Chapter 16

Thoracic Injuries

Introduction

About 15% of war injuries involve the torso. Those injuries involving the vasculature of the mediastinum (heart, great vessels, and pulmonary hilum) are generally fatal on the battlefield. Injuries of the lung parenchyma (the vast majority) can be managed by the insertion of a chest tube and basic wound treatment. Although penetrating injuries are most common, blunt chest trauma may occur and can result in disruption of the contents of the thorax, as well as injury to the chest wall itself. Blast injuries can result in the rupture of air-filled structures (the lung), as well as penetrating injuries from fragments.

The immediate recognition and treatment of tension pneumothorax is an important life-saving intervention in the treatment of chest injuries in combat. Distended neck veins, tracheal shift, decreased breath sounds, hyperresonance in the affected hemithorax, and hypotension are the cardinal signs, BUT may not be identified in the presence of other injuries/hypotension/hypovolemia. Immediate decompression is lifesaving.

The protection afforded by body armor greatly reduces the incidence of thoracic injuries, compared with extremity or head/neck injuries. Unfortunately, not all individuals have such protection; some tactical situations limit the use of body armor and some sustain chest injuries despite protection. In addition, military surgeons routinely treat injured civilians.

Anatomical Considerations

- Superior border is at the level of the clavicles anteriorly and the junction of the C7–T1 vertebral bodies posteriorly. The

thoracic inlet at that level contains major arteries (common carotids and vertebrals), veins (anterior and internal jugulars), trachea, esophagus, and spinal cord.

- Within or traversing the container of the chest itself are the heart and coronary vessels, the great vessels—including arteries (aortic arch, innominate, right subclavian, common carotid, left subclavian, and descending aorta), veins (superior and inferior vena cava, azygous vein, and brachiocephalic vein), and pulmonary arteries and veins—distal trachea, and main stem bronchi, lungs, and esophagus.
- The inferior border is described by the diaphragm, attached anteriorly at the T6 level and gradually sloping posteriorly to the T12 level.

Penetrating thoracic injuries below the T4 level (nipple line) mandate evaluation for abdominal injuries due to the variable position of the diaphragm during the respiratory cycle (Fig. 16-1).

Evaluation and Diagnosis

Knowledge of the mechanism of injury (eg, blast, fragment, among others) may increase the index of suspicion for a particular injury. A complete and accurate diagnosis is usually not possible because of the limited diagnostic tools available in the setting of combat trauma. Nonetheless, because injuries to the chest can profoundly affect breathing and circulation (and, on rare occasion, the airway), a complete and rapid assessment of each injury is mandatory.

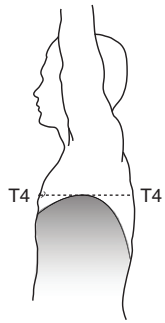

Fig. 16-1. Thoracic incision of abdominal contents.

- If the casualty is able to talk without hoarseness or stridor, there is reasonable assurance that the airway is intact.

Life-Threatening Injuries

Injuries requiring urgent intervention, include tension pneumothorax, massive hemothorax, and cardiac tamponade.

- **Tension pneumothorax.**
  - A patient with a known chest injury presenting with an open airway and difficulty breathing has a tension pneumothorax until proven otherwise. It requires rapid decompression and the insertion of a chest tube. Needle decompression alone is insufficient.
- **Massive hemothorax.**
  - The return of blood on chest tube placement may indicate a significant intrathoracic injury. Generally, the **immediate return of 1,500 cc of blood mandates thoracotomy**. When initial blood loss is <1,500 mL, but bleeding continues such that ongoing blood transfusions are required and all other sources of hemorrhage are eliminated, then thoracotomy may be indicated. Needle decompression will not identify hemothorax.
  - Casualties with massive thoracic hemorrhage require damage control techniques (see Chapter 12, Damage Control Surgery).
- **Cardiac tamponade.**
  - Distended neck veins (may be absent with significant blood loss) in the presence of clear breath sounds and hypotension indicate the possibility of life-threatening cardiac tamponade.
  - Fluid resuscitation may temporarily stabilize a patient in tamponade.
  - Perform an ultrasound if time permits.
    - If **positive,** proceed to the OR (pericardial window, sternotomy, thoracotomy). Any pericardial blood mandates median sternotomy / thoracotomy.
    - A **negative** ultrasound requires either repeat ultrasound or pericardial window, depending on the level of clinical suspicion.

- Pericardiocentesis is only a stopgap measure on the way to definitive surgical repair.

