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Because of easy access to firearms and the use of automobiles as the primary means of transportation, trauma is a significant problem in the United States. There were 95,644 deaths due to accidents and injuries in the United States in 1996.[1] More than 37 million trauma victims visited emergency departments (EDs) in the United States in 1999; 4.2 million of these victims were injured in motor vehicle collisions.[2]

In 1996, there were 82,000 patients discharged from United States hospitals following injuries to the chest, abdomen, or pelvis.[3] Although some patients with chest trauma die instantly, a large percentage reach the hospital. Fewer than 10% of blunt chest injuries and 30% of penetrating chest injuries require thoracotomy.[5] The key to prevention of death due to chest trauma is rapid recognition of critical injury and institution of treatment.

It is estimated that thoracic trauma accounts for 25% of all the trauma-associated deaths in North America. The overall mortality of thoracic trauma is 10%. Some of these patients die instantly, but many reach the hospital and potentially can be salvaged. Modern emergency medical services systems, combined with implementation of Advanced Trauma Life Support (ATLS) protocols for the management of thoracic trauma, will help ED physicians diagnose and effectively treat these patients.

The majority of patients with chest trauma will benefit from two essential interventions: endotracheal intubation and chest tube placement. Current diagnosis of thoracic trauma is based on physical examination, chest radiography, and spiral computed tomography (CT) scanning. A systematic approach to patient evaluation is required to improve patient outcomes; delays in providing definitive interventions are the most common cause of unfavorable outcomes.

With these issues in clear focus, the first of this three-part series outlines initial treatment and radiographic evaluation of all patients who present with thoracic trauma. Subsequent installments will concentrate on specific bony and pulmonary injuries and injuries to the heart and great vessels.

— The Editor

Thoracic Trauma: Principles and Practice of Emergency Stabilization, Evaluation, and Management

Part I: Radiographic Review and Initial Disposition

Authors: **Elizabeth B. Jones, MD,** Assistant Professor, Department of Emergency Medicine, University of Texas-Houston Medical Center; **Kimberly Chambers, MD,** Assistant Professor, Department of Emergency Medicine, University of Texas-Houston Medical Center; **Luis Haro, MD,** Assistant Professor, Department of Emergency Medicine, Mayo Clinic, Rochester, MN.

Peer Reviewers: **Larry B. Mellick, MD, MS, FAAP, FACEP,** Chair and Professor, Department of Emergency Medicine, Section Chief, Pediatric Emergency Medicine, Medical College of Georgia, Augusta; **Steven Winograd, MD, FACEP,** Attending Physician, Department of Emergency Medicine, Allegan General Hospital, Allegan, MI; Southwestern Michigan Emergency Services, PC.

Initial Management and Assessment

Initial management of chest trauma begins with the ABCs. The goal in patients with chest trauma is to quickly assess their airway, breathing, and circulation, and then identify the presence of six immediately life-threatening injuries that are associated with chest trauma. These injuries are: airway obstruction, tension pneumothorax, open pneumothorax, flail chest, massive hemothorax, and cardiac tamponade.[6] All of these injuries, with the exception of cardiac tamponade, can be identified during the primary assessment. Treatment of each injury is performed as it is identified. Chest x-ray (CXR) is not necessary to make any of these diagnoses, and relying on the CXR for diagnosis can cause unnecessary delays in treatment.

Airway Assessment. The physicians should look at the patient, and assess his or her color, chest wall movement, and work of breathing. Next, listen to the patient's breathing over the mouth and nose. Clinicians should look in the patient's mouth for foreign bodies, and be sure to remove the front of the C-collar and examine the neck, checking for crepitus, hematoma, and tracheal position. This quick check of the airway should identify airway obstruction and will yield clues to the presence of pneumothorax, tracheal injury, or expanding neck hematoma.

Once airway obstruction is identified, airway management begins immediately, before completion of the primary survey. Immediately open the airway, remove foreign bodies, and begin ventilation with cricoid pressure while preparing for definitive airway control. Airway control usually will occur via endotracheal intubation, although in some cases cricothyroidotomy may be required.

