



Thoracic trauma

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Approximately 25% of nonmilitary trauma-related deaths are due to thoracic trauma.¹ The majority of deaths occur after the patient reaches the hospital. Death will occur in about one third of the patients in which two or more organ systems are involved. Penetration and blunt force are the two mechanisms that cause thoracic trauma. Normal thoracic anatomy is shown in Figures 1 and 2. Penetrating thoracic trauma will cause pneumothorax in nearly all cases, with hemothorax seen in more than 75% of these cases. One third of the cases of penetrating trauma will be associated with abdominal injuries. Blunt trauma may be due to: compression (organ rupture), direct trauma (fracture), or acceleration/deceleration forces (vessel shear and tear).¹

This article discusses several major types of traumatic thoracic injuries.



General considerations

Patients sustain blunt thoracic trauma and develop acute respiratory distress have a very high mortality rate.² (Table 1) Of the patients that experience shock with respiratory distress, three fourths will die.¹

Patients that are diagnosed with respiratory distress will need airway control, optimal oxygenation, and possibly ventilatory support and resuscitation. At the time of hospital admission, 10% of these patients will require endotracheal intubation. Most likely, the respiratory problem is due to head trauma and/or spinal cord injury. Additionally, upper airway obstruction should be suspected if the patient is attempting to breathe with little or no air movement. Upper airway obstruction is common in comatose patients due to prolapse of the tongue into the pharynx. Other causes of upper airway obstruction include vomitus or blood clots within the pharynx, larynx, or upper trachea.

If laryngeal trauma is suspected, an endoscopy should be performed as soon as possible. Emergency tracheotomy may become necessary to treat total airway occlusion from any cause. Once the upper airway is determined to be intact and breath sounds remain poor, thoracic trauma should be suspected. Flail chest, hemothorax, pneumothorax, hemopneumothorax, diaphragmatic injury, or parenchymal lung damage should be considered. Table two

describes traumatic injuries to the thorax according to their location.

Subcutaneous emphysema

Subcutaneous emphysema is produced by penetrating or blunt injuries, generally to the lungs and parietal pleura, causing air to be forced into the tissues of the chest wall. The patient may display an initial pneumothorax; however, massive development of subcutaneous emphysema can delay the onset of pneumothorax. Generally, there is seldom reason to treat the subcutaneous emphysema; however, a cervical incision is useful to allow trapped air to escape. Attention should be directed toward confirming the source of air leakage, which may be due to an esophageal perforation or major bronchial injury. Once the source of air leakage is determined, immediate treatment to solve the cause of the subcutaneous emphysema is implemented.

Mediastinal emphysema

Mediastinal emphysema occurs when air enters the areolar tissue from a tracheal or bronchial wound, or from a perforation of the esophagus. Blunt injuries to the chest may disrupt the bronchioles and alveolar units without disrupting the visceral pleura. Air moves into the pulmonary interstitium, centrally along the pulmonary and bronchial vessels until it reaches the mediastinum. If the mediastinal pleura stays intact,

Table 1: Patients with respiratory failure following blunt thoracic trauma¹

Type of Injury	Incidence %	Mortality Rate %
Flail chest/multiple rib fracture	75	52
Hemopneumothorax	55	39
Lung contusion	39	45
Extremity fracture	30	53
Intraabdominal	23	46
Intracranial	23	46
Myocardial contusion	13	57
Diaphragm	9	20
Paraplegia	4	100
Other	7	100

air dissects into the neck tissue, moving through the deep tissue planes and finally spreading into the subcutaneous tissue.

Flail chest

Flail chest is a crushing chest injury that implies disruption of the mechanism of respiration, resulting in paradoxical motion of the chest wall region. For flail chest to occur, at least two segmental fractures of three adjacent ribs or costal cartilages must occur (Figure 3). Combinations of rib and sternal fractures accompanied by costochondral or chondrosternal separations result in paradoxical respiratory motion which is characteristic of a flail chest.² There are three types of flail chest: lateral, anterior, and posterior. Flail chest injury may also be accompanied by pulmonary contusion, myocardial injury, pneumothorax, and hemothorax.

