INTRODUCTION — Blunt chest trauma puts multiple structures at risk of injury. In addition to direct trauma, rapid deceleration and other mechanisms can cause injury to thoracic structures. Major concerns include chest wall injury, such as rib fractures or flail chest, cardiovascular injury, such as blunt aortic injury or cardiac contusion, and pulmonary injury, such as contusions or lacerations. Blunt aortic injury is the most lethal injury of the thorax if untreated.

The clinician must first concentrate on assessing life-threatening conditions. Depending on the presentation, evaluation may consist solely of a thorough history and physical examination or may require multiple tests including plain x-rays, computed tomography (CT) scans, and echocardiography.

This topic review will discuss the epidemiology, mechanisms, and general approach to the management of injuries sustained in adults from blunt thoracic trauma. Discussions of thoracic trauma in children and other aspects of trauma management are found elsewhere. (See "Initial evaluation and stabilization of children with thoracic trauma" and "General approach to blunt abdominal trauma in adults" and "Initial evaluation and management of shock in adult trauma" and "Rib fractures".)

EPIDEMIOLOGY — Motor vehicle collisions (MVC) represent the most common cause of major thoracic injury among emergency department (ED) patients [1,2]. Several factors are associated with a higher risk of thoracic injury:

- High speed
- Not wearing a seatbelt
- Extensive vehicular damage
- Steering wheel deformity

Increased mortality and morbidity is associated with multiple rib fractures, increased age, and higher injury severity scores (ISS) [1,3-5]. (See "Rib fractures".)

Studies of chest trauma are often based upon data from trauma registries that catalog admitted trauma patients. Patients with minor injuries or isolated rib fractures are often discharged and do not appear in such registries, leading to substantial bias in the trauma literature toward more seriously injured patients [5].

- Blunt aortic injury - The majority of blunt trauma patients who sustain a major aortic injury die immediately. Of those who reach the hospital alive, the majority either die during initial management or are unable to undergo aortic repair due to their injuries, both intra and extrathoracic [6].

A number of occupant and collision characteristics are independently
associated with blunt aortic injury (BAI), the most lethal of blunt thoracic injuries [7,8].

High risk occupant characteristics include:

- Age ≥60 (RR 3.6; 95 percent CI 2.5-5.2)
- Front-seat occupancy (RR 3.1; 95 percent CI 1.5-6.3)
- Not wearing a seatbelt (RR 3.0; 95 percent CI 2.2-4.3)

High risk collision characteristics include:

- Front or near-side motor vehicle crash (RR 3.1; 95 percent CI 1.9-5.1; and RR 4.3; 95 percent CI 2.6-7.2, respectively)
- Abrupt deceleration ≥40 km/hour (RR 3.8; 95 percent CI 2.6-5.6)
- Crushing of the vehicle (ie, ≥40 cm) (RR 4.1; 95 percent CI 2.7-6.3)
- Intrusion ≥15 cm (RR, 5.0; 95 percent CI 3.5-7.3)

The risk of injury to the thoracic aorta is also greater among passengers traveling in a car struck by a sports utility vehicle (RR 1.7; 95 percent CI 1.2-2.3).

- Blunt cardiac and pulmonary injury - Up to 20 percent of deaths from motor vehicle collisions are attributable to blunt cardiac injuries [9,10]. Most patients with such injuries die in the field. Pneumothorax is a common complication of thoracic trauma. The incidence of occult pneumothorax among victims of blunt trauma is less clear, ranging from 2 to 55 percent in patients who undergo computed tomography (CT) of the chest or abdomen [11]. The risk of pulmonary contusion appears to correlate with crash severity and the proximity of the site of impact to the patient [12].
- Sternal fractures - Sternal fractures are found in up to 8 percent of blunt chest trauma patients and 18 percent of multiple trauma patients with thoracic injuries [13,14]. A direct, high-energy blow to the sternum is the usual cause. Although life-saving in many instances, over-the-shoulder seat belts contribute to these fractures and their incidence has risen with the increased prevalence of seat belt use [13,14]. The incidence is greater among passengers in older cars where occupants wear seat belts but air bags are not available.
- Scapular fractures - Scapular fractures are uncommon, accounting for only 1 percent of all fractures and less than 5 percent of fractures to the shoulder complex. They occur in up to 3.7 percent of blunt trauma patients. Because scapular fractures generally require significant force, they are highly associated with other significant injuries, including rib fracture, pneumothorax, and pulmonary contusion [15-18]. Scapular fractures rarely cause blunt aortic injury [17].
- Rib fractures - Rib fractures occur in almost two-thirds of motor vehicle crash patients with chest trauma. These studies, however, evaluated major trauma patients admitted to trauma centers. In another study, researchers evaluated the chest radiographs of all alert blunt trauma patients presenting to their emergency department following blunt trauma [2]. They found that multiple rib fractures (>2) was the most common serious thoracic injury, and occurred in approximately 5 percent of patients. The presence of multiple rib fractures, particularly ribs one through three, increases the risk of intrathoracic injury, especially in the elderly. (See "Rib fractures").

ANATOMY AND MECHANISM
• Anatomy and physiology - The rib cage, intercostal muscles, and costal cartilage form the basic structure of the chest wall. In addition, neurovascular bundles comprised of an intercostal nerve, artery, and vein run along each rib. The inner lining of the chest wall is the parietal pleura. Visceral pleura covers the major thoracic organs. Between the two is a potential space with a small amount of lubricating fluid. The anterior chest wall also contains the sternum and pectoralis major and minor muscles, as well as the clavicle at its superior border. Posteriorly, the scapula provides added protection to the superior thorax. The scapula is a dense bone encased in muscle and significant force is necessary to fracture it.

The chest wall has two important functions: to assist in the mechanics of respiration and to protect the intrathoracic organs. Adequate ventilation is accomplished by creating negative intrathoracic pressure during inspiration and positive pressure during expiration. During inspiration, a combination of diaphragmatic excursion and contraction of the intercostal muscles to raise the ribs in a "bucket-handle" fashion increases intrathoracic volume and decreases intrathoracic pressure, which then pulls air passively into the lungs. In expiration, this process is reversed: all the muscles relax and intrathoracic pressure passively increases and volume decreases, forcing air out of the lungs.