- **Open pneumothorax** (hole in chest wall) is treated by placing a chest tube through a separate incision and sealing the hole. Alternatives include one-way valve chest dressings or a square piece of plastic dressing taped to the chest on three sides as a "flap valve."
- **Flail chest** (entire segment of the chest wall floating due to fractures of a block of ribs, with two fractures on each rib) is commonly associated with pulmonary contusion under the flail segment. Patients with flail chest should be monitored closely for respiratory distress. Pain control is essential and may require intercostal nerve blocks or epidural catheters to optimize pulmonary mechanics. Patients with evidence of respiratory distress, poor or marginal oxygenation, or ventilation should be intubated and mechanically ventilated prior to air evacuation.

Surgical Management

Most penetrating chest injuries reaching medical attention are adequately treated with tube thoracostomy (chest tube) alone.

Tube Thoracostomy (Chest Tube)

- Indications.
  - Known or suspected tension pneumothorax.
  - Pneumothorax (including open).
  - Hemothorax.
- Procedure (Fig. 16-2).
  - In cases of tension pneumothorax, **immediate decompression with a large bore needle may be lifesaving**. An IV catheter (14 gauge, 3.25 inches in length) is inserted in the midclavicular line in the second interspace (approximately 2 fingerbreadths below the clavicle on the adult male). **Do not place medial to the nipple to avoid cardiac or vascular injury.** Entry is confirmed by the sound of air passing through the catheter, if a pneumothorax was actually present. **This must be rapidly followed by the insertion of a chest tube.**

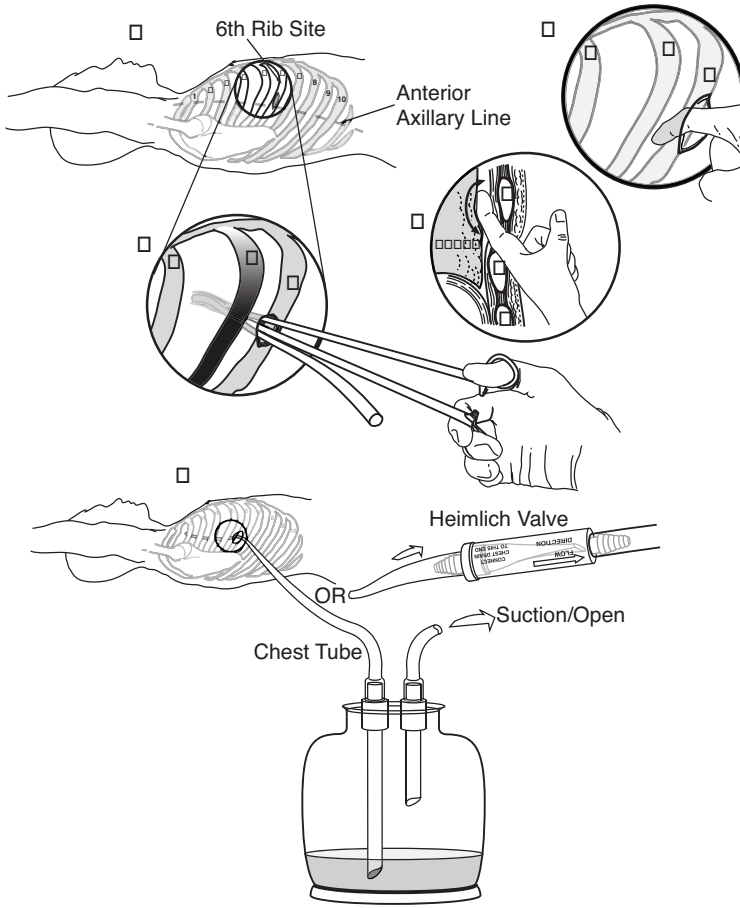

Fig. 16-2. Procedure for tube thoracostomy. Numbers indicate rib sites.

- In a contaminated environment, a single gram of IV Cefazolin (ANCEF) is recommended.
- If time allows, prep the anterior and lateral chest on the affected side with povidone-iodine.
- Identify the incision site along the anterior axillary line, intersecting the 5th or 6th rib. This is at nipple level in males and at the inframammary crease in females.