Posterior dislocation of the clavicle or sternoclavicular fracture-dislocation may cause partial or complete airway obstruction. This patient will have stridor or abnormal voice quality, along with trauma to the sternoclavicular joint. A palpable defect may be present at the sternoclavicular joint. Treatment includes airway control, which may be difficult due to pressure on the trachea by the dislocated clavicle. The clavicle may be repositioned by extending the shoulders, grasping the proximal clavicle by a towel clamp, and anteriorly pulling it into place.[6]

Breathing. Evaluate the patient's color, respiratory pattern, and work of breathing. Look for asymmetry of chest wall movement, and check for neck vein distention. Listen to breath sounds on both sides. If the patient is intubated, listen over his or her stomach. Next, clinicians should feel the patient's neck and chest, running their hands over the posterior chest. The physician should feel for air in the soft tissues, bony crepitus, and chest wall movement. If pulse oximetry is available, note the O_2 saturation. Physicians should be suspicious if saturation is not 99-100% on non-rebreather. After assessment of breathing, the physician should be able to identify tension pneumothorax, open pneumothorax, flail chest, and massive hemothorax.

Pneumothorax. Tension pneumothorax occurs when air enters the pleural space through a hole in the lung or chest wall and, as a result, creates a one-way valve. Air enters the pleural space but does not exit. As the non-compressible air accumulates, the affected lung collapses. The air pocket can then compress the mediastinum and shift it into the opposite hemithorax. This causes hypoxia, decreased venous return, and eventually, hypotension.

Tension pneumothorax is a clinical diagnosis, and treatment should not be delayed by waiting for x-ray confirmation.[6] Symptoms of tension pneumothorax are restlessness, chest pain, and shortness of breath. Signs are tachypnea, tachycardia, hypotension, hypoxia, absent breath sounds over one lung, neck vein distention, and shift of the trachea and cardiac impulse away from the injured lung. The affected side will be hyper-resonant to percussion. Cyanosis and hypotension are late signs. Tension pneumothorax may develop particularly rapidly in the patient receiving positive-pressure ventilation.

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Vice President/Group Publisher: Brenda Mooney
Editorial Group Head: Valerie Loner
Managing Editor: Suzanne Zunic
Marketing Manager: Schandale Kornegay
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Treatment of tension pneumothorax is immediate decompression of the affected lung by insertion of a large-bore needle into the second intercostal space at the mid-clavicular line. A chest tube is required after decompression as definitive treatment and because the needle decompression may have created a pneumothorax.

Open pneumothorax, also known as a communicating pneumothorax or "sucking chest wound," is caused by a large defect in the chest wall that lets air pass in and out of the chest with each breath. The loss of chest wall integrity inhibits the creation of negative intrapleural pressure, which creates lung expansion. The injury should be suspected whenever a chest wall defect is seen. Air is sometimes heard flowing in and out of the wound.

To treat this condition, place a sterile occlusive dressing over the wound and tape it down on three sides. The open side provides a one-way valve that allows air to escape the chest with exhalation while preventing air entry into the chest with inhalation. Complete occlusion of the chest defect should be avoided, as it may convert an open pneumothorax into a tension pneumothorax. Once the chest wall defect is covered, a chest tube should be placed remotely from the wound.

Flail Chest. Flail chest occurs when three or more ribs are fractured at two points, causing a section of the chest wall to lose continuity with the rest of the thoracic cage. Hypoxia primarily results from underlying lung injury, but also can be caused by paradoxical chest wall movement and pain that restricts deep breathing. The physician should look for hypoxia, poor air movement, paradoxical chest wall movement, and bony crepitus in these patients. Treatment includes oxygen, pain control, and intubation and ventilation as needed.

Circulation. The physician should check carotid and femoral pulses, and then peripheral pulses. He or she should assess quality, volume, rate, and regularity, and check blood pressure and cardiac monitor, and also look at the patient's neck veins. If pulseless electrical activity (PEA) is present, suspect and treat hypotension, tension pneumothorax, cardiac tamponade, and cardiac rupture. If the patient is hypotensive, secure large-bore IV access, begin fluids or blood, and perform either diagnostic peritoneal lavage or the Focused Assessment for the Sonographic Examination of the Trauma patient (FAST exam). The life-threatening chest injuries that should be recognized and treated during circulation assessment are massive hemothorax and cardiac tamponade.

Hemothorax. Massive hemothorax is the accumulation of more than 1500 cc of blood in the chest cavity. It usually is caused by penetrating trauma, but also may be seen with blunt trauma. This injury causes signs and symptoms similar to those seen with tension pneumothorax, except the mediastinum usually is not shifted and the affected lung is dull to percussion. Neck veins usually are flat, but may be distended if there is an accompanying tension pneumothorax or cardiac tamponade.