The chest wall protects against devastating injuries to the intrathoracic structures. In fulfilling this role, the chest wall is commonly injured. While generally not life-threatening, chest wall injuries can be extremely painful and can lead to significant morbidity if not recognized and treated appropriately.

The mediastinum is an anatomic division of the thorax extending from the diaphragm inferiorly to the thoracic inlet superiorly. Its borders include the sternum anteriorly, the vertebral column posteriorly, and the parietal pleura laterally. Contained within the mediastinum are the heart, aorta, trachea, and esophagus. Injuries to any of these structures are potentially life-threatening. One lung is located lateral to each side of the mediastinum.

With blunt trauma, the most common isolated mediastinal injury involves the aorta. Hemorrhage from other nearby structures, such as venous lacerations or fractures of the ribs, sternum or vertebra, can manifest as mediastinal blood, raising concern for aortic injury (algorithm 1). Aortic injuries are mainly transverse tears with relatively smooth margins. The underlying injury ranges from a simple subintimal hemorrhage, with or without intimal laceration, to complete aortic transection [19].

The diaphragm constitutes the floor of the thoracic cavity. The diaphragm exhibits substantial movement with inspiration and expiration, and thus posttraumatic pain in the lower thorax may reflect intraabdominal as well as intrathoracic injury.

• Selected mechanisms - Blunt chest trauma occurs through a variety of mechanisms, including motor vehicle collisions, assaults, and falls. Particularly in the elderly, apparently minor trauma (eg, fall from standing) can cause serious injury. Any of the mechanisms listed can cause rib fractures, flail chest, or chest wall contusions.

Aortic tears usually occur from high-energy injuries to the thorax, often following rapid deceleration. Several theories for the mechanism of aortic disruptions exist, including: deceleration and traction on the aorta, lever
mechanism, direct chest compression, torsion, increase in aortic hydrostatic pressure, and osseous pinch [20,21]. In the lever mechanism, the proximal aorta-aortic arch is postulated to act as the long arm, the aortic isthmus as the short arm, and the great vessels as the fulcrum. Traumatic force exerted on the long lever arm leads to injury. Elevated hydrostatic pressure can develop when aortic compression and a sudden rise in blood pressure occur simultaneously. The "osseous pinch model" postulates that the aorta is crushed between the anterior sternum, ribs, and clavicle and the posterior vertebrae. Shearing forces then cause a tear in the artery. An anticipatory valsalva maneuver (ie, gasp) just before impact, increasing intraaortic pressure, may play a role when aortic injury is sustained in lower energy crashes. While not well understood, different combinations of dynamic mechanical and anatomic forces cause proximal versus distal aortic ruptures.

Pulmonary contusions most often result from high-energy MVCs. Mortality is difficult to quantify because pulmonary contusions often occur in tandem with other severe injuries. Damage leads to ventilation-perfusion inequalities and decreased lung compliance [22,23]. Researchers postulate several possible mechanisms for pulmonary contusion, including the implosion theory, where air expansion causes alveolar tearing; the "inertia effect," which occurs when lighter alveoli are stripped from the heavier bronchi; and the "spalling effect," which involves shearing at the gas-liquid interface.

PREHOSPITAL MANAGEMENT — Prehospital management depends on patient symptoms and severity of illness. Prehospital providers should treat patients with possible underlying pulmonary, cardiac, or major extrathoracic injuries according to the principles of Advanced Trauma Life Support® (ATLS®), paying special attention to the patient's airway, breathing, and circulation. Rapid transport to the closest trauma center is crucial; interventions causing unnecessary delay must be avoided. Basic interventions, such as cervical spine immobilization, are appropriate, as is the use of high flow oxygen and monitoring. Transport should not be delayed to place IV lines or perform endotracheal intubation, unless the patient is in extremis and cannot be stabilized with bag mask ventilation. More extensive intervention may be needed if prolonged transport time is expected. A detailed discussion of prehospital trauma care is found elsewhere. (See "Prehospital care of the adult trauma patient").

If the patient shows no evidence of respiratory difficulty or underlying injury, no intervention may be necessary. Before leaving the scene of a vehicular accident, prehospital caretakers should quickly make note of important features associated with increased risk of injury and convey these findings to clinicians at the trauma center upon arrival. Such findings include: significant intrusion into the passenger compartment, deformed steering wheel, ejection of the patient from the vehicle, and fatality at the scene. Prehospital hypotension is an important indication of significant injury and this finding must be communicated to the clinicians assuming care of the patient.

PRIMARY EVALUATION AND MANAGEMENT

Initial management — Initial resuscitation and management of the trauma patient is based upon protocols from Advanced Trauma Life Support® (ATLS®). Primary assessment (ie, the primary survey) follows the ABCDE pattern: Airway, Breathing, Circulation, Disability (Neurologic status), Exposure. Details related to initial management of blunt thoracic trauma (BTT) are discussed below. A basic algorithm for management of BTT is provided (algorithm 2).
Clinicians first assess and stabilize the patient's airway, breathing, and circulation, in that order (ABCs). The one caveat to this principle in patients with respiratory distress following chest trauma is that breathing may take priority over airway. If the patient is in respiratory distress due to a tension pneumothorax, the clinician should relieve the pneumothorax before performing endotracheal intubation, if needed. Positive pressure ventilation following intubation will exacerbate a pneumothorax.

After addressing the patient's ABCs, the clinician continues the initial evaluation taking into account vital signs, the initial presentation, and the mechanism of injury. Mechanism is less predictive of injury severity and ultimate disposition than abnormal vital signs in the setting of blunt trauma [24].

For any patient with unstable vital signs, hypoxia, or obvious severe injury (eg, flail chest, multiple rib fractures, large open wounds), the clinician performs a rapid search with concurrent management of immediate life-threatening injuries of the head, cervical spine, abdomen, chest, and pelvis. With blunt chest trauma such injuries include:

- Aortic injury
- Tension pneumothorax
- Hemothorax with severe, active bleeding
- Pericardial tamponade from myocardial injury
- Tracheobronchial disruption

Patients with respiratory distress, marked hemodynamic instability, or severe injury are intubated. Rapid sequence intubation is the preferred approach whenever possible, avoiding pretreatment and induction agents with the potential to cause hypotension. (See "Rapid sequence intubation in adults").