- Inject a local anesthetic in the awake patient, if conditions allow.
- Make a transverse incision, 3–4 cm in length, along and centered over the rib, carrying it down to the bone (Fig. 16-2a).
- Insert a curved clamp in the incision, directed over the top of the rib, and push into the chest through the pleura. A distinct pop is encountered when entering the chest, and a moderate amount of force is necessary to achieve this entry. A rush of air out of the chest will confirm a tension pneumothorax. Insertion depth of the tip of the clamp should be limited by the surgeon's hand to only 3 or 4 cm to make sure that the clamp does not travel deeper into the chest, resulting in damage to underlying structures.
- Spread the clamp gently and remove. The operator's finger is then inserted to confirm entry (Fig. 16-2b,c).
- Insert a chest tube (24–36 Fr gauge) into the hole. All chest tube side holes must be in the pleural space (ie, not just below skin level). If no chest tubes are available, an adult endotracheal tube may be used (Fig. 16-2d).
- Attach a chest tube to a Heimlich valve, sealed Pleurovac, or bottles. In a resource-constrained environment, a cutoff glove with a slit in the end, or a Penrose drain may be attached to the end of the chest tube (Fig. 16-2e).
- Secure the tube with sutures, if possible, and dress to prevent contamination.

Resuscitative Thoracotomy

- Only indicated in penetrating injury in extremis or with recent loss of vital signs.
- 11% survival reported from combat casualties in Iraq/Afghanistan.
- If performed, a rapid assessment of injuries should be made; and, in the case of unsalvageable injuries, the procedure should be immediately terminated.

Procedure

- With the patient supine, make an incision in the left inframammary fold starting at the lateral border of the sternum extending to the midaxillary line (Fig. 16-3).

- The procedure should be abandoned upon discovery of devastating injuries to the heart and great vessels.
- An immediate right chest thoracostomy should be performed concurrently. If bleeding is identified, a rapid extension across the midline should be done, crossing through the sternum with a Lebsche sternum knife and performing a mirror-image thoracotomy. When doing this procedure, you will cut across both internal mammary arteries, which will be a significant source of bleeding and must be clamped as soon as possible.

Fig. 16-3. Incision for resuscitative thoracotomy.

- Elevating the anterior chest wall will expose virtually all mediastinal structures.
- Open the pericardium and assess the heart. Use an anterior longitudinal incision to avoid phrenic nerve injury.
- **Priorities are to stop bleeding and restore central perfusion.**
  - Holes in the heart and/or great vessels should be temporarily occluded.
    - Temporary occlusion can be achieved with fingers, side-biting clamps, or Foley catheters with 30 cc balloons. Any other sterile device of opportunity is acceptable. A finger is usually sufficient, and less traumatic.
  - Major pulmonary hilar injuries should be cross-clamped en masse.
  - Distal thoracic aorta should be located, cross-clamped, and cardiac function restored via defibrillation or massage. (Make sure to open the mediastinal pleura over the aorta to securely apply the vascular clamp.)
  - If unable to restore cardiac function rapidly, abandon the operation.
- With successful restoration of cardiac function, injuries should be more definitively repaired.

Subxiphoid Pericardial Window

Subxiphoid pericardial window should not be attempted in an unstable patient. Unstable patients with penetrating injuries suspicious for cardiac injury should undergo immediate median sternotomy/thoracotomy.

Procedure

- With the patient supine, make a 4–5 cm longitudinal incision just on and below the xiphoid process through the skin and fascia.
- Bluntly dissect superiorly toward the heart exposing the phrenopericardial membrane below the heart.
- Sharply incise pericardium with care to avoid the heart, opening the pericardial sac, and exposing the underlying beating heart.
- Presence of pericardial blood mandates sternotomy to assess/repair cardiac injury.

Median Sternotomy

- Indications.
  - Suspected cardiac injury.
  - Positive pericardiocentesis/subxiphoid pericardial window.
  - Suspected injury to the great vessels in the chest.
  - Suspected distal tracheal injury.
- Procedure.
  - In the supine position, make a midline skin incision from the sternal notch to just below the xiphoid.
  - Through blunt/sharp dissection, develop a plane for several centimeters both superiorly and inferiorly beneath the sternum.
  - Divide the sternum with a sternal saw or Lebsche knife. Keep the foot of the knife/saw tilted up toward the undersurface of the sternum to avoid cardiac injury. Bone wax can be used to decrease bleeding on the cut edges of the sternum.
  - Separate the halves of the sternum using a chest retractor.

- Carefully divide the pericardium superiorly, avoiding the innominate vein, and exposing the heart and base of the great vessels.

In general, exposure to the heart and great vessels is best achieved through a median sternotomy. For proximal left subclavian artery injuries, additional exposure (trap door) may be necessary.