Treatment requires prompt drainage of the affected hemithorax with a chest tube and restoration of intravascular volume with transfusion. When possible, drained blood should be autotranfused back into the patient. If more than 20 mL/kg is initially drained, the patient probably will require thoracotomy. If less blood is drained, the patient may be observed. Indications for thoracotomy are listed in Table 1. Penetrating wounds medial to the nipples or scapulae also will likely require thoracotomy.

Table 1. Indications for Thoracotomy

- Initial chest tube output > 20 mL/kg
- Continued bleeding > 7 mL/kg/hr
- Increasing hemothorax seen on CXR
- Continued hypotension despite blood transfusion, after other causes of blood loss have been ruled out
- Decompensation after initial response to resuscitation

Source: Vukich DJ, Morkovchick V. Thoracic trauma. In: Rosen P, Barkin R. *Emergency Medicine: Concepts and Clinical Practice.* Fourth ed. Mosby; 1998.

Cardiac Tamponade. Cardiac tamponade is caused by the accumulation of fluid in the pericardial sac, which restricts atrial filling and interferes with cardiac activity. This most often is seen with penetrating injuries to the heart, but also may be found in blunt trauma. Signs of tamponade include muffled heart sounds, hypotension, venous distention, and pulsus paradoxus. The diagnosis of tamponade is difficult to make. Hypotension and venous distention may have other causes. Neck vein distention may be absent when hypotension and tamponade are present together. Muffled heart sounds and pulsus paradoxus may be hard to appreciate because of noise in the trauma room.

Electrocardiogram (ECG) and CXR usually are not helpful for diagnosing acute tamponade. Ultrasound is the tool of choice. Ultrasound of the heart and abdomen can be performed during resuscitation of the unstable trauma patient. The finding of pericardial fluid, along with right atrial or right ventricular collapse during diastole, is diagnostic of pericardial tamponade. In the hypotensive trauma patient, the presence of fluid in the pericardium is suggestive of tamponade.

Immediate treatment of cardiac tamponade includes pericardiocentesis or emergency thoracotomy. Which procedure is preferred depends on the setting. In all patients, if tamponade is suspected, begin fluid resuscitation. If a surgeon and operating room are available and the patient is not responding to resuscitation, thoracotomy is indicated. This may be performed in the ED, on the way to the operating room (OR), or in the OR, depending on the patient's condition. If no surgeon is available and the patient does not respond to resuscitation, pericardiocentesis should be performed. In acute tamponade, removal of as little as 15-20 mL of fluid may cause immediate relief of tamponade. If the patient responds, arrange immediate transfer for thoracotomy to inspect the heart.

Resuscitative Thoracotomy. Patients with penetrating injuries to the chest who arrest in the ED should undergo immediate thoractomy. While the patient is being intubated, ventilated, and fluid-resuscitated, left anterior thoracotomy should be performed. Once the chest is opened, the pericardial sac is opened,

Table 2. Resuscitative Thoracotomy Rules

INDICATIONS	CONTRAINDICATIONS
Penetrating thoracic trauma	No qualified surgeon present
Pulseless electrical activity	Blunt injury
	Pulseless, without electrical activity

Source: Subcommittee on Advanced Trauma Life Support of the American College of Surgeons Committee on Trauma, 1993-1997. Thoracic Trauma. In: *Advanced Trauma Life Support.* Chicago: American College of Surgeons; 1997.

any large intrathoracic hemorrhage is controlled, and the aorta is cross-clamped below the diaphragm. ED thoracotomy is not effective in blunt trauma patients who arrest prior to ED arrival.[7] The prognosis is almost as bleak for patients with penetrating injuries who arrest prior to ED arrival and for blunt trauma victims who arrest in the ED. Indications for resuscitative thoracotomy are listed in Table 2.

Secondary Survey

Once the primary survey is complete and life-threatening injuries are treated, a more detailed assessment of the patient is performed; this may include repeat chest examination, CXR, ECG, pulse oximetry, and arterial blood gas. During the secondary survey, the physician should look for potentially lethal chest injuries, including: simple pneumothorax, hemothorax, pulmonary contusion, tracheobronchial tree injury, blunt cardiac injury, aortic disruption, diaphragmatic injury, and wounds traversing the mediastinum.[6] Once diagnosed, the above injuries should be treated expeditiously. Often, one or more of these injuries will be suspected after the secondary survey. Further diagnostic testing will be needed to fully define the injury.