Suspected tension pneumothorax is treated with immediate needle decompression using a large angiocatheter (eg, 14 gauge). Needles as long as 7 cm may be necessary [25-27]. Acceptable sites for needle insertion include the second or third intercostal space in the midclavicular line or the fifth intercostal space in the midaxillary line. Decompression is followed by tube thoracostomy using a chest tube of at least 36 French.

If the patient stabilizes in the ED and does not require emergent operative treatment, a chest CT with contrast is performed to define the extent of thoracic injury and exclude aortic rupture. If the patient is unable to undergo CT, due to the need for immediate operation, transesophageal echocardiography can be performed in the ED or operating room to assess the aorta and heart. (See "Tube thoracostomy").

Pericardial tamponade, most likely from myocardial rupture, is detected by ultrasound as the first study of the standard FAST (Focused Assessment with Sonography for Trauma) examination (movie 1). Pericardiocentesis is performed immediately in patients with a pericardial effusion and significant hypotension. If hemodynamic compromise is severe and tamponade cannot be relieved by percutaneous drainage or if the patient develops cardiac arrest while being resuscitated, emergency department thoracotomy (EDT) may be necessary. (See 'Emergent thoracotomy' below.)

Hemothorax is treated with tube thoracostomy using a large (minimum 36 French) chest tube. Immediate bloody drainage of ≥20 mL/kg
is generally considered an indication for thoracotomy in the operating room. Vital signs, fluid resuscitation requirements, and concomitant injuries are also considered when determining the need for thoracotomy.

The evaluation of hemodynamically stable patients without obvious signs of injury vary depending upon mechanism, age, and clinical suspicion. (See ‘Subsequent management’ below.)

Emergent thoracotomy — In the setting of blunt trauma, emergency department thoracotomy (EDT) rarely results in successful resuscitation [28-33]. Among blunt trauma patients, EDT enables neurologically intact survival in approximately less than five percent of those in shock, one percent of those without vital signs upon arrival to the ED, and none of those without signs of life in the field [32]. A trauma or thoracic surgeon should be readily available if EDT is performed: immediate surgical intervention may be necessary if the patient is to survive.

The subset of blunt trauma patients most likely to survive an EDT neurologically intact include either of the following:

- Patients who lose vital signs in the ED and appear to have no obvious nonsurvivable injury (eg, massive head trauma, multiple severe injuries)
- Patients with cardiac tamponade rapidly diagnosed by ultrasound, with no obvious nonsurvivable injury

Given the resources required and risks entailed in EDT, we recommend hospitals develop policies to determine the circumstances under which the procedure is to be performed. EDT in blunt trauma patients appears to be futile in any one or more of the following circumstances:

- Patient required over 15 minutes of prehospital CPR
- Patient is apneic, pulseless, and has no rhythm on cardiac monitor in the field
- Patient has massive, nonsurvivable injuries

Some observational data suggest that no blunt trauma patient who requires more than five minutes of CPR survives neurologically intact [31].

History, examination, and monitoring — Acute evaluation of blunt thoracic trauma consists of rapidly assessing whether injury has occurred to cardiopulmonary and mediastinal structures. Depending on the presentation, this may be as simple as a thorough history and physical examination or may require multiple tests, including x-rays, computed tomography (CT) scans, and echocardiography.

The clinician first determines whether the patient is at low or high risk for significant injury. This determination is based on the vital signs (most important), the mechanism and potential for injury, and the patient’s complaints and general clinical appearance [1-5]. The limited utility of mechanism should be emphasized: a young, healthy patient involved in a severe, rollover motor vehicle crash (MVC) may sustain no injuries, while a frail elderly patient who trips and falls may incur multiple rib fractures accompanied by a pulmonary contusion. (See ‘Anatomy and mechanism’ above.)

Studies suggest the history and physical examination are insensitive for detecting intrathoracic injury. This insensitivity stems in part from the nature of the studies, which often include a heterogeneous mix of patients and injuries, a low number of positive findings, and lack follow-up.
The risk of serious injury is low among alert patients without discomfort, dyspnea, or tenderness [34-36]. Hypoxia and abnormal lung sounds are the most specific signs for pneumothorax or hemothorax, while chest pain and tenderness are most sensitive, albeit nonspecific. Normal lung sounds showed a high negative predictive value for pneumothorax in one prospective, observational study, but the number of patients with abnormal findings was too low to draw definitive conclusions [36].

Chest radiograph — The chest radiograph (CXR) is the initial test for all patients with blunt thoracic trauma [37]. The CXR is inexpensive, noninvasive, easy to obtain, and in many instances reveals useful information; studies purporting to demonstrate in which blunt trauma patients CXR is unhelpful are unconvincing. For these reasons, we suggest a CXR be obtained in all patients who have sustained blunt thoracic trauma of any significance, unless the patient requires immediate surgery or warrants immediate chest CT.

The CXR is systematically reviewed for evidence of hemothorax, pneumothorax, pulmonary contusion, fractures, and aortic injury. Studies to determine CXR findings suggestive of blunt aortic injury (BAI) are limited by their observational design and the small number of injuries [38-40]. Nevertheless, although no single finding on CXR possesses high sensitivity or specificity for BAI, the following findings on a plain CXR are consistent with BAI and indicate a need for further investigation:

- Wide mediastinum (supine CXR > 8 cm; upright CXR >6 cm)
- Obscured aortic knob; abnormal aortic contour
- Left "apical cap" (ie, pleural blood above apex of left lung)
- Large left hemothorax
- Deviation of nasogastric tube rightward
- Deviation of trachea rightward and/or right mainstem bronchus downward
- Wide left paravertebral stripe

A widened mediastinum is a sensitive but nonspecific sign of aortic injury. Such injuries account for about 20 percent of abnormal mediastinal widening on CXR after blunt trauma [41]. Further study, usually CT of the chest, is performed if CXR abnormalities consistent with aortic injury are identified. (See 'Chest CT' below.)

Initial evaluation with a portable, anterior-posterior (AP) CXR is performed in patients at greater risk of significant injury who must remain in the ED for closer monitoring. Such patients include those with: major mechanism of injury, hemodynamic instability, severe tenderness, a seat belt sign across the abdomen, hypoxia, or clinical signs of multiple rib fractures. The plain CXR may not have sufficient sensitivity to detect injury in these patients, and minor abnormalities on CXR or clinical concern are sufficient to justify more detailed imaging with chest CT or other modalities.