- Close with wire suture directly through the halves of the sternum, approximately 2 cm from the edge, or around the sternum through the costal interspaces using wire sutures. Large, permanent sutures can be used if wire is unavailable.
- Place one or two mediastinal tubes for drainage, exiting through a midline stab wound inferior to the mediastinal skin incision.

Other Approaches

- **Supraclavicular (Fig. 16-4).**
  - Indication.
    - Mid- to distal subclavian artery injury.
  - Procedure.
    - Make an incision 2 cm above and parallel to the clavicle, beginning at the sternal notch and extending laterally 8 cm.
- **Trap door (Fig. 16-5).**
  - Indication.
    - Proximal left subclavian artery injury.
  - Procedure.
    - Perform supraclavicular approach as previously described.
    - Perform a partial median sternotomy to the 4th intercostal space.
    - At the 4th intercostal interspace, incise the skin laterally in the submammary fold to the anterior axillary line.
    - Divide the sternum laterally and continue in the 4th intercostal space to the anterior axillary line. The internal mammary artery will be divided and must be controlled.
    - It may be necessary to either fracture or remove a section of the clavicle to gain adequate exposure of the proximal left subclavian artery.

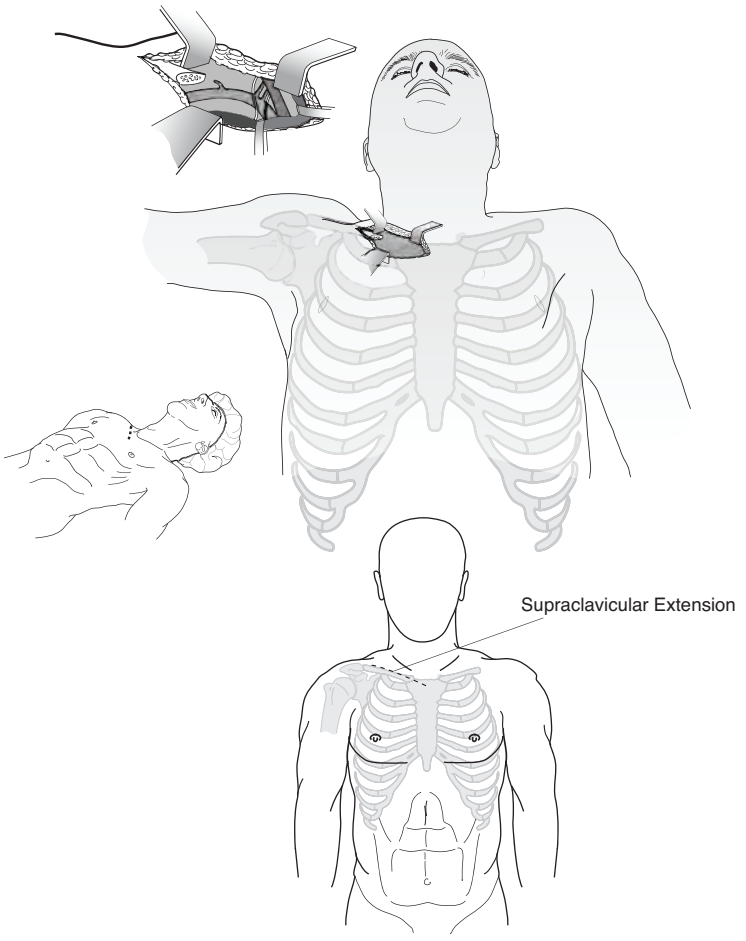

Fig. 16-4. Supraclavicular approach.

- ♦ Approach distal left subclavian artery injuries through a supraclavicular incision.

- **Thoracoabdominal.**
  - Indication.
    - ♦ Combined thoracic and abdominal injuries.
  - Procedure.
    - ♦ The resuscitative thoracotomy can be continued medially and inferiorly across the costal margin into the abdominal midline to complete a thoracoabdominal incision.