Myocardial contusion must be considered, especially with anterior chest wall traumas. A serial electrocardiogram, cardiac isoenzyme study, and radioisotope delineation of injured myocardium may be appropriate for correlation with clinical evidence of cardiac failure or pericardial friction rubs.

While the posterior flail chest is rare, it is the easiest to manage due to strong muscular and scapular support in the region and the patient's tendency to lie on his or her back. Respiratory distress with hypoxemia and intrapulmonary shunt, as seen in flail chest injuries, is often due to pulmonary contusion rather than the paradoxical motion of the overlying chest wall. The paradoxical motion of the chest wall injury may become apparent only after the associated lung injury has produced a sharp reduction in pulmonary compliance and a severe increase in respiratory effort. Pneumothorax is often present in severe flail chest injuries, and in these patients, placement of an intercostal catheter may relieve the respiratory distress.

The two main concepts for treatment of flail chest are chest-wall stabilization and reduction of intrathoracic dead space. Treatment options for stabilizing a flail chest include the use of an external compression dressing, application of

traction (by encircling the fractured ribs with towel clips or wire), and mechanical ventilation. Improvements in respiratory therapy and the increased availability of arterial blood-gas studies have improved the outcomes for patients with flail chest injuries.² Mild to moderate flail chest injuries can often be managed without a ventilator by:

- Relief of pain (intercostal nerve block or analgesic)
- Physiotherapy of the chest
- Restriction of IV fluids to prevent volume overload.¹

Ventilatory support may be implemented if the patient's arterial PO_2 falls below 80 mm Hg

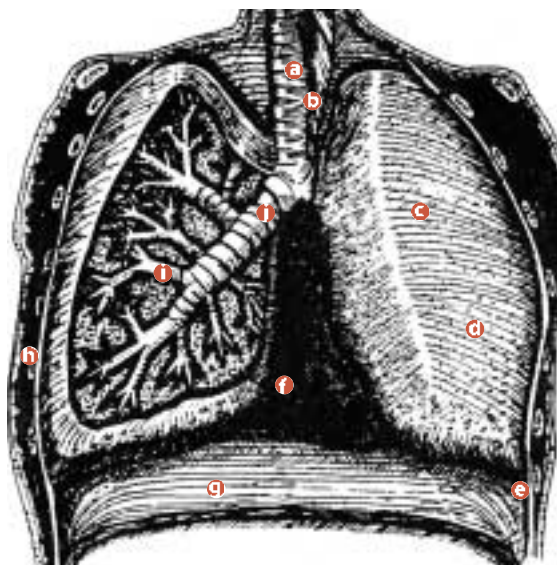


FIGURE 1

Thoracic cavity

- a trachea
- b mediastinal space
- c visceral pleura
- d left lung
- e parietal pleura
- f pericardial sac
- g diaphragm
- h rib
- i secondary bronchi
- j right primary bronchus

while on supplemental oxygen. Ventilatory support is necessary if: the patient is in shock; suffers from three or more associated injuries; has severe head trauma, preexisting pulmonary disease, or fracture of eight or more ribs; or is 65 years old or older.¹ Early ventilatory support in patients with flail chest trauma can reduce mortality by about 7%. Patients not given immediate ventilatory support have a mortality rate of 65% or greater. Early diagnosis and prompt medical management can greatly reduce mortality.

Pulmonary contusion

Pulmonary contusion is defined as direct damage to the lung resulting in both hemorrhage and

edema in the absence of a pulmonary laceration. It has a very high morbidity and mortality rate following penetrating and blunt trauma. Modern diagnostic techniques, such as the CT scan, have made recognition of this common problem much more frequent. Opacification seen on X-ray within six hours of trauma generally is considered to be a pulmonary contusion.

