THE RADIOLOGY OF THORACIC TRAUMA

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THORACIC injury can take many forms, but can be classified into two broad groups, blunt and penetrating. Blunt injury may result from being struck by a heavy object, or it may occur as an impact injury such as being thrown against a steering column in an automobile accident. The shock wave of a blast injury can create a form of blunt injury to the thorax.

We often think of gunshot or stab wounds when penetrating injury is mentioned. Flying missiles from a myriad of causes such as high storm winds or from explosions can cause penetrating thoracic injury.

Combinations of blunt and penetrating injury also occur. When injury is sustained from a high velocity bullet not only is there the obvious penetrating wound but blunt injury as well. The shock wave created by the bullet dissipates energy from the bullet as it slows. The energy lost in the soft tissues is related to the change in the velocity as

$$E_{dissipated} = \int_{v_1}^{v_2} mv\ dv$$

In its final form the energy dissipated is a function of the differences in the square of the velocity

$$E_{dis} = 0.5m(v_1^2 - v_2^2)$$

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With low velocity missiles this energy wave is usually inconsequential, but marked slowing of a high velocity missile will deposit tremendous energy in a small volume to produce an injury which is often more severe and life threatening than the penetrating injury alone.

Severe thoracic injury requires that crucial diagnostic decisions be made with rapidity, employing a limited number of imaging examinations. Close cooperation and precise communication between the radiologist and referring physician are required. Whenever possible, standard posteroanterior and lateral chest radiographs should be obtained, but in the clinical setting of acute thoracic injury this is usually not possible. During the interval required for patient stabilization, the anteroposterior chest radiograph is the primary imaging procedure available to the radiologist to evaluate the nature and severity of the thoracic trauma. Most thoracic injuries can be detected by careful review of well-performed anteroposterior radiographs. Other examinations, such as thoracic aortography and contrast esophagography, may be indicated subsequent to this review but the anteroposterior radiograph will provide the diagnostic information required for initial therapy and patient stabilization. After stabilization, more complex and time-consuming imaging examinations can be performed.

Technique

Optimal anteroposterior positioning for chest radiography places the patient in erect or semierect posture when his condition and injuries permit. The thoracic spine is flat against the film cassette and the scapulae and humeri are rolled toward the x-ray tube. Patient rotation out of the anteroposterior plane must be minimized so that mediastinal components may be evaluated for displacement secondary to the injury. To minimize geometric variation from examination to examination, a minimum x-ray tube-to-film distance of 48 inches is used in the supine and 72 inches in the semierect or erect position. Radiographs may be obtained using either portable or permanently installed radiographic equipment. To minimize patient motion and radiation exposure, fast-speed film and screen combinations are employed, and preferred radiographic technique incorporates short exposure times and high kilovoltage beams.

Thoracic Fractures

In the thorax, injuries of the chest wall are the most common manifestation of mild thoracic trauma. Chest-wall contusion followed by contusion and associated rib fractures are the more frequent injuries. The treatment objective in these injuries is the relief of symptoms after more significant injury has been excluded. When subcutaneous emphysema is appreciated radiographically and no skin laceration is noted on the physical examination, a tear in either the visceral or parietal pleura should be suspected and the radiograph should be carefully examined for pneumothorax.

Fractures of certain ribs have a higher incidence of associated life-threatening injury. Injury to one of the first or second ribs alerts the radiologist to the possibility of a more serious injury such as a cardiovascular, tracheobronchial, or nervous system injury. The reported morbidity and associated mortality is high, with Harrison's series reporting a mortality rate of 36% in first rib fractures and 29% in second rib fractures.[1] Wilson reports the associated morbidity of first and second rib fractures is reported to be 72% and 53%, respectively.[2]

Fractures of the lower three ribs should alert the radiologist to possible direct injury to the liver, spleen, or other upper abdominal organs. Significant abdominal injury is associated with first and second rib fractures, with Wilson's series reporting a combined rate of approximately 17%.[2] The abdominal portion of the chest radiograph should be evaluated for signs of injury in patients with first and second rib fractures and lower rib fractures. The patient's history and physical examination should be reviewed with the consulting physician for findings suggestive of abdominal injury and to determine the need for possible abdominal organ imaging or laparotomy.

Pleural Fluid Collections

Traumatic pneumothoraces in most instances, and spontaneous pneumothoraces occasionally, are associated with small amounts of pleural fluid or hydrothorax. This fluid frequently is blood extravasated from tears in the pulmonary parenchyma and visceral pleura. Where pleural or parenchymal lacerations are small, bleeding often stops spontaneously. In more serious bleeding from the pulmonary or bronchial vessels, the expanding volume of blood tends to compress or to tamponade the soft tissues of the lung and to produce hemostasis.[3] In situations where serial chest radiographs demonstrate that the amount of pleural fluid appears to be increasing, a nonpulmonary source of bleeding should be suspected. A rib fracture with an isolated hemothorax is more often due to intercostal artery laceration secondary to the rib fracture. With more serious thoracic injury, laceration of the aorta or great vessels should be considered along with possible rupture of one of the major branches of the pulmonary artery. In this situation a widened mediastinum may be concomitantly present with an expanding hydrothorax or hemothorax.