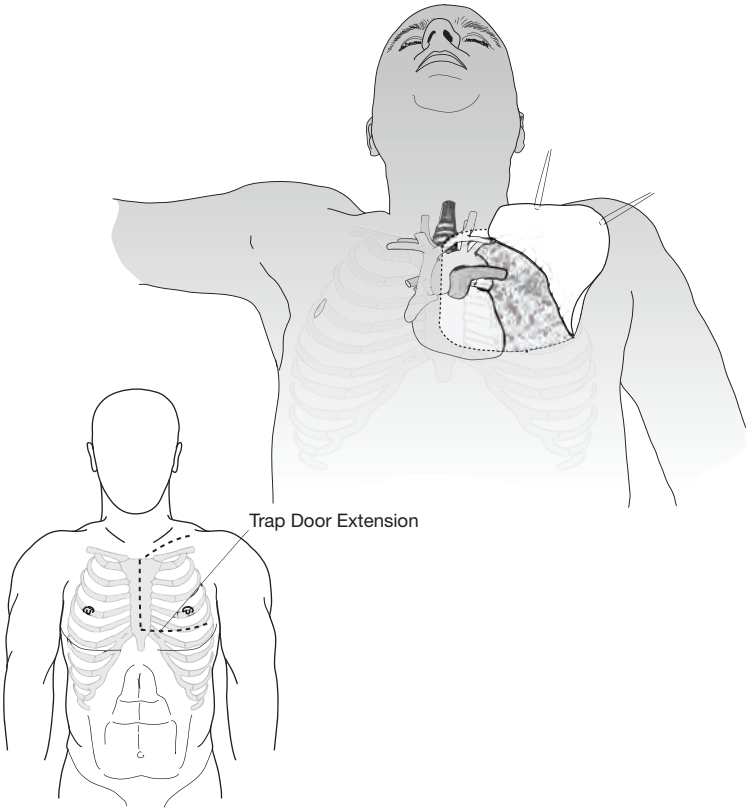

Fig. 16-5. Trap door procedure.

- ♦ Alternatively, a separate abdominal incision can be made.
- ♦ With right-sided lower chest injuries, the liver and retrohepatic vena cava can be exposed well using a right thoracoabdominal approach.

Specific Injuries

- **Vascular.**
  - Initially, holes in vessels should be digitally occluded. Stopgap measures include placing Fogarty or Foley catheters, side-biting clamps, or—in the case of venous injuries—sponge sticks.

- Total occlusion or clamping may temporarily be necessary to allow resuscitation to continue and restore cardiac function.
- If cardiac function cannot be restored within 5 to 10 minutes, the procedure should be abandoned (on-the-table triage) and the patient managed expectantly.
- Repair of vessels should follow the principles detailed in Chapter 25 (Vascular Injuries), with shunting or repair by autogenous or synthetic grafts as indicated.

- **Heart.**

The usual result of high-velocity injuries to the heart is irreparable destruction of the muscle.

- Isolated punctures of the heart should be exposed (opening the pericardium) and occluded by finger pressure. Other methods include the use of a Foley catheter or skin staples.
- Use pledgeted horizontal mattress sutures (2-0 PROLENE) on a tapered needle for definitive repair. **Care must be taken to avoid additional injury to coronary vessels.** Extreme care must be taken to avoid tearing the cardiac muscle. Autologous pericardium can be used if commercial pledgets are not available (Fig. 16-6).
- Atrial repairs may include simple ligature, stapled repair, or running closures.
- Temporary inflow occlusion may prove helpful in repair.
- More complex repairs are impractical without cardiac bypass.

- **Lung.**
  - **Tube thoracostomy alone is adequate treatment for most simple lung parenchymal injuries.**
  - **Large air leaks not responding to chest tubes** or that do not allow adequate ventilation will require open repair (see section on "Tracheobronchial Tree").
  - **Posterolateral thoracotomy is preferred for isolated lung injuries.** Anterior thoracotomy may also be used.
  - Control simple bleeding with absorbable suture on a tapered needle. Alternatively, staples (eg, TA-90) may be used for bleeding lung tears.