Radiologic Evaluation

Chest X-Ray. The CXR that is completed in the trauma room can be very helpful, but its accuracy is limited. The CXR should be performed and developed as soon as is practical during the initial evaluation of the trauma patient. The CXR is fast, portable, can confirm diagnoses suspected on physical exam, and provide evidence of injuries that are difficult to diagnose by physical exam alone. The ED physician must be able to interpret the CXR. It is best to develop a systematic plan for evaluating a CXR and not deviate from it. This will help the clinician avoid missing less obvious injuries. ATLS recommends reviewing the CXR in this order: Trachea and bronchi, pleural spaces and lung parenchyma, mediastinum, diaphragm, bony thorax, soft tissues, and tubes and lines.[6]

The portable CXR will not diagnose every chest injury. The trauma room patient typically is supine, which may obscure a small pneumothorax or hemothorax and distort the mediastinum. Portable films may be too light in large patients, and the presence of backboards, tubes, and ECG leads may detract from image quality. Further, some injuries, like a small pneumothorax, may take time to develop. The initial portable CXR can miss 28-38% of injuries subsequently found on chest CT.[8-10] The additional injuries found on CT require treatment in 6-24% of patients.[8,11]

Rib Fractures. Rib fractures are best diagnosed using CXR. While single-rib fractures may not be seen on 50% of initial chest radiographs,[12] rib and clavicle fractures are more commonly identified on CXR than on CT.[8] As there is no specific treatment for single rib fractures and they usually heal without complications, there is no reason to order rib films to find suspected single mid-chest rib fractures;[13] CXR should be ordered in these patients to look for underlying pulmonary injuries. Rib films are recommended when multiple rib fractures are suspected in vulnerable patients—the elderly and those with pre-existing pulmonary disease.

Sternoclavicular Dislocation. The diagnosis of sternoclavicular dislocation begins with careful physical exam, but should be confirmed radiologically. Because anteroposterior (AP) and lateral x-rays may be difficult to interpret due to overlapping structures, CT scan of the chest is the best way to study the sternoclavicular joint.[14] The CT scan also will provide information about surrounding structures which may have been injured by posterior clavicular dislocation.

Sternal fractures usually are transverse and are easily demonstrated on a lateral x-ray.[14] The problem is that few trauma patients routinely have lateral CXRs performed. CT scan can be used to evaluate the sternum. It may miss horizontal fractures, but can pick-up fractures in the coronal plane that are hard to demonstrate on plain films. Sternal fracture has, in the past, been reported to have a high mortality due to associated cardiac and pulmonary injuries.[15] More recent studies, however, do not support this observation. Therefore, if the diagnosis is suspected on physical exam, check the lateral film, consider other injuries, and watch the patient carefully.

Scapular Fractures. Scapular fractures frequently are missed on CXR. In one study of 100 scapular fractures, 43 were missed on initial CXR. Seventy-two percent of the missed fractures were visible on the CXR, but were not recognized.[16] When a scapula fracture is clinically suspected, perform shoulder films; these films should be diagnostic.

Pneumomediastinum. Subcutaneous emphysema seen in the soft tissues on CXR means air has been introduced into the soft tissues from the outside, the lung, or the esophagus. While a penetration of the chest may carry a small amount of outside air into the surrounding tissues, it is best to assume that any subcutaneous air is caused by pneumomediastinum or pneumothorax. Air visualized in the lateral soft tissues usually indicates pneumothorax; air may be over the neck, pneumomediastinum. tracheobronchial tree or esophagus. Pneumomediastinum will cause streaks of air that outline mediastinal structures; it often is better seen on lateral x-ray. On the AP CXR, lucent lines may be seen outlining the heart, especially on the left side. The track of the air will extend superiorly past the heart and outline structures in the superior mediastinum. A dark line also may be seen along the superior surface of the central diaphragm and cardiac base. This is the "continuous diaphragm sign"—the diaphragm appears continuous from the left to the right hemithorax.[14] As with pneumothorax, CT is more sensitive than CXR for the detection of mediastinal air.[26]

Pneumomediastinum is caused by extra-alveolar air in the mediastinum. Mediastinal air may be difficult to distinguish from pneumopericardium and medial pneumothorax. Mediastinal air is confined to soft tissues and will not shift when the patient's position is changed. The air in pneumothorax and pneumopericardium is in an existing potential space, so it will shift when the patient's position is changed. Pneumopericardium, which may occur following penetrating trauma, is recognized as air outlining the heart, but not other mediastinal structures. Rarely, air in the pericardium will inhibit cardiac filling and cause tamponade. The patient will have the clinical findings of tamponade, and CXR will show a small heart with surrounding pneumopericardium.