Depending upon the amount of pleural fluid present and its composition, radiographic manifestations of the fluid will change in different projections. For small to moderate free pleural fluid collections, the only anteroposterior radiographic finding may be a uniform increase in the density of the entire hemithorax. In this situation, when a pleural effusion is suspected, special views such as a lateral decubitus radiograph with the involved side dependent with respect to gravity can be used. Often it is helpful to obtain the opposite decubitus view to evaluate the suspected pleural effusion for loculation and to evaluate the opposite lung for an unsuspected small effusion. An alternate view is an erect anteroposterior chest radiograph which may be helpful in clinical settings where patient movement is limited, such as in the presence of multiple unilateral rib fractures. When the amount of pleural fluid is small and pneumothorax coexists, an air-fluid level in the erect examination or in the decubitus view may be the only radiographic finding of a small hydropneumothorax (Figure 1).[4]

Moderate to large pleural effusions tend to envelop the lung, and costophrenic angle may blunt as increased density presents between the aerated lung and the chest wall. Fluid may also insinuate between the lung fissures to produce a pseudotumor.

In patients with pleural opacities where no appreciable fluid shift is identified by changing radiographic positions, densities may represent loculated pleural fluid. Radiographically, the radiologist cannot distinguish between loculated pleural fluid or other pleural or peripheral lung processes. In this clinical setting, thoracic ultrasonography can be very useful in guiding diagnostic thoracentesis or chest tube placement.[5]

Pulmonary Parenchymal Trauma

Pulmonary contusion. Pulmonary contusion is the most frequent radiographic abnormality in patients who have sustained significant blunt

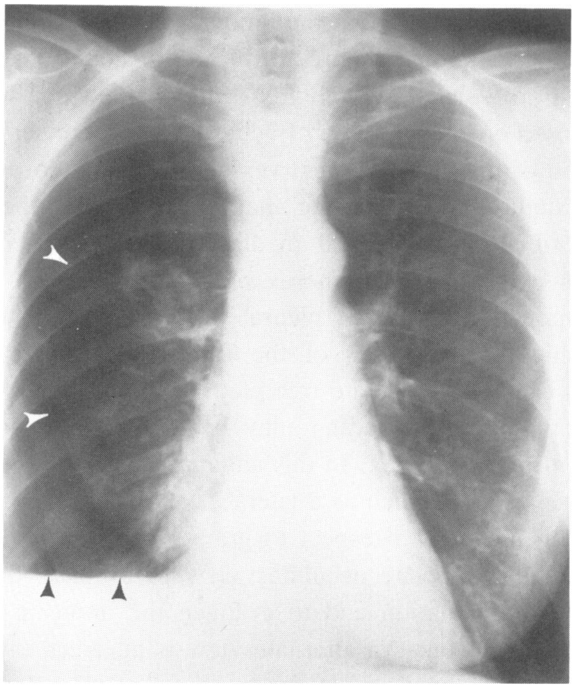


Fig. 1. This middle aged woman came to the Emergency Room following right sided blunt chest trauma. The admission radiograph at that time reveals an air-fluid level with a moderate sized pneumothorax. The air-fluid level (black arrowheads) indicates both fluid, probably blood, and air within the pleural space. The pneumothorax is confirmed by identification of the visceral pleural line (white arrowheads).

thoracic trauma.[6] The radiographic manifestations have two patterns. One is a coarse, patchy, stringy, density thought to represent extravasation of blood along the terminal bronchopulmonary tree. The other predominant pattern is a diffuse homogeneous pattern relating to extravasation of blood and fluid into the alveoli (Figure 2). Frequently, the pattern identified is related to both processes occurring in the injured lung.

Radiographic findings of pulmonary contusion progress during the first day after injury and pulmonary densities clear rapidly during the following two to three days. Those patients having post-traumatic pulmonary densities compatible with pulmonary contusion who do not follow this sequence of delayed clearing should be investigated for such other causes of pulmonary abnormalities as infection, an unrecognized endobronchial obstructing lesion, pulmonary hematoma, or recurrent pulmonary hemorrhage.[7,8]

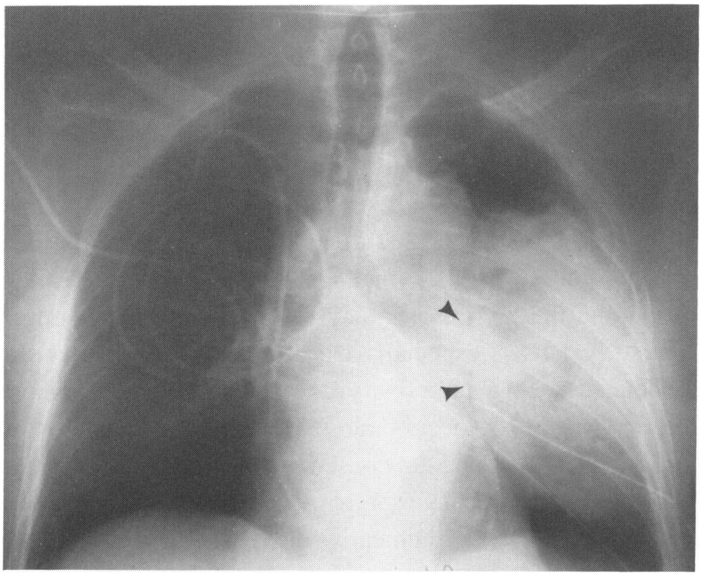


Fig. 2. This 35-year-old man presented with decreased breath sounds on the left following blunt chest trauma. Note the large homogeneous density in the left midlung with air bronchograms (black arrowheads). Fluid is also present in the pleural space. This large left midlung density represents a pulmonary contusion.

