS, ATLS Division)
2. Identification key to roentgenograms
3. View boxes to display films.

Objectives

1. Upon completion of this station, the participant will be able to identify various thoracic injuries by using six specific anatomic guidelines for examining a series of chest roentgenograms.
   
   a. Soft tissues of the chest wall
   
   b. Bony thorax
   
   c. Pleural spaces and lung parenchyma
   
   d. Trachea and bronchi
   
   e. Diaphragm
   
   f. Mediastinum

2. Given a series of roentgenograms, the participant will be able to:
   
   a. Diagnose fractures.
   
   b. Delineate associated injuries.
   
   c. Define other areas of possible injury.

Skill Procedure: Roentgenographic Identification of Thoracic Injuries

Note: Chest roentgenograms are obtained during the primary survey/resuscitation phase or the secondary survey, based on the urgency of the patient's condition. Six-foot, upright films provide better anatomic detail of the chest; however, practicality and safety dictate that anteroposterior (AP), supine films are adequate for identifying injuries in the
potentially or obviously unstable patient. For example, when the patient's torso or neck has been injured or when the unconscious patient is at risk of aspirating, an AP supine roentgenogram should be obtained. A lateral thoracic film may be necessary to identify a suspected sternal fracture.

A systematic review of the roentgenogram must be performed, preferably using a view box. The anatomic guidelines outlined herein identify areas in the thorax that should be assessed when examining a chest film. Each of these areas should be assessed for potential injury when viewing the specific roentgenograms associated with this skill station. (See Resource Document 5, Roentgenographic Studies.)

I. Soft Tissues

Asses for:

1. Displacement or disruption of tissue planes
2. Evidence of subcutaneous air.

II. Bony Thorax

A. Clavicle

Assess for evidence of:

1. Fracture
2. Associated injury, eg, great vessel injury.

B. Scapula

Assess for evidence of:

1. Fracture
2. Associated injury, eg, airway or great vessel injury, pulmonary contusion.

C. Ribs

1. Ribs 1 through 3: Assess for evidence of:
   a. Fracture
   b. Associated injury, eg, pneumothorax, major airway or great vessel injury.

2. Ribs 4 through 9: Assess evidence of:
   a. Fracture, especially in two or more contiguous ribs in two places (flail chest).
b. Associated injury, eg, pneumothorax, hemothorax, pulmonary contusion.

3. Ribs 9 through 12: Assess for evidence of:
   a. Fracture, especially in two or more places (flail chest).
   b. Associated injury, eg, pneumothorax, pulmonary contusion, spleen, liver, and/or kidney.

D. Sternum

1. Assess the sternoclavicular junction and sternal body for evidence of fracture. (Sternal fractures may be confused on the AP film as a mediastinal hematoma. After the patient is stabilized, a coned-down view, over-penetrated film, lateral view, or CT may be obtained to better illuminate a suspected sternal fracture.)

2. Assess for associated injuries, eg, myocardial contusion, great vessel injury (widened mediastinum).

III. Pleural Space and Lung Parenchyma

A. Pleural Space

1. Assess for abnormal collections of fluid that may represent a pneumothorax.

2. Assess for abnormal collections of air that may represent a pneumothorax - usually seen as an apical lucent area absent of bronchial or vascular markings.

B. Lung Parenchyma

1. Assess the lung fields for infiltrates that may suggest pulmonary contusion, hematoma, aspiration, etc. Pulmonary contusion appears as air space consolidation that can be irregular and patchy or homogenous, diffuse, or extensive.

2. Assess the parenchyma for evidence of laceration. Lacerations appear as a hematoma, vary according to the magnitude of injury, and appear as areas of consolidation.

IV. Trachea and Bronchi

A. Assess for the presence of interstitial or pleural air that may represent a large airway injury.

B. Assess for tracheal lacerations that may present as pneumomediastinum, pneumothorax, subcutaneous and interstitial emphysema of the neck, or pneumoperitoneum.