Tracheobronchial Injury. Tracheobronchial injury may be diagnosed by the bayonet sign (the end of the ruptured bronchus is seen as a tapering, air-filled structure) or the fallen lung sign (the lung is torn from its bronchus and falls into the lower chest), but these rarely are seen. More commonly, massive subcutaneous emphysema and pneumomediastinum are seen,[17] though up to 10% of patients with tracheobronchial injury initially will have no x-ray findings.[18]

Pneumothorax. Pneumothorax frequently is missed on initial trauma CXR either due to small size or the supine position of the patient. Initial CXR will miss between 20% and 30% of pneumothoraces found on CT.[10,19,20] Up to one-third of these develop into tension pneumothoraces. If the patient can sit up, the pneumothorax will collect in the apex and be easier to diagnose. The expiratory film also may make a small pneumothorax more obvious. When a pneumothorax is suspected, but not seen initially, the x-ray may be repeated in three hours; at that time any significant pneumothorax should be visible.[21]

To diagnose pneumothorax on CXR, physicians should look for a thin line with no vascular markings beyond the line. Skin folds, clothing, ECG leads, and IV lines may produce lines on the CXR that can be confused with pneumothorax. These lines will have vascular markings lateral to them and can be followed outside the pleural space. In the supine position, air will collect in the anterior costophrenic sulcus, making recognition difficult. Look for hyperlucency in the lower chest, deepening of the lateral costophrenic sulcus, and depression of the involved hemidiaphragm.

Hemothorax. Hemothorax is found in about 50% of major trauma victims.[22] Any pleural fluid seen following chest trauma should be assumed to be blood. On the upright CXR, 250 mL of fluid is required to produce blunting of the costophrenic angle.[23] When the patient is supine, the fluid layers posteriorly. This may produce an increased density over the affected hemithorax and be the only sign of hemothorax. As more blood accumulates, the fluid may collect laterally, medially, or at the costophrenic sulcus. Hemothorax is associated with pneumothorax in 25% of cases.[24] This will be seen as an air-fluid level on the upright CXR. Shift of the mediastinum is more likely to be seen with arterial bleeding than with lower pressure venous bleeding.[14]

As with pneumothorax, CT is more sensitive for small hemothorax than CXR.[25] Most of these hemothoraces will not require treatment, but all should be watched. CT also can differentiate serous effusion from bloody effusion. The helical CT using power-injected IV contrast can reveal active hemorrhage into the pleural space.

Extrapleural hemorrhage, seen with rib fractures, should not be mistaken for pleural fluid. The extrapleural fluid will dissect the parietal pleura away from the chest wall and will produce a convex bulge that points toward the lung. In contrast to pleural fluid, extrapleural fluid will not be mobile. Extrapleural fluid also may collect under the lung as a subpulmonic effusion. This will produce a pseudodiaphragm that looks like an elevated hemidiaphragm.

Pulmonary Contusion. Pulmonary contusion is the most common lung injury in adults and children.[27,28] Pulmonary contusions usually are present on the initial CXR and always appear within six hours. On CXR, the contusion will appear as patchy or diffuse air space disease. The distribution corresponds to the area of impact. CT is more sensitive and specific than CXR for diagnosis of pulmonary contusion.[9,10,25,29] Despite this, the "occult" contusions identified by chest CT rarely affect management: large contusions usually are seen on CXR and respiratory management is based on clinical findings. CT is most helpful when it is used to distinguish pulmonary contusion from atelectasis, aspiration, or infection.