Pulmonary laceration. Rents in the pulmonary parenchyma are most commonly caused by such penetrating traumas as stab wounds or bullet wounds. Blunt chest injury, however, can produce substantial pulmonary laceration.[9] When the laceration is large a pulmonary hematoma results. Depending upon the severity of the blunt injury, the laceration may be totally within the pulmonary parenchyma or may extend to the pleural surface to involve both the pulmonary parenchyma and visceral pleura with extravasation of blood into the pleural space. On the chest radiograph the pulmonary contusion, associated with and surrounding the pulmonary laceration, usually masks the laceration.[6] For this reason pulmonary lacerations and their associated hematomas are often diagnosed retrospectively after the pulmonary contusion is in its resolution phase. Single, isolated lacerations are most common but multiple lacerations may occur.

Radiographically the pulmonary laceration and associated hematoma is identified as a radiodensity either spherical or elliptical in configuration. The hematoma is contained within a thin-walled cavity, the defect resulting from the laceration, in which air may be initially trapped to produce an air-fluid level.[10] In those instances where the cavity is completely filled with blood initially, a crescent of air may later develop within the cavity as the clot contracts.[6] The resolution time of pulmonary hematomas varies widely and some persist as long as a year after the injury.

Pulmonary laceration without an associated hematoma may trap air and produce a spherical or oval cavity surrounded by a thin membrane. The resultant pneumatocele usually has a variable course and resolves within one to three weeks. It may persist as long as several weeks. The residual is usually a pulmonary parenchymal scar.[11] Pulmonary lacerations related to penetrating and missile injuries may follow a different radiographic and clinical course.[12] This is especially true for high velocity missile injuries where, associated with a pulmonary contusion, a large amount of tissue destruction and necrosis occurs along the missile track. Complicated lacerations may not respond to conservative medical therapy and many persist for months, requiring surgical resection of the nonresponding involved segment.[12] Radiographically these cavities persist unchanged, with a thick wall of tissue surrounding the cavity.

EXTRAPULMONARY AIR

Extrapulmonary air in patients with an injured thorax groups all patients with pneumomediastinum, pneumothorax, and extrapleural air into one broad category. The air is a manifestation of the interruption of the integrity of the thorax and relates to different aspects of thoracic injury.

Pneumothorax. A pneumothorax is an abnormal collection of air in the pleural space between the visceral and parietal pleura. In acutely injured patients, the clinical significance of a pneumothorax may not relate to the volume of air trapped in the pleural space. Quantitation of the amount of air is difficult and such general categories as small, moderate, and large provide referring physicians adequate information to initiate therapy. In patients with blunt thoracic injuries, the pneumothorax is most frequently associated with laceration of the visceral pleura produced by large shearing forces.[8] In penetrating injuries, air may enter from a laceration of the visceral pleura or from direct access from the wound tract itself across the parietal pleura. This direct access is most dramatically illustrated by "sucking" chest wounds as air enters and leaves the pleural space with each respiration.

Tension pneumothorax is a special form in which air trapped in the pleural space is under considerable pressure, collapses the associated lung, and depresses the associated hemidiaphragm. The mediastinum is shifted

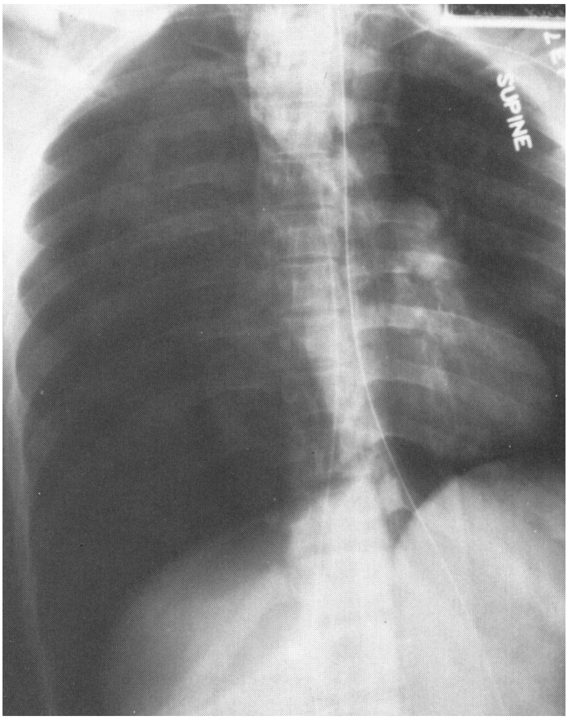
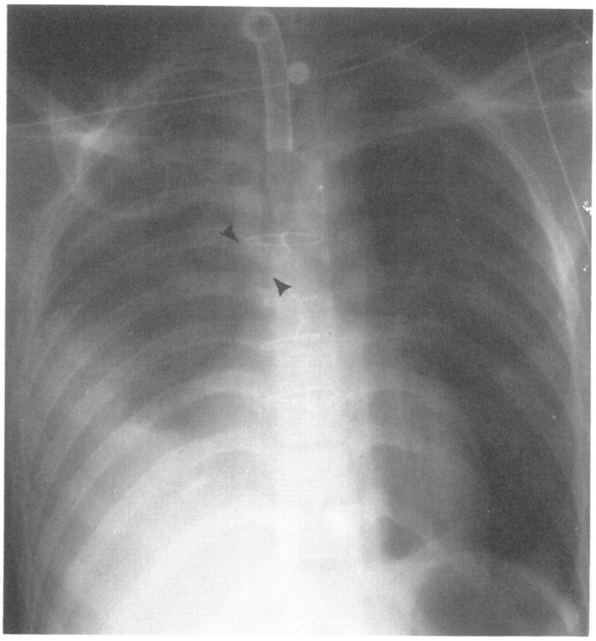