The stable patient with minimal findings (eg, minor abrasion, mild tenderness, and normal vital signs) can be sent to radiology for standard posterior-anterior (PA) and lateral CXR, provided the physical examination is otherwise unremarkable and there is no suspicion of major injury. Patients with pain and tenderness of the lower ribs, especially with pleuritic complaints, or abdominal pain and tenderness, are at higher risk for both intrathoracic and intraabdominal injuries [42].

Normal PA and lateral chest radiographs in a low-risk patient obviate the need for additional studies to rule out intrathoracic or chest wall injury. Rib films are rarely needed. They may provide more information about fractures but rarely change management. The clinician can treat patients likely to have sustained a rib fracture on
the basis of symptoms and signs, despite the absence of radiographic evidence [43,44]. (See "Rib fractures").

Few studies have evaluated the utility of a CXR in the assessment of blunt trauma:

- One prospective cohort study of patients evaluated with a CXR for blunt trauma at two major urban trauma centers found that 31 of 492 patients had a significant chest injury [2]. The presence of hypoxia or tenderness identified all patients with important chest radiographic findings. While a decision rule based on these findings would potentially eliminate the need for 46 percent of radiographs, a validation study has yet to be performed, and these preliminary findings should not be used to determine the need for CXR.

- Similar results were found in a prospective study of 523 stable blunt trauma patients at another major urban trauma center. The presence of tachypnea, pain or tenderness, or abnormal lung sounds identified all patients with pneumothorax or hemothorax [36]. The utility of this study is limited by the small number of patients with disease, the use of portable AP CXRs, and lack of follow-up.

- Conflicting results were found in a retrospective study of 581 patients with minor blunt chest trauma [45]. In 6 of 20 patients with hemothorax or pneumothorax the physical examination was normal, suggesting clinicians should have a low threshold for obtaining a CXR in blunt trauma.

Ultrasound — Ultrasound (ie, Focused Assessment with Sonography in Trauma, or FAST, exam) has become an integral part of trauma evaluation, primarily to assess for pericardial tamponade (movie 1) and intraabdominal injury.

Ultrasound of the chest is also commonly performed in the ED to rule out or diagnose pneumothorax or hemothorax [46-48]. Two signs, the sliding lung and "comet tail" artifact, appear to reliably rule out pneumothorax. A systematic review of four prospective studies found the sensitivity and specificity of ultrasound for pneumothorax to range from 86 to 98 percent, which was superior to supine chest radiograph (sensitivity 28 to 75 percent) [47]. Both techniques demonstrated high specificity.

Ultrasound appears to be more sensitive in diagnosing hemothorax than plain film. Should a trauma patient become acutely unstable, ultrasound provides a fast and effective method to assess for pericardial tamponade or pneumothorax [46-48].

Chest CT — In many trauma centers, patients involved in high energy trauma are appropriately sent almost immediately for computed tomography (CT), before a chest radiograph can be performed.

The diagnostic accuracy of CT is far greater than plain radiography for intrathoracic injury, and allows for detailed evaluation of the pulmonary and mediastinal structures [49-52]. CT provides greater sensitivity in diagnosing small pneumothoraces, as well as pneumomediastinum and pulmonary contusions and lacerations. If a multidetector CT scan is used, reconstructions of the aorta and bony structures can be rapidly completed if there are any findings or concerns raised in the initial physical or radiological evaluation [11,49,53]. Patients with a low-risk mechanism, minor injuries, and normal chest radiographs generally do not require CT imaging, which may be overutilized in these circumstances [54].

SUBSEQUENT MANAGEMENT — Patients manifesting hemodynamic instability, hypoxia, or obvious severe injury require immediate assessment for life-threatening
injuries with concurrent management. This is discussed above. (See 'Primary evaluation and management' above.)

Patients who appear clinically stable without apparent injury, but have sustained high energy blunt trauma with rapid deceleration are at risk for severe injury. Their initial evaluation is performed in the trauma or critical care area within the emergency department (ED). A portable chest radiograph (CXR) is obtained as part of this immediate evaluation. If this study is normal and no severe extrathoracic injury is identified, a posterior-anterior (PA) CXR is subsequently obtained. A chest CT is obtained if any concerning findings are identified on CXR, the patient has persistent chest pain or dyspnea, or the patient is unable to undergo a thorough clinical examination because of an extrathoracic injury.

Patients who appear clinically stable, without apparent injury, without a concerning mechanism, and without abnormal findings on standard PA and lateral CXR require no further evaluation, with the possible exception of an electrocardiogram (ECG). An ECG is performed in all patients with anterior chest trauma, the elderly, and patients with a history of coronary heart disease.

Patients without evidence of injury after appropriate evaluation may be discharged. Patients are informed of the possibility of delayed presentations of injury and told to return to the ED immediately for such symptoms as severe pain, difficulty breathing, and lightheadedness.

SPECIFIC INJURIES

Aortic injury

Approach — Patients involved in high energy blunt trauma involving rapid deceleration (eg, fall over 3 meters/10 feet, motor vehicle crash at speeds over 65 kilometers/40 miles per hour) are at significant risk for blunt aortic injury (BAI). Almost 80 percent of BAI s cause immediate death from aortic transection. In a minority of patients the adventitia and mediastinal structures contain the rupture, allowing the patient to survive transport to the hospital. If BAI goes undiagnosed, these patients generally sustain an aortic rupture within 24 hours [55]. Prompt ED diagnosis is crucial and may be lifesaving in some patients (algorithm 1).

There are no clinical signs or examination findings with sufficient sensitivity or specificity to detect BAI. Therefore, the clinician should use appropriate radiographic studies to assess every patient involved in high energy trauma with rapid deceleration or who shows signs of severe chest injury. The initial study is a chest radiograph (CXR), which should be closely scrutinized for any signs of aortic injury. (See 'Chest radiograph' above.)

The risk of aortic injury is negligible in patients with a truly normal CXR, no significant injury on examination, and a mechanism that does not involve rapid deceleration [41,56]. No further testing is needed in such patients.

Any abnormality on CXR should be followed by a computed tomography (CT) scan of the chest. A normal CT scan essentially rules out BAI [39,57,58]. Clinicians often have difficulty obtaining an upright, posterior anterior (PA) CXR in a trauma patient, and subtle abnormalities may be missed on supine studies. If the clinician has a strong suspicion for BAI, CT scan should be obtained, regardless of CXR appearance. CT
scan is extremely sensitive and specific for BAI, and surgeons can determine the need for operative intervention on the basis of CT findings [56,59].