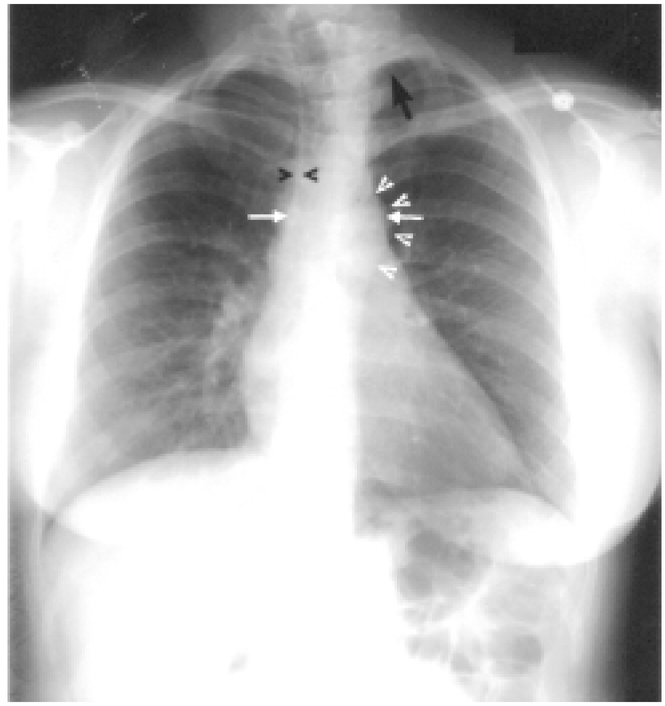
Esophageal Perforation. Esophageal perforation is seen in penetrating and, uncommonly, in blunt trauma. Many patients with penetrating trauma near the esophagus will be taken immediately to the operating room and should have their esophagus' evaluated during surgery. When there is no other indication for exploration of the injury, esophagography is the diagnostic study of choice, despite a sensitivity of only 50-60%.[30] In penetrating trauma, perforation is suggested by the path of the projectile or blade. In blunt trauma, a high index of suspicion is needed, as a delay in diagnosis may be fatal. On CXR, physicians should look for mediastinal air, left-sided pleural effusion, pneumothorax, and widened mediastinum. Air-fluid level in the mediastinum also may be seen. On lateral C-spine film, retropharyngeal air may be a clue to either cervical or thoracic perforation. Cervical or mediastinal air will be identified in 60% of cases.[31] Unfortunately, there may be no evidence of perforation acutely due to periesophageal hematoma.[32]

Diaphragmatic Injury. Diaphragmatic injury following blunt trauma often is missed acutely. On the initial CXR, findings of intrathoracic bowel gas or nasogastric tube in the chest are seen in only 44% of patients.[33,34] Nonspecific findings, such as hemothorax and elevated hemidiaphragm may be seen in 42% of patients. Other findings suggestive of diaphragmatic injury are air-fluid levels in the lower thorax, indistinct hemidiaphragm,

Table 3. Radiographic Findings of Mediastinal Hematoma

FINDING	SENSITIVITY	SPECIFICITY
Mediastinal widening	50-90%	10%
Depression of the left mainstem bronchus	70-80%	80-100%
Deviation of nasogastric tube	23-71%	90-94%
Lateral displacement of trachea	12-100%	80-95%
Left apical pleural cap	20-63%	75-76%
Loss of paravertebral pleural stripe		
Obscured aortic knob		
Widened paratracheal stripe		

Figure 1. Normal Aortic Landmarks



White arrows: normal mediastinum
White arrow heads: normal aortic arch
Black arrow heads: normal right paratracheal stripe
Black arrow: normal left apex, no apical cap

mediastinal shift, and lower rib fractures. In one series of 57 diaphragmatic injuries, 15% of patients had normal initial CXRs.[34] In the same series, recognition of the injury was delayed in all patients who did not have indications for immediate surgery. This is particularly concerning, as surgeons generally more aggressively pursue non-operative management of blunt abdominal injury.

Because of the difficulty with identifying diaphragmatic injury acutely, investigators have evaluated diagnostic peritoneal lavage (DPL), ultrasound, CT scan, nuclear medicine techniques, thoracoscopy, exploratory laparotomy, and magnetic resonance imaging (MRI) for this purpose. Of these, DPL has been found to be unreliable,[34] ultrasound nuclear medicine techniques haven't been well evaluated, and thoroscopy and exploratory laparotomy are invasive. The sensitivity of CT scanning has been reported to be anywhere from 0% to 100%.[25,33-38] While not well studied, some authors recommend helical CT with sagittal and coronal reformations.[14] Unlike the CT scan, MRI directly obtains images in the sagittal and coronal planes. Though there is not much reported experience, MRI may be the best modality for evaluation of diaphragmatic injury.[39-42] The chief difficulty with MRI is that it is not suitable for unstable patients.