The most common cause of this type of trauma is a compression/decompression injury to the chest, such as may occur during a high-speed automobile crash. Airbags can lessen but do not entirely prevent this type of injury. A compression/decompression injury occurs when a high-pressure wave within the thoracic cavity is

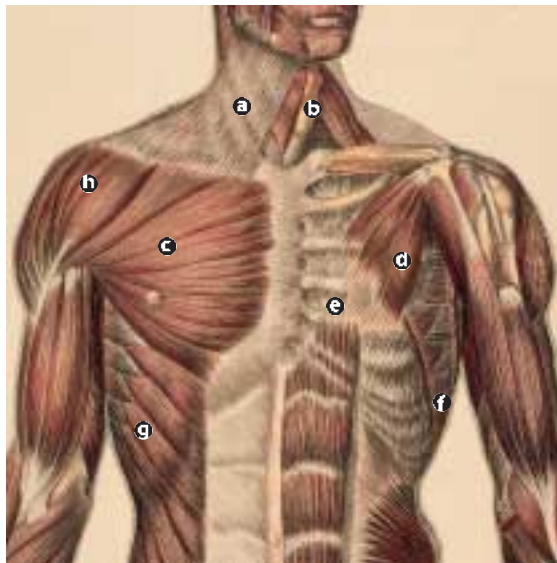
and blood out of the capillaries and into the interstitium and alveoli. During this process, the congestion and contusion continue to the next uninjured segment of the lung. Changes within the capillaries leads to extravasation of red blood cells and the accumulation of edema fluid within the interstitium. These processes do not occur simultaneously, but rather in a sequence. The main problem is intra-alveolar hemorrhage and edema followed by a course of fluid resuscitation. The hemorrhage and edema, together with an accumulation of debris and mucous secretions, cause pulmonary atelectasis to occur, leading to large areas of unventilated but still perfused lung. Intrapulmonary shunting is increased, as is the resistance to airflow, causing an increase in respiratory effort to move oxygen into and carbon dioxide out of the lungs. Pulmonary ventilation is decreased, and the patient becomes hypoxic, hypercarbic, and acidotic. As a result, the heart will try to adapt to an increase in cardiac output, but because of the hypoxia, cardiopulmonary decompensation will occur quickly.

Treatment of pulmonary contusion generally involves maintenance of adequate ventilation of the lungs. Chest physiotherapy, intercostal nerve blocks, epidural analgesia, and nasotracheal suction are necessary to ensure the patient is adequately oxygenated.

FIGURE 2

Muscles of the chest wall

- a** platysma muscle
- b** sternocleidomastoid muscle
- c** subclavius
- d** pectoralis major
- e** pectoralis minor
- f** intercostal muscle
- g** serratus anterior
- h** deltoid muscle



caused by rapid compression. As the wave moves through the chest wall, the pressure wave reaches the lungs, causing an instant increase in intrathoracic pressure followed by an instant drop (decompression).²

Pulmonary contusion has two stages: the first is related to the initial injury; the second to resuscitative measures and massive fluid overload. Administration of fluids to patients with unilateral pulmonary contusion can cause extravasation of fluid to the contralateral (uninjured) lung. A reduction in the pulmonary vascular resistance of the uninjured lung causes the right side of the heart to increase hydrostatic pressure within the capillaries to force both fluid

Hemothorax

Hemothorax is most frequently caused by bleeding from lung injuries. Only 5 to 15% of patients with hemothorax require thoracotomy, due to the fact that the bleeding in the chest, along with a high concentration of thromboplastin in the lungs and low pulmonary arterial pressure, reduces the chance of surgery.² A volume of more than 300-500 ml of blood in the chest cavity must be removed completely as soon as possible. In the chest, large clots act as local anticoagulant by releasing fibrinolytics and fibrogenolytics from their surface. A large amount of blood in the chest can also restrict ventilation and venous return. Bleeding from multiple small intrathoracic vessels will often

Table 2: Types of thoracic trauma

1. Trauma to the outer region of the chest

- A. subcutaneous emphysema
- B. paradoxical respiration (flail chest)
- C. open pneumothorax

2. Trauma to the inner region of the chest

- A. closed pneumothorax
- B. hemothorax
- C. secretional obstruction of the lower airways (as in pulmonary contusion, “wet lung,” and aspiration pneumonitis)

3. Trauma to the innermost region of the chest

- A. mediastinal emphysema
- B. cardiac tamponade
- C. compression atelectasis (trauma to the diaphragm)

stop fairly rapidly after the volume of blood is completely removed.