C. Assess for bronchial disruption that may present as a free pleural communication producing a massive pneumothorax with a persistent air leak that is unresponsive to tube thoracostomy.
V. Diaphragm

Diaphragmatic rupture requires a high index of suspicion, based on the mechanism of injury, the patient's signs and symptoms, and roentgenographic findings. Initial chest roentgenograms may not clearly identify a diaphragmatic injury. Sequential films or additional studies may be required.

A. Carefully evaluate the diaphragm for:

1. Elevation (may rise to fourth intercostal space with full expiration)
2. Disruption (stomach or bowel gas above the diaphragm)
3. Poor identification (irregular or obscure) due to overlying fluid or soft tissue masses.

B. Roentgenographic changes suggesting injury include:

1. Elevation, irregularity, or obliteration of the diaphragm - segmental or total
2. Mass-like density above the diaphragm may be due to a fluid-filled bowel, omentum, liver, kidney, spleen, or pancreas (may appear as a "loculated pneumothorax")
3. Air or contrast-containing stomach or bowel above the diaphragm
4. Contralateral mediastinal shift
5. Widening of the cardiac silhouette if the peritoneal contents herniate into the pericardial sac
6. Pleural effusion
7. The inferior border of the liver may appear higher than expected; lower rib fractures, pulmonary contusions, and the appearance of foreign bodies in the chest cavity may be associated with diaphragmatic injury; eg, a nasogastric tube coiled in the chest may represent a stomach herniated into the thorax or a hole in the esophagus.

C. Assess for associated injuries, eg, splenic, pancreatic, renal, and liver.

VI. Mediastinum

A. Assess for air or blood that may either displace mediastinal structures, blur the demarcation between tissue planes, or outline them with radiolucency.

B. Assess for radiologic signs associated with cardiac or major vascular injury.

1. Air or blood in the pericardium may result in an enlarged cardiac silhouette. Progressive changes in the cardiac size may represent an expanding pneumopericardium or
hemopericardium.

2. Aortic rupture may be suggested by:

a. Widened mediastinum - most reliable finding
b. Fractures of the first and second ribs
c. Obliteration of the aortic know
d. Deviation of the trachea to the right
e. Presence of a pleural cap
f. Elevation and rightward shift of the right mainstem bronchus
g. Depression of the left mainstem bronchus
h. Obliteration of the space between the pulmonary artery and the aorta
i. Deviation of the esophagus (nasogastric tube) to the right.

VII. Roentgenographic Assessment

After careful, systematic evaluation of the initial chest film, additional roentgenograms or radiographic studies may be necessary as historical facts or physical findings dictate. For example, repeat chest films may be indicated if significant changes in the patient's status develop. Computed tomography and arteriography may be indicated for specificity of diagnosis.
Table 1. Chest Roentgenographic Suggestions

<table>
<thead>
<tr>
<th>Abnormal Findings</th>
<th>Diagnoses to Consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any rib fracture</td>
<td>Pneumothorax</td>
</tr>
<tr>
<td>Fracture, first 3 ribs</td>
<td>Airway or great vessel injury</td>
</tr>
<tr>
<td>Lower ribs, 9 to 12</td>
<td>Abdominal injury</td>
</tr>
<tr>
<td>Two or more rib fractures in two or more places</td>
<td>Flail chest, pulmonary contusion</td>
</tr>
<tr>
<td>GI gas pattern in the chest (loculated air)</td>
<td>Diaphragmatic rupture</td>
</tr>
<tr>
<td>NG tube in the chest</td>
<td>Diaphragmatic rupture or ruptured esophagus</td>
</tr>
<tr>
<td>Air fluid level in the chest</td>
<td>Hemothorax or diaphragmatic rupture</td>
</tr>
<tr>
<td>Sternal fracture</td>
<td>Myocardial contusion, head injury, c-spine injury</td>
</tr>
<tr>
<td>Mediastinal hematoma</td>
<td>Great vessel injury, sternal fracture</td>
</tr>
<tr>
<td>Disrupted diaphragm</td>
<td>Abdominal visceral injury</td>
</tr>
<tr>
<td>Respiratory distress without roentgenographic findings</td>
<td>CNS injury, aspiration</td>
</tr>
<tr>
<td>Persistent large pneumothorax after chest tube insertion</td>
<td>Bronchial tear, esophageal disruption</td>
</tr>
<tr>
<td>Mediastinal air</td>
<td>Esophageal disruption, pneumoperitoneum, tracheal injury</td>
</tr>
<tr>
<td>Scapular fracture</td>
<td>Airway or great vessel injury, or pulmonary contusion</td>
</tr>
<tr>
<td>Free air under the diaphragm</td>
<td>Ruptured hollow abdominal viscus.</td>
</tr>
</tbody>
</table>
Skill Station VII: Chest Trauma Management