Aortic Injury. Blunt aortic injury has presented a diagnostic dilemma for a long time. It must be considered with any rapid deceleration, such as falls and motor vehicles collisions, and cannot be missed. Of those who survive the first hour, 90% will die within four months.[43] CXR has been extensively studied as a screening tool for mediastinal hematoma. Specific findings to look for are mediastinal widening, depression of the left mainstem brochus, loss of paravertebral stripe, deviation of the nasogastric tube, lateral displacement of the trachea, left apical cap, obscured aortic knob, and widened paratracheal stripe. *(See Table 3.)*

Mediastinal widening has been defined in different ways by different authors. Commonly cited definitions are: width greater than 8 cm on supine AP film, greater than 7.5 cm at the aortic knob, and ratio of mediastinal width to chest width of 0.38 cm. One study reports that the subjective interpretation of mediastinal widening is more reliable than direct measurement.[44] The right paratracheal stripe is abnormal when it is greater than 5.0 mm wide at any point between the suprasternal notch and the carina. One study reports that right paratracheal stripe was widened in 22.9% of patients with aortic injury.[45] Two other authors found that it was less than 5 mm in all normal subjects.[46,47]

The left mediastinal or paraspinal stripe represents the medial pleural surface of the left lung and is the lateral margin of the left paraspinal space. The right paraspinal stripe is not useful, as it is only seen in one-third of normal subjects. The left paraspinal stripe is found on 97% of normal subjects. It should not be visible above the level of the aortic knob. Extension of this line above the knob raises the possibility of mediastinal blood. The left apical cap will be seen as a line that continues the mediastinal stripe to cover the left apex. It represents mediastinal blood extending up the left paraspinous space to cover the apex of the left lung. *(See Figures 1 and 2.)*

Multiple CXR findings have been found to be suggestive of aortic injury, but none are completely reliable.[44,45,47-58] The CXR actually visualizes the mediastinum, not the aorta. These CXR findings indicate mediastinal hematoma, which may have many causes. The sensitivity of widened mediastinum for aortic injury is about 89%, while the reported sensitivity of any suggestive abnormality on CXR is 92-98%. The key point is that CXR alone will miss 2-11% of these critical injuries.[52]

Most of the above studies evaluated supine CXR. An erect PA film may be better for excluding aortic injury,[56] but this film is not always practical. In the time spent clearing the spine and then

Figure 2. Abnormal Aortic Landmarks

Large white arrows: wide mediastinum
Black arrow heads: wide right paratracheal stripe
Small white arrows: loss of definition of aortic arch
Black arrows: left apical cap
Black lines: left paraspinal stripe

obtaining the upright view, the patient could have undergone a more definitive study.

Aortography has long been the "gold standard" test for aortic injury. Under this premise, its sensitivity is 100%. The specificity of aortography is about 95%,[59-61] with false positives typically due to anatomic abnormalities. Alternatives to aortography have been sought because aortography can be time consuming, is not uniformly available, is typically performed in a place remote from the ED, and has complications related to the needlestick and intravenous dye injection. The complication rate was 2.6% in a series of arteriograms performed in trauma patients.[62]

CT scan offers many advantages over aortography: it is readily accessible (sometimes in the ED), has a low complication rate; it uses less IV contrast than aortography, is fast, and offers information about structures other than the aorta. Often, the trauma patient will need CT of another area anyway. Early experience with CT for the diagnosis of aortic injury was disappointing, but helical CTs have overcome these problems.[63-66] Helical CT boasts nearly 100% sensitivity for aortic injury identification and a specificity of 80-85%. False positives usually are due to a remnant of the ductus arteriosus or atherosclerosis.

Transesophageal echocardiography (TEE) is yet another means of evaluating the thoracic aorta. It is very accurate—86% sensitive and 90% specific.[59-61] Unlike CT and aortography, TEE can be performed at the bedside while other interventions continue. Unfortunately, it requires specialized training and does not visualize the ascending aorta or aortic branches well.

Despite the current widespread use of spiral CT and, to a lesser extent, TEE to evaluate possible aortic injury, there still may be some use for aortography. Aortography does localize the injury precisely. It also provides information about the brachiocephalic vessels that may be missed by other techniques.