Fig. 3*a*, *b*. This 27-year-old man was brought to the Emergency Room after an automobile slipped off a jack onto his thorax. He had decreased breath sounds on the right. The radiograph at that time reveals tension pneumothorax with a moderate amount of air in the pleural space, shift of the mediastinal structures to the left and depression of the right hemidiaphragm (Figure 3*a*). Follow-up radiographs two weeks later revealed increasing opacification of the right hemithorax (Figure 3*b*). The discontinuity of the right main-stem bronchus (black arrowheads) demonstrates the site of the bronchial rupture.

into the opposite hemithorax and produces atelectasis in the contralateral lung (Figure 3*a*). The cardiorespiratory embarrassment caused by tension pneumothorax can be severe, life-threatening, and require immediate therapy.

Perception of a pneumothorax in the anteroposterior radiograph can be difficult, especially if the pneumothorax is small and the patient is supine because of distribution of the small volume of air over the large anterior surface of the lung. When this happens the only indication of a pneumothorax may be a lucency in the region of the costophrenic angle. Because small pneumothoraces can be hidden from perception, whenever possible erect radiographs should be obtained using a horizontal beam. The relative



size of a pneumothorax can be enhanced by obtaining the exposure in expiration. In expiration, air within the pleural space has no ready path for escape and the relative percentage of this trapped air compared to the total volume within the hemithorax is increased. Very small pneumothoraces may be obscured to the point of undetection in a patient in full inspiration. The most important radiographic finding in the diagnosis of a pneumothorax is the highlighting of the visceral pleura by the intrapleural air producing the visceral pleural line (Figure 1).

Delayed injury and followup. Subsequent to therapy and stabilization of the chest-injured patient, radiography is used to define the efficacy of therapy. Placement of a chest tube can be determined on the radiograph. The efficacy of removal of both air and pleural fluid is easily determined on erect or semierect anteroposterior radiographs. In patients with loculations or in patients in which the chest tubes employed are not functioning as they should, follow-up radiographs will delineate the areas that require further therapy.

In clinical situations where pneumothorax is large or where pneumothorax or pneumomediastinum is not responding to treatment, undiagnosed injury may be present or injury may have occurred during the course of therapy. Increases in pleural, mediastinal, or subcutaneous air are signs on

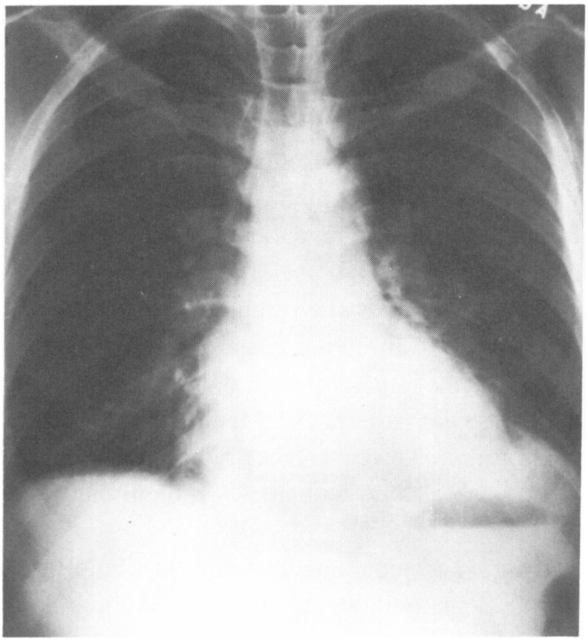
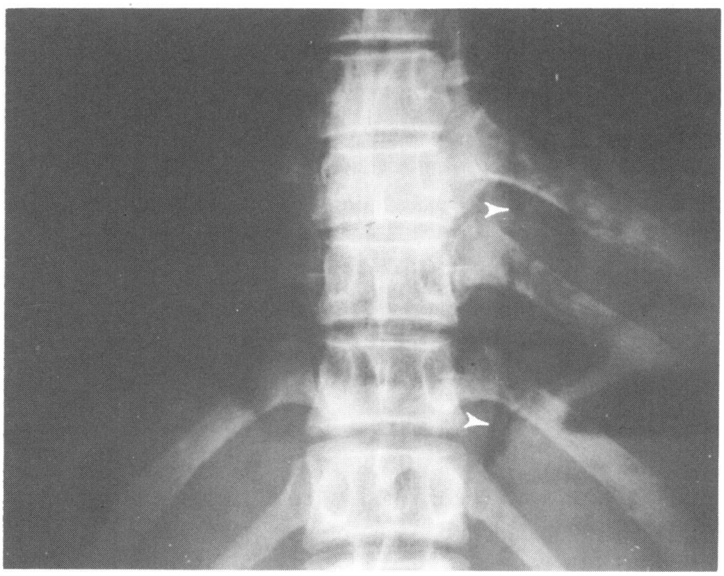