The other modalities used to diagnose BAI include angiography and transesophageal echocardiography. While angiography is the traditional gold standard, and is theoretically more sensitive than CT, its use should be reserved for those patients with equivocal CT scans. Angiography is more time consuming and invasive, and rarely improves upon CT.

Imaging — Clinicians should obtain CT of the chest to assess for BAI if mechanistic, clinical, or radiographic evidence suggests the possibility of intrathoracic injury (table 1 and algorithm 1). Such evidence includes the following:

- High energy trauma involving rapid deceleration AND any of the following:
  - Chest wall contusions or deformity OR
  - Multiple rib fractures OR
  - Pneumothorax or hemothorax OR
  - Abnormal chest x-ray (eg, wide mediastinum) (see 'Chest radiograph' above)

Chest CT has great sensitivity and specificity for BAI and is used most often to make the diagnosis [60-62]. CT also enables detection of other intrathoracic injuries.

Among patients with abnormal CXR findings, chest CT identifies injuries that would not otherwise be found, resulting in significant changes in management, between 20 and 30 percent of the time [49,63]. Among patients without abnormal CXR findings in whom chest CT is performed solely based on mechanism, the study leads to changes in management only 5 percent of the time. An equivocal CT scan should be followed by angiography to exclude aortic injury [56,59].

Most studies that assess the use of CT in chest trauma involve critically ill or multiply injured patients. Therefore it is difficult to draw conclusions about the appropriate use of CT in patients without evidence of severe injury, based solely on mechanism.

Transesophageal echocardiography (TEE) is an excellent modality to assess for BAI in patients too unstable for chest CT. TEE has high sensitivity and specificity for BAI, can be performed in the emergency department or the operating room, requires no contrast, and provides information about cardiac injury and function.

Transesophageal echocardiography (TEE) is operator dependent and suffers in some studies from loss of sensitivity as the interposition of the air-filled trachea between the aorta and esophagus creates a blind spot, precluding adequate evaluation of the distal ascending aorta and proximal arch. It should not be performed in patients with unstable cervical spine injuries or esophageal injuries. TEE compares favorably to angiography or CT scan in the majority of cases and diagnoses some intimal tears not seen on corresponding angiography, although the clinical significance of these tears is unclear [64-66]. It also has utility in diagnosing valvular injuries and pericardial effusions. Unlike transesophageal imaging, transthoracic echocardiography, while excellent for diagnosing significant pericardial effusions, cannot reliably diagnose BAI [64,65].

Management — If BAI is found, the goal of emergency treatment is to prevent propagation of adventitial dissection and subsequent free rupture by controlling the wall stress or shearing forces exerted on the aorta. This is accomplished by lowering the heart rate with a beta-blocker, and decreasing the blood pressure with intravenous
nitroprusside or nitroglycerin, if beta blockade alone does not accomplish this. Intravenous esmolol, a rapidly acting beta blocker with a short half-life, is ideal for this purpose. Beta blockade should be in effect before additional medications are added to reduce the blood pressure. If not, compensatory elevations in heart rate may increase shearing forces. A calcium channel blocker such as diltiazem may be used should beta blockers be contraindicated.

Clinicians should strive to maintain the heart rate below 100 and the systolic blood pressure around 100 mmHg [67]. Prior to the advent of antihypertensive therapy, mortality in stable patients in the emergency department, before surgical thoracotomy could be performed, was approximately 12 percent [11]. Antihypertensive therapy has reduced this rate substantially.

Options for repair include thoracotomy with open repair or graft and endovascular stenting, and percutaneous stenting. In some cases, emergency operation is not feasible. Multiple case series report patients who undergo delayed repair of BAI after diagnosis and management of wall stress [68-70]. After controlling for comorbidities, the mortality and morbidity of these patients is similar to those who undergo immediate repair. Patients undergoing delayed repair often have concomitant injuries (eg, head or abdomen) or other preexisting comorbidities.

Surgery should not be delayed if radiographic studies or clinical findings reveal evidence of active or impending rupture, such as contrast extravasation, pseudocoarctation, rapid enlargement of a pseudoaneurysm, or large, reaccumulating hemothorax, and the patient is hemodynamically stable without other major injuries.

Cardiac injury

Cardiac contusion — Clinicians should obtain an electrocardiogram (ECG) on all blunt trauma patients with any of the following:

- Pain and tenderness directly over the mid-anterior chest
- Sternal fracture
- History suggestive of cardiac disease (eg, accident precipitated by syncope, severe chest pain, or shortness of breath)
- Active symptoms or signs suggestive of cardiac disease
- Major mechanism of injury (eg, rollover, high speed, fatality at scene)

Findings such as unexplained persistent tachycardia, new bundle branch block, or dysrhythmia raise concern for cardiac contusion and patients with such findings should be admitted for cardiac monitoring and possibly echocardiography. Unexplained tachycardia should also prompt the clinician to look for other injuries or ongoing hemorrhage.

It remains unclear whether the elevation of cardiac biomarkers, in the absence of an abnormal ECG or hemodynamic instability, provides any prognostic value [71,72]. Without clear utility, obtaining cardiac biomarkers cannot be considered standard. We do not routinely obtain cardiac biomarkers, but some trauma surgeons do.

Myocardial rupture — Most patients with severe blunt cardiac injury do not reach the ED alive [9,10]. Of those who do, hypotension may have reduced pressure on the injured myocardium, which may subsequently rupture as fluid resuscitation restores systemic pressure. Other injuries may lead to delayed rupture within several days of admission.
Nonspecific signs and concomitant injuries make clinical diagnosis of myocardial injury difficult [10]. Signs such as hypotension associated with distended neck veins and muffled heart sounds suggest tamponade, which often occurs with severe cardiac injury. Immediate bedside ultrasound (US) by a skilled ultrasonographer can reveal the diagnosis rapidly (movie 1) [9,73,74]. The clinician should perform or obtain bedside echocardiography in any patient with unexplained shock out of proportion to apparent injuries or despite aggressive resuscitation. When immediate bedside US is unavailable and the clinician strongly suspects tamponade, pericardiocentesis should be performed.