Cardiac Tamponade. Cardiac tamponade is best evaluated by echocardiography. This is a rapid, non-invasive, and accurate method of detecting cardiac injury. In a prospective study, echocardiography was found to be 90% sensitive and 97% specific for cardiac injury.[67] CXR is not helpful for the diagnosis of acute tamponade. The classic "bottle-shaped heart" is seen in chronic pericardial effusion when the pericardium has time to stretch, not in acute effusions.

Disadvantages of echocardiography are that accuracy is diminished in patients with hemothorax[68] and cardiologists traditionally have been required to interpret the study. In the ED, however, a complete echocardiogram is not being sought. ED physicians merely need to look for pericardial fluid. Four hours of training may be sufficient to teach ED physicians to identify pericardial fluid. After such training, 80% of ED physicians studied could reliably identify pericardial fluid using two views of the heart.[67]

Currently, the FAST exam uses bedside ultrasound performed by surgeons and ED physicians to look for intraperitoneal fluid. The FAST exam also includes a subcostal view of the heart. This is used to try to identify pericardial fluid. One study reported a sensitivity of 100% and specificity of 97.3% for pericardial fluid.[69] Echocardiography is the test of choice to identify tamponade, if it can be done immediately at the bedside. As more surgeons and ED physicians are trained in the FAST exam, it may become the diagnostic method of choice.

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Physician CME Questions

33. When first evaluating the patient with chest trauma:
    A. only check airway for obstruction.
    B. quickly assess their airway, breathing, and circulation, and then identify the presence of six immediately life-threatening injuries that are associated with chest trauma.
    C. perform CXR for suspected tension pneumothorax.
    D. begin oxygen administration by nasal cannula on all patients.

34. Which of the following injuries are immediately life-threatening and should be treated immediately in the ED?
    A. Hemothorax
    B. Pneumothorax
    C. Cardiac tamponade
    D. Traumatic aortic injury
    E. Blunt cardiac injury

35. Which of the following is true of thoracic trauma?
    A. Almost all patients with penetrating chest trauma require thoracotomy.
    B. It accounts for more than 90% of all trauma fatalities.
    C. The majority of patients with chest trauma will benefit from two essential interventions: endotracheal intubation and chest tube placement.
    D. Rib fractures are never serious injuries.

36. Which patient should undergo ED thoracotomy?
    A. The patient with distended neck veins, muffled heart sounds, P 100, and BP 120/75.
    B. The patient who has been shot in the chest and who was in asystole when discovered by EMS and in the ED.
    C. The car crash victim who goes into asystole 2 minutes from the ED.
    D. The patient who was stabbed in the chest and arrives to the ED in PEA.

37. Which is true of pulmonary contusion?
    A. Mortality is related to the number of ribs fractured.
    B. CT is more sensitive and specific for pulmonary contusion.
    C. CXR often misses clinically important contusions.
    D. CXR better differentiates contusion from atelectasis or aspiration than chest CT.

38. Which of the following is the best test for diaphragmatic rupture?
    A. CXR
    B. DPL
    C. Chest CT
    D. Abdominal ultrasound
    E. MRI

39. Which of the following statements concerning blunt aortic injury is correct?
    A. Multiple CXR findings have been found to be suggestive of aortic injury, and a majority are completely reliable.
    B. Conventional chest CT is the best test to identify blunt aortic injury.
    C. Helical CT boasts nearly 100% sensitivity for aortic injury identification and a specificity of 80-85%.
    D. Transesophageal echocardiography (TEE) does not require specialized training and visualizes the ascending aorta or aortic branches well.
    E. Aortography

40. Which of the following would be diagnostic of pericardial tamponade?
    A. Pericardial effusion
    B. Beck's triad: hypertension, muffled heart sounds, and distended neck veins
    C. Bottle-shaped heart on CXR is always seen
    D. The finding of pericardial fluid, along with right atrial or right ventricular collapse during diastole

Emergency Medicine Reports CME Objectives

To help physicians:

- quickly recognize or increase index of suspicion for specific conditions;
- understand the epidemiology, etiology, pathophysiology, and clinical features of the entity discussed;
- be educated about how to correctly perform necessary diagnostic tests;
- take a meaningful patient history that will reveal the most important details about the particular medical problem discussed;
- apply state-of-the-art therapeutic techniques (including the implications of pharmaceutical therapy discussed) to patients with the particular medical problems discussed;
- understand the differential diagnosis of the entity discussed; understand both likely and rare complications that may occur;
- and provide patients with any necessary discharge instructions.

In Future Issues: Thoracic Trauma: Part II