These surgical procedures, if performed on a live, anesthetized animal, must be conducted in a USDA-Registered Animal Laboratory Facility. (See ATLS Instructor Manual, Section II, Chapter 9 - Policies, Procedures, and Protocols for Surgical Skills Practicum.)

Resources and Equipment

This list is the recommended equipment to conduct this skill session in accordance with the stated objectives for and intent of the procedures outlined. Additional equipment may be used providing it does not detract from the stated objectives and intent of this skill, or from performing the procedure in a safe method as described and recommended by the ACS Committee on Trauma.

1. Live, anesthetized animals

2. Licensed veterinarian (see guidelines referenced above)

3. Animal troughs, ropes (sandbags optional)

4. Animal intubation equipment
   a. Endotracheal tubes
   b. Laryngoscope blade and handle
   c. Respirator with 15-mm adapter

5. Electric shears with #40 blade

6. Tables or instrument stand

7. Needles and catheters
   a. Assorted #14-gauge over-the-needle catheters (3 to 6 cm in length)
   b. #18-gauge spinal needles (5 to 6 inches or 12.7 to 15.2 cm in length)
   c. #22-gauge spinal needles (5 to 6 inches or 12.7 to 15.2 cm in length)
   d. Pericardiocentesis catheter kit (optional)

8. Syringes
   a. 6-mL syringes
   b. 12-mL syringes
   c. 35-mL syringes, plastic and glass

9. Suture
   a. 2-0 and 3-0 silk with cutting needle
   b. 2-0 and 3-0 silk with taper needle
c. 4-0 Monofilament/noncutting needle (optional)

10. drugs

a. Lidocaine 1% (optional)
b. Heparin 1:1000 (optional)

11. Chest tubes without trocars - #32-French (for animal use); #36-40 French (for patient use)

12. 3x3 or 4x4 gauze sponges

13. One-inch (2.5 cm) adhesive tape

14. Underwater seal device

15. Small basin for water to inject into the pericardial sac (methylene-blue dye may be added to the water for a more dramatic appearance when performing pericardiocentesis)

16. Flutter-type valve

17. Three-way stopcocks

18. Surgical instruments

a. Scalpel handles with #10 and #11 blades
b. Needle holders
c. Small Finochetti chest retractors or small self-retaining chest retractors
d. Mosquitoes
e. Heavy curved scissors
f. Suture scissors
g. Metsenbaum curved dissecting scissors
h. Tissue forceps - with and without teeth

19. Antiseptic swabs

20. Surgical drapes (optional)

21. Electrocardiographic monitor (optional)

22. Surgical garb (gloves, shoe covers, and scrub suits or cover gowns).

Objectives

1. Performance at this station will allow the participant to practice and demonstrate on a live, anesthetized animal the technique of inserting a chest needle and chest tube for the emergency care of hemothoraces and/or pneumothoraces.
2. Upon completion of this station, the participant will be able to describe the surface markings and technique for pleural decompression with needle thoracocentesis and chest tube insertion.