Emergency department thoracotomy (EDT) rather than pericardiocentesis may be the best treatment for tamponade from blunt myocardial injury if the patient is too unstable to be moved to the operating room [9]. For patients amenable to operative intervention, intubation should be delayed if possible until just before sternotomy because abundant anecdotal evidence suggests induction may precipitate hemodynamic collapse [73]. (See 'Emergent thoracotomy' above.)

Myocardial infarction — Myocardial Infarction (MI) is a rare complication of blunt chest trauma [75,76]. Causes include coronary artery dissection and thrombosis [76-78]. The left anterior descending artery appears to be involved most often, but any coronary artery may be involved [76,79].

A rapid ECG is obtained in the blunt thoracic trauma patient to screen for cardiac contusion and to rule out the rare MI. Management of MI in this setting is controversial due to the rarity of the disease and the frequent presence of multiple injuries. Catheterization with stenting may be the best approach [79,80]. Thrombolysis has been used successfully and may be considered if angiography is unavailable, although it may be ineffective and severe bleeding complications may occur [80,81].

Pulmonary injury — Major pulmonary injuries that require treatment and admission include: pneumothorax, hemothorax, pulmonary contusion, pulmonary parenchymal injuries, and tracheobronchial injuries.

Pneumothorax — Pneumothorax is a common complication of blunt trauma, often sustained from a fractured rib [82]. Patients may manifest tachypnea, hypoxia, unilateral diminished or absent breath sounds, or unilateral hyperresonance to percussion, depending on the extent of the pneumothorax. (See 'Initial management' above.)

The supine chest radiograph has high specificity for diagnosing a pneumothorax from blunt injury, but its sensitivity is variable. Ultrasound may be a more sensitive initial screening tool. (See 'Ultrasound' above and 'Chest radiograph' above.)

Patients with historical features (eg, pleuritic pain, dyspnea) or examination findings (eg, rib fracture) that place them at risk for pneumothorax should be evaluated with an upright PA chest x-ray using inspiratory and expiratory views or a CT scan of the chest (picture 1 and picture 2 and picture 3). Another approach in patients whose initial x-ray does not reveal a pneumothorax but who are at risk is to repeat the radiograph in 6 hours.

Occult pneumothorax diagnosed by CT scan in asymptomatic blunt trauma patients requires no intervention other than observation [11,83]. Patients who require positive pressure ventilation may require a thoracostomy tube to prevent the development of a tension pneumothorax [84]. In general, a pneumohemothorax is treated with drainage.
by tube thoracostomy. Small, clinically insignificant collections may be treated with needle aspiration or drainage, at the discretion of the trauma surgeon [85].

One meta-analysis and several prospective studies support the use of a first generation cephalosporin to decrease the incidence of pneumonia, but not empyema, in patients undergoing tube thoracostomy following chest trauma [84, 86, 87].

Hemothorax — Injuries leading to massive hemothorax include aortic rupture, myocardial rupture, and injuries to hilar structures. Other causes include injuries to the lung parenchyma and intercostal or mammary blood vessels. A volume of 300 mL is needed for hemothorax to manifest on an upright CXR. In skilled hands, ultrasound can diagnose hemothorax accurately. (See 'Ultrasound' above.)

Hemothorax is treated with tube thoracostomy using a large (minimum 36 French) chest tube. Immediate bloody drainage of ≥20 mL/kg is generally considered an indication for surgical thoracotomy. Shock and persistent, substantial bleeding (generally >3 mL/kg/hour) are additional indications. Vital signs, fluid resuscitation requirements, and concomitant injuries are considered when determining the need for thoracotomy.

Pulmonary contusion — Pulmonary contusion is another common consequence of blunt chest trauma [22, 88]. Pulmonary contusions generally develop over the first 24 hours and resolve in about one week. Irregular, nonlobular opacification of the pulmonary parenchyma on chest x-ray is the diagnostic hallmark. About one-third of the time the contusion is not evident on initial radiographs [88]. Chest CT provides better resolution, but rarely alters management, unless other injuries are found. Contusions evident on CT but not plain x-ray have better outcomes [89].

Pain control and pulmonary toilet are the mainstays of treatment. Prophylactic endotracheal intubation is unnecessary, but patients with hypoxia or difficulty ventilating require airway management. While opinions vary, fluid resuscitation with crystalloid to euvoolemia appears appropriate. Common complications include pneumonia and acute respiratory distress syndrome (ARDS).

Tracheobronchial injury — Tracheobronchial injuries occur in less than one percent of patients with blunt thoracic trauma, and few studies exist to guide diagnosis and management [90, 91]. Most patients who sustain such injuries die at the scene [91]. The trachea is protected from injury by its position relative to the mandible, sternum and vertebral column, and its relative elasticity [91]. Injury of the cervical trachea is uncommon but can occur from a direct blow, which may be of low energy; injury of the intrathoracic trachea results from high energy trauma, generally motor vehicle crashes (MVC) and sometimes crush injuries [92, 93]. Most tracheal or bronchial injuries occur as part of multiple trauma, including additional injuries to the lungs and chest wall [90, 93]. The right main bronchus is involved most often, generally within one to two cm of the carina, followed by the left main bronchus.

Diagnosis is difficult and often delayed [93]. Intrathoracic injury can be subtle and indolent, presenting with retained secretions, recurrent pneumothoraces, and obstruction. The sine qua non of intrathoracic tracheobronchial injury is a significant air leak and pneumothorax or pneumomediastinum that reaccumulates despite tube thoracostomy. A cervical injury may present without a significant air leak, if the tear or rupture is contained by the adventitia. Signs of cervical tracheal injury include dyspnea, hoarseness, and subcutaneous emphysema.
Radiographs generally reveal marked air in local soft tissue (ie, subcutaneous emphysema). If tracheal disruption occurs, the larynx can rise, allowing the hyoid bone to ascend above the level of the third cervical vertebra, an unusual finding otherwise. Fractures of the first three ribs are associated with intrathoracic injury [92,93]. Other radiologic findings on plain film include: persistent pneumothorax with a dependent lung, interstitial air in the wall of the trachea or mainstem bronchus, abnormal location of the endotracheal tube (ETT), and a distended ETT cuff due to protrusion of the trachea. Of note, an isolated finding of air outlining the trachea or mainstem bronchus from pneumomediastinum does not correlate significantly with tracheobronchial rupture [92].