Fig. 4*a*, *b*. This 32-year-old man presented to the Emergency Room following an episode of violent vomiting. The preliminary chest radiograph reveals pneumomediastinum, an increased density behind the heart with obliteration of the left hemidiaphragm, and a left subpulmonic effusion (Figure 4*a*). The overpenetrated chest radiograph (Figure 4*b*) better demonstrates the pneumomediastinum as evidenced by linear gas shadows within the mediastinum (white arrowheads).



the chest radiograph that the response is incomplete. When such an undiagnosed injury as a ruptured larynx, bronchus, or esophagus is suspected, endoscopic evaluation of the airways or esophagus is required. More sophisticated radiographic evaluation also may be required to define the injury, including such modalities as tomography, contrast bronchography, and contrast esophagography.

Acquired barotrauma occurs in patients requiring endotracheal intubation and assisted ventilation.[13] A pneumothorax may result or persist in a situation where ventilation pressure ruptures an emphysematous bleb or an alveolus. Overinflation of an endotracheal tube cuff can produce tracheal necrosis and subsequent fistula formation into the mediastinum, esophagus, or adjacent vascular structures. Mediastinal air is one sign of the developing problem and prompts the radiologists to confer with the referring physician about the potential problem and the need for its investigation.

Pneumomediastinum. Pneumomediastinum can be a benign radiographic observation in patients with significant blunt thoracic injury (Figures 4*a* and 4*b*). In patients with pronounced injury, air can escape from the mediastinum into the pleural space to produce pneumothorax or tension pneumothorax. Air in the mediastinum under pressure can produce cardiovascular embarrassment which, if not treated immediately, may be fatal. Thus, careful correlation of the patient's clinical status and symptoms is required so that proper therapy and diagnostic evaluation will be undertaken.

A review of 200 cases of major blunt thoracic trauma revealed that 80 patients (40%) had subcutaneous emphysema or pneumomediastinum in the initial chest radiograph.[14] In these 80 patients, 10 (12.5%) suffered significant injury to the larynx, tracheobronchial tree, or esophagus. Two thirds of these patients had associated pneumothoraces. Ten patients had isolated pneumomediastinum with no apparent cause. In these 10 patients air was thought to have dissected from a ruptured distal airway or alveolus along the bronchovascular sheaths from the hilar regions into the mediastinum.

Esophageal injury. External blunt injury to the thorax rarely produces isolated esophageal rupture, which is more frequently associated with such other injuries as aortic transection and massive cardiac contusion. The site of rupture may be anywhere from the cervical esophagus to the distal esophagogastric junction. When esophageal rupture occurs, it is a nearly fatal condition and the associated mortality approaches 90%.[15] The cause of death is almost always secondary to mediastinitis. Chest radiographic findings reveal mediastinal or cervical air in approximately 60% of these patients. Other patients will show widening of the mediastinum secondary to edema and inflammation related to mediastinitis or from extravasation of gastric fluid and other liquids which may enter the mediastinal compartment.[15]

In most cases, an esophagogram employing water soluble contrast material will demonstrate esophageal perforation in 50% of cervical perforations and 75% of thoracic esophageal perforations.[16] These figures indicate that an esophagogram may not find the site of perforation on the initial examination and if clinical signs and symptoms continue to suggest possible esophageal perforation or if subsequent chest radiographs persist in providing indirect signs of esophageal rupture, repeat esophagography is indicated in several positions, turning the patient from side to side. Barium may be used to improve delineation of suspected areas of extravasation.[16] Delayed esophageal rupture may occur after lung injury as a result of necrosis following interruption of segmental blood supply or accumulation of a large esophageal hematoma.[17] Esophageal intubation with nasogastric tubes or inadvertent intubation of the esophagus during endotracheal intubation may perforate by overstressing an esophagus which has suffered earlier damage. Patients who survive the earlier problems of mediastinitis are at high risk for development of a fistulous communication between the esophagus and the trachea or bronchi.

Tracheobronchial injury. Severe blunt thoracic trauma can produce tracheobronchial injuries resulting in either complete or incomplete laceration. Death is frequent from this injury and the highest mortality rate (75%) is in patients older than 50 years of age.[18] The mortality rate in children is somewhat less (30%) and that for adults between the ages of 20 and 50 years the least (16%). Slightly more than half of the deaths reported in Burke's review occurred within one hour of the injury.

No specific combinations of physical findings lead one to suspect tracheobronchial laceration. In 10% of the patients there will be no clinical features at initial presentation.[19] Some patients with incomplete tears will undergo spontaneous resolution of initial symptoms and present later with bronchial stenosis at the site of injury.

No bronchus is more susceptible to injury as compared to the other. In Burke's review, 51% of the injuries occurred on the right, 47% occurred on the left, and bilateral injuries were present in the remaining 2%.[18] In reviewing chest radiographs in these patients, a sign which appears to be pathognomonic is the falling of the collapsed lung away from the hilum, the opposite to what one would expect in simple pneumothorax.[10] Pneumothorax is the most common associated radiographic sign of a bronchial tear (Figure 3*a*), and is frequently associated with pneumomediastinum and subcutaneous emphysema. Atelectasis of the pulmonary segment associated with the injured bronchus usually occurs at the time of injury, though this may not appear for hours or even days after the injury.