3. Upon completion of this station, the participant will be able to discuss the underlying pathophysiology of cardiac tamponade as a result of trauma.

4. Upon completion of this station, the participant will be able to describe the surface markings and technique for pericardiocentesis.

5. Performance at this station will allow the participant to practice and demonstrate on a live, anesthetized animal the technique of inserting a needle into the pericardium (pericardiocentesis) for the emergency treatment of cardiac tamponade or hemopericardium.

6. Upon completion of this station, the participant will be able to discuss the complications of needle thoracocentesis, chest tube insertion, and pericardiocentesis.

Procedures

1. Needle thoracocentesis
2. Chest tube insertion
3. Pericardiocentesis.
Skills Procedures: Chest Trauma Management

Note: Universal precautions are required whenever caring for the trauma patient.

I. Needle Thoracocentesis

Note: This procedure is for the rapidly deteriorating critical patient who has a life-threatening tension pneumothorax. If this technique is used and the patient does not have a tension pneumothorax, a pneumothorax and/or damage to the lung may occur.

A. Assess the patient's chest and respiratory status.
B. Administer high-flow oxygen and ventilate as necessary.
C. Identify the second intercostal space, in the midclavicular line on the side of the tension pneumothorax.
D. Surgically prepare the chest.
E. Locally anesthetize the area if the patient is conscious or if time permits.
F. Place the patient in an upright position if a cervical spine injury has been excluded.
G. Keeping the Luer-Lok in the distal end of the catheter, insert an over-the-needle catheter (3 to 6 cm long) into the skin and direct the needle just over (ie, superior to) the rib into the intercostal space.
H. Puncture the parietal pleura.
I. remove the Luer-Lok from the catheter and listen for a sudden escape of air when the needle enters the parietal pleura, indicating that the tension pneumothorax has been relieved.
J. Remove the needle and replace the Luer-Lok in the distal end of the catheter. Leave the plastic catheter in place and apply a bandage or small dressing over the insertion site.
K. Prepare for a chest-tube insertion, if necessary. The chest tube should be inserted at the nipple level anterior to the midaxillary line of the affected hemithorax.
L. Connect the chest tube to an underwater seal device or a flutter-type-valve apparatus and remove the catheter used to relieve the tension pneumothorax initially.
M. Obtain a chest roentgenogram.
Complications of Needle Thoracentesis

1. Local cellulitis
2. Local hematoma
3. Pleural infection, empyema
4. Pneumothorax
II. Chest Tube Insertion

A. Fluid resuscitation via at least one, large-caliber intravenous catheter, and monitoring of vital signs should be in process.

B. Determine the insertion site - usually the nipple level (5th intercostal space) anterior to the midaxillary line on the affected side. A second chest tube may be used for a hemothorax.

C. Surgically prepare and drape the chest at the predetermined site of the tube insertion.

D. Locally anesthetize the skin and rib periosteum.

E. Make a 2- to 3-cm transverse (horizontal) incision at the predetermined site and bluntly dissect through the subcutaneous tissues, just over the top of the rib.

F. Puncture the parietal pleura with the tip of a clamp and put a gloved finger into the incision to avoid injury to other organs and to clear any adhesions, clots, etc.

G. Clamp the proximal end of the thoracostomy tube and advance the thoracostomy tube into the pleural space to the desired length.