Hemothorax should be suspected following trauma if: breath sounds are reduced; the chest is dull to percussion on the involved side; or fluid collections greater than 300 ml are seen on upright or decubitus roentgenograms of the chest. Treatment depends on the size of the hemothorax. Large hemothoraxes should be treated by insertion of a chest tube (tube thoracostomy).

Blood that collects within the pleural cavity causes a reduction in the vital capacity of the lung and an increase in intrathoracic pressure, thereby decreasing minute ventilation and venous return to the heart. During inspiration, the negative intrapleural pressure increases the tendency for blood and air to leak into the pleural cavity through the wound in the lung or chest wall. The patient with an upper airway obstruction has additional air forced into the pleural space during expiration, increasing the possibility of a tension pneumothorax because the intrapleural pressure exceeds atmospheric pressure.

Pneumothorax

Pneumothorax is the presence of air in the pleural space (Figure 4). Chest X-ray upon admission to the emergency department is the ideal diagnostic tool. However, a clinical diagnosis can be made based on the following criteria:

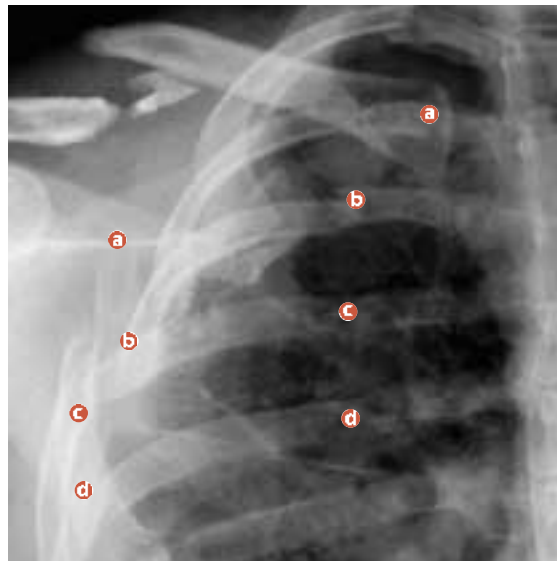


FIGURE 3
Flail chest detail

- a** rib 3—two fractures
- b** rib 4—two fractures
- c** rib 5—two fractures
- d** rib 6—two fractures

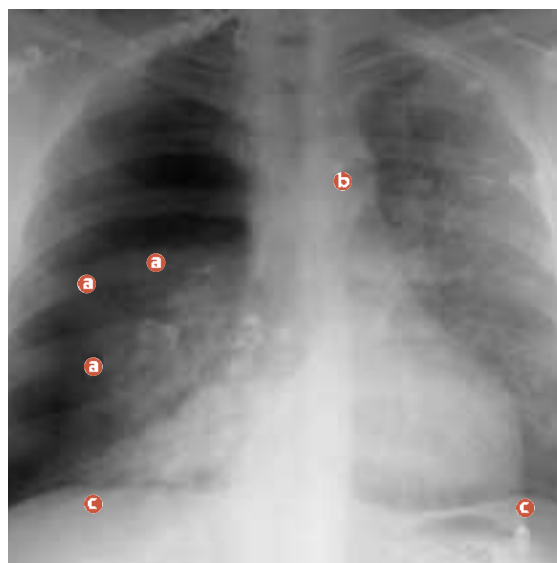


FIGURE 4
Pneumothorax

- a** pleural edge
- b** mediastinum at midline
- c** hemidiaphragms at equal heights

- Severe respiratory distress
- Distended neck veins
- Decreased breath sounds and hyperresonance unilaterally
- Deviation of the trachea away from the affected side.²