Because most tracheobronchial injuries occur within 2.5 cm. of the carina, the great majority of bronchial injuries are in the region of the mainstem bronchi and radiographic examination should detect many of these.[18] There may be a complete cutoff or interruption of the bronchial air column on routine radiographs. Evidence of interruption of the contour of the bronchial air column may suggest an incomplete laceration (Figure 3*b*). In those patients with pneumomediastinum, progressive atelectasis and incomplete expansion of a pneumothorax, despite continuous chest tube suction, tracheobronchial injury should be suspected.

There is an important radiographic correlation associated with tracheobronchial injury. In patients over 30 years of age with tracheobronchial rupture, 100% had a fracture of one of the first five ribs, and more than 90% of the fractures were of the first three ribs as reported by Burke.[18] When considering all patients in his review with tracheobronchial laceration, 58% had associated rib fractures. Therefore, the absence of rib fracture mitigates against a tracheobronchial laceration only in patients older than 30.

Repair of tracheobronchial lacerations is best performed as soon as possible because chronic pulmonary complications are less likely if injury is detected early. If a laceration is suspected and none can be detected on conventional radiographs, bronchoscopy should be performed and tomography and bronchography considered as imaging avenues for further diagnostic investigation.

Widened Mediastinum

Vascular injury. Significant blunt thoracic trauma with subsequent widening of the mediastinal contour may be due to any of several etiologies. One of the most important causes of widened mediastinum is

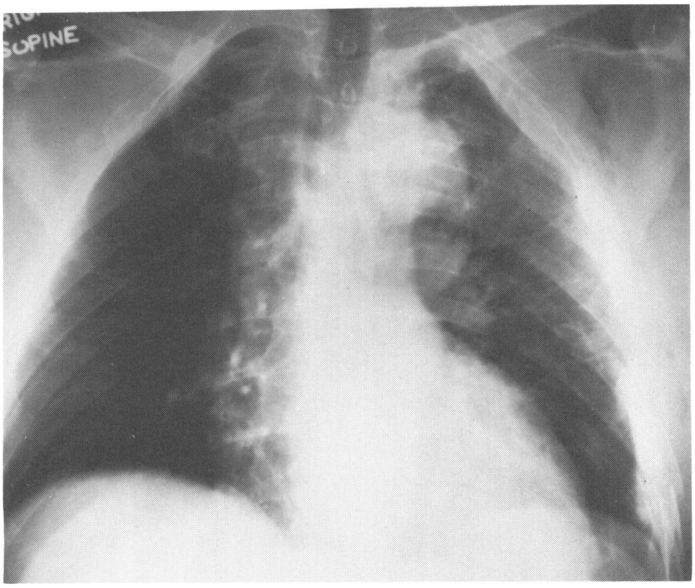


Fig. 5. This 50-year-old man presented to the Emergency Room subsequent to blunt thoracic injury in an automobile accident. The radiograph at that time revealed a wide mediastinum, left apical pleural cap, fractures of the first five ribs on the left and of the second rib on the right, and subcutaneous air in the left axilla. All these findings indicate severe trauma with a potential for more serious injury and that thoracic aortography should be performed rapidly and expeditiously.

great vessel injury. Esophageal and tracheobronchial injuries may also contribute to the widened mediastinum.

The mortality of traumatic rupture of the thoracic aorta is high, and more than 80% of patients suffering this injury do not live long enough to receive initial hospital therapy.[20] Of those patients surviving the initial injury, the mortality rate, if surgical treatment is not instituted, approximates 85% within the first four weeks after the injury.[20] This high mortality associated with aortic rupture means that aortic and great vessel injury must be excluded before other sources of mediastinal widening are investigated. Because the adventitia is intact in approximately 60% of the patients with aortic rupture, the mediastinal hematoma may not be directly from the aortic rupture itself. The injury that produced the aortic rupture will also damage smaller arteries and veins in the mediastinum and may cause sternal fractures. Extravasation from these small vessel injuries in most cases produces the associated mediastinal widening.[21]

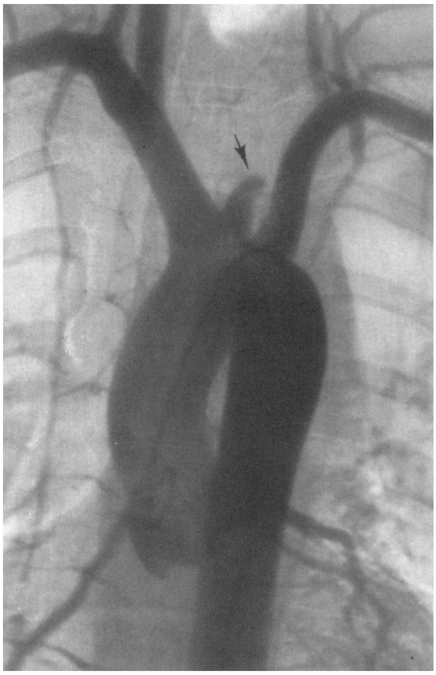


Fig. 6. This thoracic aortogram was performed in a 21-year-old man who presented to the Emergency Room following massive blunt trauma to the anterior thorax in an automobile accident. The patient was asymptomatic neurologically and had minimal mediastinal widening on the admission chest radiograph. The aortogram demonstrated a complete interruption of the proximal left carotid artery (black arrow).