H. Look for "fogging" of the chest tube with expiration or listen for air movement.

I. Connect the end of the thoracostomy tube to an underwater-seal apparatus.

J. Suture the tube in place.

K. Apply a dressing, and tape the tube to the chest.

L. Obtain a chest roentgenogram.

M. Obtain arterial blood gas values as necessary.

Complications of Chest Tube Insertion

1. Anaphylactic or allergic reaction to surgical preparation or anesthetic.

2. Chest tube dislodgment from the chest wall or disconnection from the underwater-seal apparatus.

3. Chest bottle elevated above the level of the chest, and fluid flows into the chest cavity.

4. Chest tube kinking or clogging.

5. Damage to the intercostal nerve, artery, or vein
a. Converting a pneumothorax to a hemopneumothorax  
b. Resulting in intercostal neuritis/neuralgia

6. Damage to internal mammary vessels if puncture is too medial, resulting in hemopneumothorax

7. Incorrect tube position, extrathoracic or intrathoracic

8. Intercostal myalgia

9. Introduction of pleural infection (eg, thoracic empyema)

10. Laceration or puncture of intrathoracic and/or abdominal organs, all of which can be prevented by using the finger technique before inserting the chest tube

a. Heart  
b. Lung  
c. Esophagus  
d. Aorta  
e. Pulmonary artery  
f. Pulmonary vein  
g. Long thoracic nerve  
h. Mediastinum  
i. Liver  
j. Spleen

11. Leaky underwater-seal apparatus

12. Local cellulitis

13. Local hematoma

14. Mediastinal emphysema

15. Persistent pneumothorax

a. Large primary leak  
b. Leak at the skin around the chest tube; suction on tube too strong  
c. Leaky underwater-seal apparatus

16. Subcutaneous emphysema (usually at tube site)

17. Recurrence of pneumothorax upon removal of chest tube; seal of thoracostomy wound not immediate

18. Lung fails to expand due to plugged bronchus; bronchoscopy required.

III. Pericardiocentesis
A. Monitor the patient’s vital signs, CVP, and ECG before, during, and after the procedure.

B. Surgically prepare the xiphoid and subxiphoid areas, if time allows.

C. Locally anesthetize the puncture site, if necessary.

D. Using a #16- to #18-gauge, 6-inch (15 cm) or longer over-the-needle catheter, attach a 35-mL empty syringe with a three-way stopcock.

E. Assess the patient for any mediastinal shift that may have caused the heart to shift significantly.

F. Puncture the skin 1 to 2 cm inferior to the left of the xiphochondral junction, at a 45-degree angle to the skin.

G. Carefully advance the needle cephalad and aim toward the tip of the left scapula.

H. If the needle is advanced too far (into the ventricular muscle) an injury pattern (eg, extreme ST-T wave changes or widened and enlarged QRS complex) appears on the ECG monitor. This pattern indicates that the pericardiocentesis needle should be withdrawn until the previous baseline ECG tracing reappears. Premature ventricular contractions also may occur, secondary to irritation of the ventricular myocardium.

I. When the needle tip enters the blood-filled pericardial sac, withdraw as much nonclotted blood as possible.

J. During the aspiration, the epicardium reapproaches the inner pericardial surface, as does the needle tip. Subsequently, an ECG injury pattern may reappear. This indicates that the pericardiocentesis needle should be withdrawn slightly. Should this injury pattern, persist, withdraw the needle completely.

K. After aspiration is completed, remove the syringe, and attach a three-way stopcock, leaving the stopcock closed. Secure the catheter in place.

L. Should the cardiac tamponade symptoms persist, the stopcock may be opened and the pericardial sac reaspirated. The plastic pericardiocentesis needle can be sutured or taped in place and covered with a small dressing to allow for continued decompression en route to surgery or transfer to another care facility.
Complication of Pericardiocentesis

1. Aspiration of ventricle blood instead of pericardial blood.
2. Cellulitis.
3. Laceration of coronary artery or vein.
4. Laceration of ventricular epicardium/myocardium.
5. New hemopericardium, secondary to lacerations of the coronary artery or vein, and/or ventricular epicardium/myocardium.
6. Local hematoma.
7. Pericarditis.
8. Ventricular fibrillation.
9. Pneumothorax, secondary to lung puncture.
10. Puncture of aorta.
11. Puncture of inferior vena cava.
13. Mediastinitis secondary to puncture of esophagus.
15. Peritonitis, secondary to puncture of peritoneum.