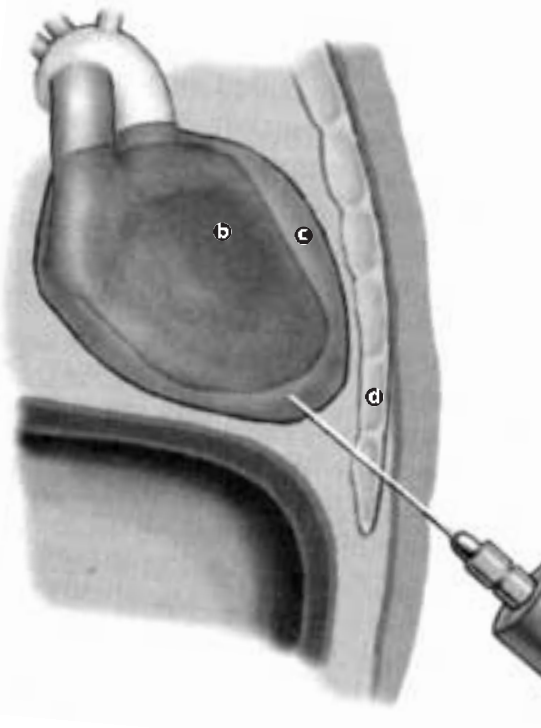
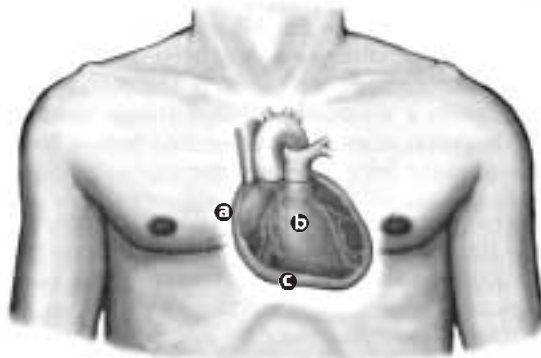
When pneumothorax is suspected, but not seen clearly on the first chest X-ray, an expiratory film may be helpful. The patient may not show severe symptoms of pneumothorax unless: it occurs in patients with shock or preexisting cardiopulmonary disease; it is a tension pneumothorax; or it occupies more than 40% of the hemothorax.²

FIGURE 5

Emergency

pericardiocentesis

- Ⓐ pericardium
- Ⓑ heart
- Ⓒ blood
- Ⓓ sternum



The patient with a small stab wound may experience a delayed pneumothorax that can occur 12 or more hours following the trauma. Serial chest X-rays every six hours for 12 to 24 hours are generally indicated in these patients. Following observation and repeated chest X-rays, the patient may be discharged if no other problems are noted.

When pneumothorax is assumed, treatment should be started without waiting for a chest X-ray. Treatment of pneumothorax consists of placement of a large needle into the involved pleural space through a midclavicular or second intercostal space puncture and aspirating any air. This procedure can also confirm the diagnosis of the pneumothorax and may provide temporary relief until a tube thoracostomy can be performed. If a pneumothorax persists in spite of one or more well-placed chest tubes, an emergency bronchoscopy should be performed to clear the bronchi and identify any damage to the tracheobronchial tree that may need repair. Continued air leakage and failure of the lung to expand adequately is an indication for early thoracotomy.²

Trauma to the diaphragm

The most common cause of a diaphragmatic injury is penetrating trauma, particularly gunshot wounds to the lower chest or upper abdomen. Diaphragmatic injury due to blunt trauma is less frequent, only occurring in 4 to 5% of patients with diaphragmatic injury. If a rib fracture is present, the incidence of diaphragmatic injury due to blunt trauma increases to 8 to 10%.²

Rupture of the diaphragm can cause serious ventilatory problems, but the initial signs and symptoms are generally masked by other injuries. If the diaphragmatic injury is large, the intestinal viscera enters the chest cavity immediately. On the other hand, if the diaphragmatic defect is small, the intestinal viscera may take time to move into the chest cavity, eventually becoming obstructed or strangulated, leading to the formation of a tension pneumothorax.

Generally, patients suffering penetrating diaphragmatic injury are diagnosed according to

the location of an entrance wound or intraoperatively. Fifty percent of diaphragmatic injuries are diagnosed surgically (via thoracotomy or laparotomy). Patients suffering blunt trauma may show an abnormality of the lower lung fields or diaphragm on chest X-ray. Additionally, diaphragmatic injuries may be diagnosed using the following methods.

1. Peritoneal lavage with a chest tube in place
2. Upper GI series
3. Pneumoperitoneum with carbon dioxide
4. CT scan with contrast
5. Intraperitoneal technetium sulfur colloid.²

Optimal repair of a diaphragmatic injury occurs during laparotomy.