In viewing a chest radiograph for changes due to injury, radiographic findings of aortic rupture other than mediastinal widening would include deviation of the trachea to the right, deviation of the nasogastric tube to the left, loss of the aortic knob shadow, left sided pleural fluid (blood), rib fractures, and depression of the left mainstem bronchus.[22,23] Pneumothorax, pneumomediastinum, and pulmonary contusion may also be present. The extrapleural cap is an early sign of a vascular leak caused by blood flowing into the potential space along the left subclavian artery between the parietal pleura and the extrapleural soft tissues (Figure 5).[24]

In a thoracic trauma patient, where thoracic hemorrhage is pronounced and the patient's stability is either labile or uncontrolled, surgery is usually necessary with a minimum of diagnostic evaluation. In a patient whose stability is controlled acutely, thoracic aortography is the diagnostic procedure of choice for diagnosis of an aortic rupture, for evaluation of the

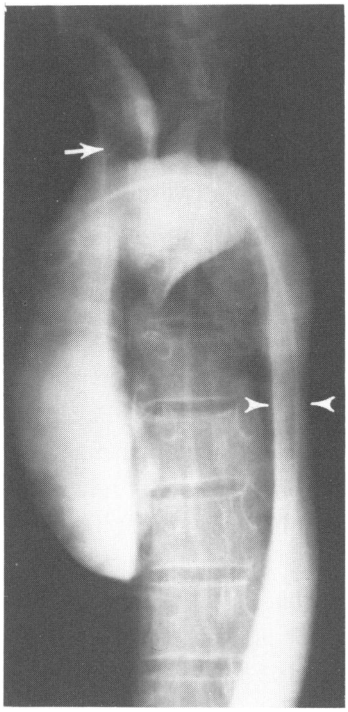


Fig. 7. This thoracic aortogram in a 40-year-old woman reveals a dissection of the thoracic aorta extending from the aortic root into the distal thoracic aorta. Note the intimal flap extending into the right innominate artery (white arrow) and the narrowing of the distal thoracic aortic lumen (white arrowheads).

extent of the rupture and location of the injury, and for the status of the brachiocephalic vessels which originate from the aortic arch.[23] Of those patients who reach the hospital and can be stabilized, approximately 25% will die within 24 hours if untreated surgically.[20] This is because of delayed rupture and exsanguination from the site of the injury. The potential for delayed rupture dictates that thoracic aortography be performed in an immediate, expeditious manner:

Thoracic aortography should be performed with serial radiographs taken in at least two projections. The examination should not be terminated until these films are carefully examined for delineation of anatomy and possible intimal damage. Areas of questionable damage often require further examination in an oblique projection. The right posterior oblique opens the arch geometrically and provides the best profile of the arch and great vessel origins. Radiographic signs of aortic injury are complete transection of the aorta with extravasation of contrast medium into the surrounding soft tissues; complete termination of a major vessel without extravasation (Figure 6); the presence of a false aneurysm indicated by contrast material remaining in a region communicating with the aorta subsequent to injection and contrast run off; linear radiolucencies within the contrast filled aorta (Figure 7); one or more vascular channels filling synchronously, thereby indicating an intimal flap; and dissection with irregularity of the contour of the aortic isthmus. Depending upon the nature and extent of the injury, surgery may be performed to stabilize the patient and to prevent the disaster of delayed rupture.

Cardiac trauma. Blunt thoracic injury can inflict serious damage to the heart and the other thoracic structures. Penetrating cardiac injuries are lethal to the vast majority who sustain them.[25] Radiographically, cardiac injury may present as a number of signs related to the injury of the chest or heart. The cardiopulmonary radiographic presentation may be a widened cardiac silhouette and the pulmonary vascular changes of congestive heart failure similar to what is seen in an acute myocardial infarction. Fractures of the sternum or anterior ribs, signs of pericardial effusion by displacement of the epicardial fat pad and pneumopericardium are important radiographic signs which may be associated with an injured myocardium.

Severe hemodynamic embarrassment with or without cardiac tamponade may be present without a significant change in the cardiac silhouette in the chest radiograph. Advances in echo cardiographic imaging have demonstrated that cardiac sonography is an extremely important imaging modality for evaluating small pericardial fluid collections. Sonography also monitors many other factors such as mitral valvular damage, papillary muscle damage or dysfunction, cardiac chamber kinesis and compartment size. In addition, the aortic root and the aortic valve may be evaluated for possible change.

Following blunt thoracic injury, a patient may develop acute electrocardiographic changes which result from myocardial injury such as myocardial infarction. While this information often is not directly available to the radiologist, it is important that the referring physician include this information as part of the patient's history so that the radiologist will be alert for findings associated with myocardial injury.