Definitive diagnosis is made in the operating room or by bronchscopy. Multidetector CT scan (MDCT) enables diagnosis of some tracheal tears, but its sensitivity is unknown [92]. If tracheobronchial injury is suspected, obtain a MDCT or consult a thoracic surgeon for evaluation and possible bronchscopy. Most patients undergo primary repair or possible lung resection, although good results using selective nonoperative management have been reported [91,93,94].

Diaphragm rupture — Blunt diaphragmatic rupture occurs in approximately 1 percent of thoracic trauma patients, although it has been reported in up to 8 percent of those requiring laparotomy. Its incidence is increasing, however, as the resolution and diagnostic accuracy of multidetector CT scanners improves. While case reports exist of diaphragmatic rupture following minor trauma, [95,96] the great majority of cases result from high energy injuries, most often motor vehicle crashes (MVC). Data from studies of highway MVCs suggest that significant intrusion (≥ 30 cm) into the passenger compartment following head-on or near-side collisions and rapid deceleration (≥40 km/hour) increase the risk of sustaining a diaphragmatic rupture [97]. Left-sided rupture occurs approximately twice as often as right sided [98,99]. Anatomic differences account for this discrepancy: the posterolateral aspect of the left hemidiaphragm is relatively weak and the bowel and stomach provide less protection than the liver.

Diaphragmatic rupture can occur from several possible mechanisms: increased abdominal pressure from forceful impact can cause stretching and avulsion; the same pressure can cause direct lacerations; or fractured ribs can penetrate the muscle [92]. Tears tend to be in a radial orientation along the posterolateral aspect of the diaphragm. Diagnosis is easiest in left sided injuries when bowel enters the thoracic cavity. Small tears may require years before negative intrathoracic pressure and the positive intraabdominal pressure ultimately lead to herniation of viscera.

Severe concomitant injuries occur in 50 to 90 percent of cases. Injuries to the spleen and liver are most common. Pelvic and long bone fractures, closed head injuries, and blunt aortic injury can also occur [92,97,100-102]. Diaphragmatic injuries are often diagnosed incidentally during laparotomy or thoracotomy to treat coexistent injuries. Symptoms vary and generally reflect the severity of both the diaphragmatic injury (eg, tear versus rupture with herniation) and associated injuries.

Diaphragmatic injury may be associated with epigastric and abdominal pain, referred shoulder pain, shortness of breath, vomiting, dysphagia, or shock. The initial chest x-ray (CXR) is normal or nondiagnostic in up to 50 percent of patients. Nevertheless, the CXR may reveal diagnostic findings, such as abdominal viscera in the hemithorax, a nasogastric tube in the thorax, or a focal constriction of herniated viscera at the site of the tear, producing circumferential compression (collar sign). CXR may also reveal nonspecific findings such as atelectasis, pleural effusion, loss of the usual hemidiaphragm contour, eventration of the diaphragm, and pneumothorax or
hemothorax, although none of these is sensitive or specific for diaphragmatic injury. Serial CXRs may be useful, especially in patients in whom positive pressure ventilation has prevented bowel herniation [92,103]. Because many studies do not differentiate between penetrating and blunt injuries, plain CXR may have greater accuracy in detecting injuries due to blunt trauma than has been thought.

The multidetector CT (MDCT) has improved our ability to diagnose diaphragmatic injury and is the best available test. In addition to improved resolution, MDCT allows for production of sagittal and coronal reformattting, which appears to improve accuracy. Conventional CT scanning has limited accuracy. At one institution with a large experience using single-slice CT, the sensitivity for diagnosing left-sided diaphragmatic tear was 78 percent and right-sided tear 50 percent with 100 percent specificity [104]. However, if visceral herniation was not present, accuracy was poor. Right-sided injuries are more difficult to diagnose because the liver and diaphragm have a similar appearance on CT [92,105]. Coexisting injuries, atelectasis, and aspiration can obscure the diaphragm and decrease sensitivity. Congenital left hemidiaphragmatic defects may represent a normal variant in a significant subset of patients, further decreasing accuracy [92].

Esophageal rupture — Blunt trauma patients rarely sustain esophageal rupture. Esophageal injury lacks specific symptoms and generally occurs in multiple trauma making it difficult to diagnose. Injuries may be seen in the cervical, thoracic, and distal esophagus [92,106-108]. Given the small number of reported cases, it is difficult to describe any specific patterns of injury. Potential mechanisms include: compression, traction from cervical hyperextension, and direct penetration from thoracic fractures [92]. Signs of injury may include: blood in the nasogastric aspirate, subcutaneous cervical air, and neck hematoma, but none is sensitive [109,110].

Plain x-ray may reveal pneumomediastinum, pleural effusion, mediastinal contour changes (which progress with inflammation), or a gas bubble in the nasogastric tube or esophagus, if a tracheoesophageal communication exists. Diagnosis is made by endoscopy or esophagography using water-soluble contrast. CT may show subtle air leaks beside the site of perforation, although the sensitivity or specificity of such findings is unclear [92]. Pneumomediastinum without a clear cause suggests the need for further evaluation. Esophageal injuries are often associated with severe concomitant injuries that may mask findings, delaying diagnosis until mediastinitis or an empyema develops [92,106].

Sternal fracture — The degree of sternal fracture displacement correlates with the risk for associated thoracic injury, although even nondisplaced fractures carry a substantial risk [111-113]. Common associated injuries include: rib fracture, myocardial contusion, hemopericardium, spinal fracture, retrosternal hematoma, hemothorax, and pneumothorax.

In a small autopsy study, AP chest radiograph had approximately 50 percent sensitivity for detecting sternal fractures [114]. Lateral views improve sensitivity, but it is unclear by how much. CT appears to be more sensitive, but no gold standard exists. We suggest a CT of the chest and an electrocardiogram (ECG) be obtained to rule out associated injuries if a sternal fracture is diagnosed on plain film. Depending upon clinical circumstances, cardiac biomarkers may also be obtained.

In a hemodynamically stable patient with an isolated, nondisplaced sternal fracture and no ECG abnormalities, cardiac monitoring is rarely warranted [113]. We suggest patients with associated intrathoracic injuries, severe pain, or poor pulmonary reserve,
particularly the elderly, be admitted for observation. Some sternal fractures may be treated better by subperiosteal anesthesia or operative fixation. Clinicians should obtain consultation with a general or trauma surgeon if complicating factors are present.