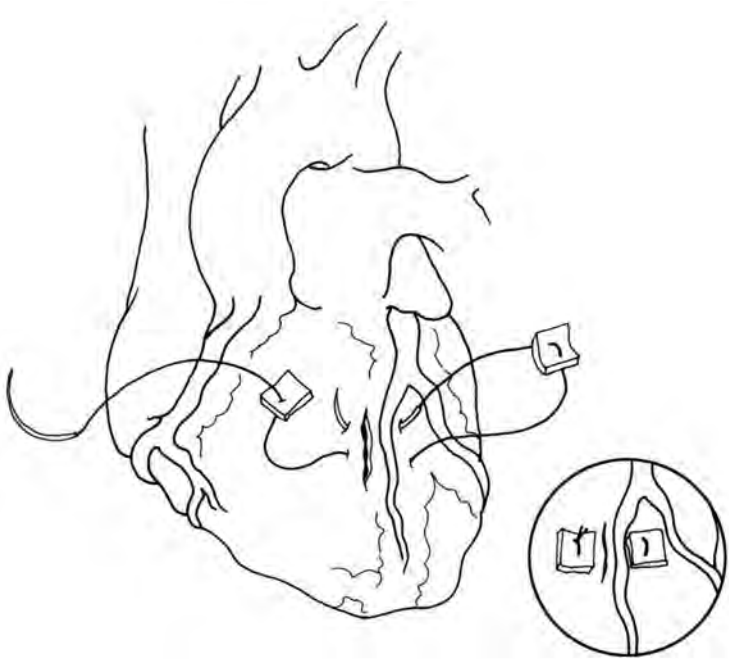

Fig. 16-6. Repair of penetrating cardiac injury.

- **Tractotomy**: Open any bleeding tracts (through-and-through lung penetrations) with a GIA stapler or between straight vascular clamps and ligate bleeding points.

Do not simply close the entrance and exit points of penetrating tracts in the lung. With positive pressure ventilation, the risk is air embolism. The more central the injury, the higher the risk.

- Resection for bleeding may be indicated with severe parenchymal injury. Anatomical resections are not indicated, and simple stapled wedge excisions are recommended.
- Uncontrolled parenchymal/hilar bleeding, or complex hilar injuries with massive air leak, should be controlled with hilar clamping and repair attempted. Pneumonectomy is performed as a last resort, because survival is very low.

- **Tracheobronchial tree.**
  - Suspect the diagnosis with massive air leak, frothy hemoptysis, and pneumomediastinum.
  - Confirm by bronchoscopy.
  - Airway control is paramount.
  - Median sternotomy is best approach.
  - Repair over endotracheal tube with absorbable suture—may require segmental resection. Bolster with pleural or intercostal muscle flap, especially between the trachea and esophagus.
  - Temporizing measures include:
    - Single lung ventilation.
    - Control the airway through the defect.
- **Esophagus.**
  - Isolated thoracic esophageal injuries are exceedingly rare. They will usually be diagnosed incidentally associated with other intrathoracic injuries.
  - Diagnostic clues include pain, fever, leukocytosis, cervical emphysema, Hamman's sign, chest X-ray evidence of pneumothorax, mediastinal air, and pleural effusion. Contrast swallow may confirm the diagnosis.
  - Start IV antibiotics as soon as the diagnosis is suspected, and continue post-op until fever and leukocytosis resolve. This is an adjunctive measure only. **Surgery is the definitive treatment.**
  - For stable patients in a forward location, chest tube drainage and a nasogastric tube placed above the level of injury are temporizing measures. Ideally, primary repair is performed within 6–12 hours of injury. Beyond 12 hours, isolation of the injured segment may be necessary.

The preferred approach for intrathoracic esophageal injuries is posterolateral thoracotomy: right for the upper esophagus and left for the lower esophagus.

  - Locate the injury by mobilizing the esophagus. Primarily repair with a single layer or two layers of 3-0 absorbable sutures and cover with the pleural or intercostal muscle flap.
  - Drainage with chest tubes (one apical, one posterior) is recommended.

- If unable to primarily repair (as with a large segmental loss or severely contaminated/old injury), staple above and below the injury, place a nasogastric tube into the upper pouches, and place a gastrostomy tube into the stomach. Drain the chest as indicated previously. Complex exclusion procedures are not indicated in a forward operative setting.
- An alternative when the esophageal injury is too old for primary repair is to close the injury over a large T-tube, which converts the injury to a controlled fistula. The mediastinum is then widely drained using chest tubes or closed-suction catheters placed nearby. After a mature fistula tract is established, slowly advance the T-tube; later, the mediastinal drains can be slowly advanced.

- **Diaphragm.**
  - All injuries of the diaphragm should be closed.
    - Lacerations should be reapproximated with nonabsorbable 0 or 2-0 running or interupted sutures.
    - Care should be exercised in the central tendon area to avoid inadvertent cardiac injury during the repair.
  - If there is significant contamination of the pleural space by associated enteral injuries, anterior thoracotomy and pleural irrigation and drainage with two well-placed chest tubes should strongly be considered.
    - Inadequate irrigation and drainage, such as when attempted through the diaphragmatic defect via the abdomen, can lead to a high incidence of empyema.

For Clinical Practice Guidelines, go to
http://usaisr.amedd.army.mil/clinical_practice_guidelines.html