Diaphragmatic Injury

Injury to the diaphragm may occur from such penetrating trauma as stab

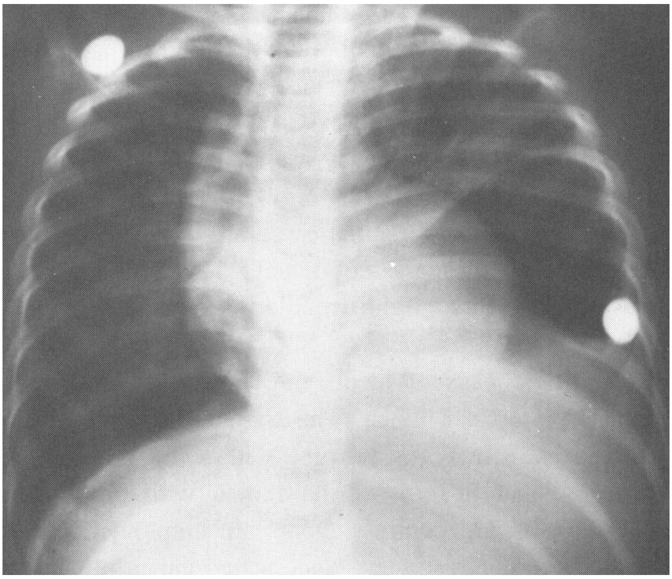
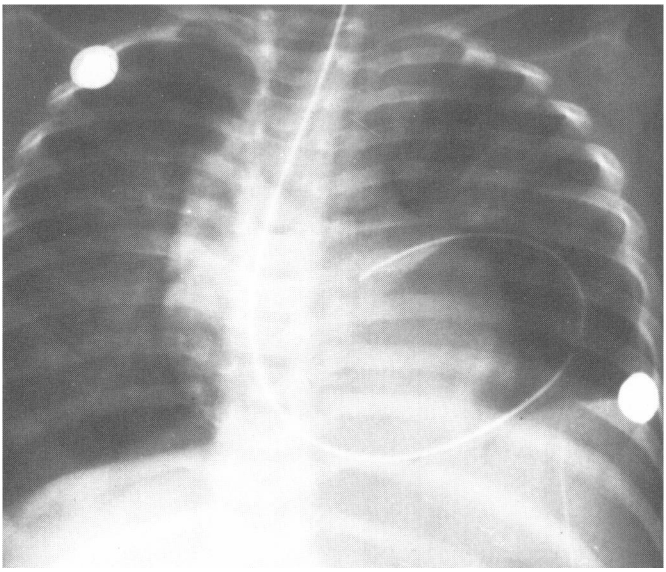


Fig. 8*a*, *b*. This two-year-old boy, after being struck by an automobile, presented to the Emergency Room with respiratory distress and decreased breath sounds on the left. The admission chest radiograph (Figure 8*a*) revealed a large radiolucency in the left lung base with atelectatic changes in the left upper and left mid lung zones. There is also a mediastinal shift to the right. Following passage of a nasogastric tube, a repeat radiograph (Figure 8*b*) confirmed the suspected stomach herniation through a ruptured left hemidiaphragm.



wounds or gunshot wounds or from such severe crush injuries as sudden deceleration injuries.[26,27] The diaphragmatic injury may be diagnosed from the initial radiograph in many cases by the appearance of bowel containing gas within the hemithorax. At times severe cardiovascular, pulmonary, or chest wall injuries may mask the ruptured diaphragm, and detection of the injury may occur only after stabilization and early treatment of the patient. Diaphragmatic rupture can occur without escape of abdominal contents through the defect. The pertinent radiographic finding in these patients is a slight irregularity in the associated diaphragmatic contour.[28]

The more specific means of identifying bowel within the hemithorax identifies the gastrointestinal lumen. This may be facilitated by inserting a nasogastric tube and identifying the tube within the hemithorax (Figures 8*a* and 8*b*) or by opacification of the lumen with orally administered contrast agents. When oral contrast agents are employed, examination is not complete until the contrast agent has reached the colon and is followed past the splenic flexure. Bowel herniation associated with diaphragmatic rupture occurs approximately 95% of the time on the left side and herniation cannot be excluded until all of the bowel in the suspected region is opacified.[29] The right hemidiaphragm may also be ruptured by injury, but the liver protects the right diaphragm and prevents visceral herniation through the defect. There are reported cases of traumatic liver herniation through the right hemidiaphragm.[30]

Many nonspecific signs are associated with diaphragmatic rupture and visceral herniation. Pleural effusions, atelectasis, apparent elevation of the hemidiaphragm, loss of the diaphragmatic contour radiographically, and shift of the mediastinum into the opposite hemithorax may raise a radiologist's index of suspicion of rupture, prompting further radiographic examination. In an acute clinical setting, air can be introduced into the peritoneal cavity under fluoroscopic control. Diagnosis of diaphragmatic rupture is then made by following the air into the hemithorax.

Radionuclides may also be helpful by combining a perfusion lung scan and a liver-spleen scan to identify the interfaces between the liver, spleen, and lung. If the common areas of perfusion overlap in two or more dimensions, herniation should be strongly suspected.

CONCLUSION

An acutely injured patient requires expeditious radiography to delineate possible life-threatening injury. The anteroposterior radiograph is often the primary means to determine the location and extent of thoracic trauma. Close cooperation between referring physician and radiologist is necessary so that a continuous dialogue is established. In this setting, injuries and potential injuries can be diagnosed promptly. As treatment progresses, continual dialogue evaluates the efficacy of therapy and promotes detection of delayed injury and chronic sequelae. The overall result is better patient care, which is more cost effective and more efficiently utilizes diagnostic imaging facilities.

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