Cardiac tamponade

Cardiac tamponade may be caused by penetrating or blunt trauma to the chest, due to an accumulation of blood within the pericardial sac. The most common penetrating cause of cardiac tamponade is a stab wound to the mid-chest; while blunt compressive forces to the anterior heart cause rupture of the right atrium. Due to the injury, blood fills the pericardial sac causing pressure within the sac to rise rapidly. During this time, the right ventricle may be able to maintain enough blood volume to sustain life for a short interval. The patient will show the same symptoms as seen with a tension pneumothorax. Both cardiac tamponade and tension pneumothorax will cause obstruction of venous return to the heart. Patients will have hypoperfusion, and distended neck veins. As the tamponade progresses, the heart sounds will also be muffled and become more distant as the pericardial pressure increases.²

The initial treatment is emergency pericardiocentesis (Figure 5), followed by surgical intervention, if necessary, to control bleeding. The patient should be given an intravenous bolus of fluid to fill the right atrium and increase cardiac output. Aspiration of 5 to 10 ml of blood can substantially improve cardiac performance and outcome.

Conclusion

Rapid diagnosis and immediate treatment are necessary when chest trauma is suspected. Modern radiographic techniques, blood laboratory studies, and pulse oximetry give the patient care team valuable diagnostic treatment shortly after admission to the emergency department allowing treatment to be implemented within minutes, lowering the mortality rate.

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References

1. Tintinalli JE. *Emergency Medicine*. New York: McGraw-Hill; 2000.
2. Schwartz SI. *Principles of Surgery*, 4th ed. New York: McGraw-Hill; 1984
3. Active First Aid Online—Chest Injuries www.parasolemt.com.au Accessed 1-9-01
4. Medic Boss—Chest and Abdominal Injuries www.cyberramp.net/~johnholt/chest%20and%20abdominal%20injuries Accessed 1-9-01
5. Trauma.org—Thoracic Trauma www.trauma.org/thoracic/index.html Accessed 1-9-01
6. Virtual Hospital—Chest Trauma www.vh.org/Providers/TeachingFiles/M3M4TeachingModules/Mullan/ChestTrauma.html Accessed 1-9-01

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1. **Pneumothorax is defined as ____.**
 - A. blood within the pleural space
 - B. air within the pleural space
 - C. chyle within the pleural space
 - D. pus within the pleural space

2. **Under normal circumstances, lung expansion is maintained by ____.**
 - A. positive pressure within the pleural cavity
 - B. negative pressure within the pleural cavity
 - C. positive pressure mechanical ventilation
 - D. atmospheric pressure within the pleural cavity

3. **Following pneumothorax, lung expansion is maintained with the use of ____.**
 - A. positive pressure mechanical ventilation
 - B. tracheotomy
 - C. thoracotomy
 - D. tube thoracostomy

4. **Treatment options for flail chest include ____.**
 - A. mechanical ventilation
 - B. stabilization
 - C. pain control
 - D. all of the above

5. **The term opacification refers to ____.**
 - A. application of a sequential compression device
 - B. a large hemothorax
 - C. the development of a white spot on a X-ray
 - D. spasm of the heart

6. **Emergency pericardiocentesis is used to treat ____.**
 - A. cardiac tamponade
 - B. pneumothorax
 - C. trauma to the diaphragm
 - D. None of the above

7. **What is the most common cause of diaphragmatic trauma?**
 - A. blunt trauma
 - B. penetrating trauma
 - C. tension pneumothorax
 - D. increased intrathoracic pressure

8. **Which of the following is the best approach to treating a diaphragmatic injury?**
 - A. tube thoracostomy
 - B. median sternotomy
 - C. thoracotomy
 - D. laparotomy

9. **Cardiac tamponade is described as ____.**
 - A. blood contained within the pleural space
 - B. air contained within the pericardial sac
 - C. blood contained within the pericardial sac
 - D. massive fluid overload

10. **Cardiac tamponade may be difficult to diagnose because the patient will show the same symptoms as ____.**
 - A. pneumothorax
 - B. tension pneumothorax
 - C. diaphragmatic trauma
 - D. subcutaneous emphysema

Thoracic trauma

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