Sternal fractures usually result from a high-energy direct blow to the anterior chest wall. Typically these fractures occur during a motor vehicle crash when the driver's chest strikes the steering column or rapid deceleration causes an occupant's chest to slam against their cross-shoulder seatbelt [113,115].

Scapular fracture — Scapular fractures occur from trauma involving significant force and raise concern for further injury [16]. High-speed motor vehicle crashes and falls from heights are common mechanisms. Associated injuries include intrathoracic injuries, clavicle fractures, rib fractures, spine fractures, spleen and liver injuries, and tibial fractures (usually in pedestrians struck by motor vehicles). The association between scapular fracture and blunt aortic injury may be overestimated [17].

We obtain a chest CT in most patients with a scapular fracture following significant blunt chest trauma because of the forces involved and the risk of concomitant injury. We further suggest clinicians obtain consultation with trauma and orthopedic surgery. If the chest CT and workup for extrathoracic trauma reveal no injuries, and no concerns exist about analgesia, comorbidities, or the patient's social circumstances, patients with scapular fractures may be discharged.

Rib fracture — Patients with three or more rib fractures, especially elderly patients, are at significant risk for complications, such as pulmonary contusion and pneumonia, even in the absence of other injuries, and should be admitted for observation. Rarely, healthy, younger individuals with three rib fractures, having undergone a thorough clinical and radiographic evaluation by clinicians experienced in trauma management, and an appropriate period of observation, may be discharged from the emergency department. (See "Rib fractures", section on 'Disposition'.)

Admitted patients are monitored, ideally using pulse oximetry and capnography, while being provided with oxygen, analgesia, and treatment of any complications. We suggest anaesthesia consultation be obtained for invasive pain management (eg, epidural anesthesia, intercostal nerve block). While intravenous narcotics are usually given acutely to decrease pain and provide for better pulmonary mechanics, epidural anesthesia may provide superior pain control and enable improved pulmonary function among patients with multiple rib fractures. Epidural anesthesia may also decrease the length of time patients spend in the ICU and on ventilators. (See "Rib fractures", section on 'Analgesia and monitoring'.)

Flail chest — Flail chest occurs when three or more adjacent ribs are each fractured in two places, creating one floating segment comprised of several rib sections and the soft tissues between them (figure 1). This unstable section of chest wall exhibits paradoxical motion (ie, it moves in the opposite direction of the uninjured, normal-functioning chest wall) with breathing, and is associated with significant morbidity from pulmonary contusion. Abnormal motion can be difficult to detect making the diagnosis difficult.

Initial management of flail chest consists of oxygen and close monitoring for early signs of respiratory compromise, ideally using both pulse oximetry and capnography in addition to clinical observation. Stabilization of the segment with manual or object pressure restricts chest wall expansion thereby interfering with proper respiratory
mechanics and is no longer used. Use of noninvasive positive airway pressure by mask may obviate the need for endotracheal intubation in alert patients. Patients with severe injuries, respiratory distress, or progressively worsening respiratory function require endotracheal intubation and mechanical ventilatory support.

Minor injury — If the chest radiograph (preferably PA and lateral) is normal or there is an isolated rib fracture(s), the patient can be treated for pain control and discharged with appropriate follow-up. The patient should be carefully instructed to return to the ED if any concerning symptoms, such as any shortness of breath or signs of pneumonia, develop. Incentive spirometry may help some patients prevent atelectasis and subsequent pneumonia, though no evidence exists to support this practice.

SUMMARY AND RECOMMENDATIONS — Initial management of the patient with blunt thoracic trauma follows the basic principles of Advanced Trauma Life Support®. A basic algorithm for management of BTT is provided (algorithm 2). (See 'Initial management' above.)

- Clinicians managing blunt thoracic trauma first assess and stabilize the patient's airway, breathing, and circulation. The one caveat to this principle is that breathing may take priority over airway if a tension pneumothorax is present. In this case, the clinician should relieve the pneumothorax before performing endotracheal intubation, if needed. (See 'Initial management' above.)
- When determining the likelihood of severe injury from blunt thoracic trauma, abnormal vital signs are more important than mechanism of injury. Immediate life-threatening injuries from blunt chest trauma include:
  - Aortic injury
  - Tension pneumothorax
  - Hemothorax with severe, active bleeding
  - Pericardial tamponade from myocardial injury
  - Tracheobronchial disruption

Emergent management of life-threatening injuries is discussed above. (See 'Initial management' above.) Subsequent management of specific injuries is discussed separately above. (See 'Aortic injury' above and 'Pulmonary injury' above and 'Cardiac injury' above.)

- In the setting of blunt trauma, emergency department thoracotomy (EDT) rarely results in successful resuscitation. The subset of blunt trauma patients most likely to survive an EDT neurologically intact include either of the following:
  - Patients who lose vital signs in the ED and appear to have no obvious nonsurvivable injury (eg, massive head trauma, multiple severe injuries)
  - Patients with cardiac tamponade rapidly diagnosed by ultrasound, with no obvious nonsurvivable injury (see 'Emergent thoracotomy' above).

- We suggest a chest x-ray (CXR) be obtained in all patients who have sustained blunt thoracic trauma of any significance, unless the patient requires immediate surgery or warrants immediate chest CT. The CXR is systematically reviewed for evidence of hemothorax, pneumothorax, pulmonary contusion, fractures, and aortic injury. (See 'Chest radiograph' above.)
- Patients involved in high energy blunt trauma involving rapid deceleration are at significant risk for blunt aortic injury (BAI). Almost 80 percent of BAIs cause
immediate death. No clinical signs or examination findings and no single finding on CXR possess adequate sensitivity or specificity for BAI. The following CXR findings are consistent with BAI and indicate a need for further investigation, usually chest CT:

- Wide mediastinum (supine CXR > 8 cm; upright CXR > 6 cm)
- Obscured aortic knob; abnormal aortic contour
- Left "apical cap" (i.e., pleural blood above apex of left lung)
- Large left hemothorax
- Deviation of nasogastric tube rightward
- Deviation of trachea rightward and/or right mainstem bronchus downward
- Wide left paravertebral stripe

BAI is discussed in detail above. (See 'Aortic injury' above.)

- Bedside ultrasound is a critical tool for the diagnosis of traumatic pericardial tamponade. It is also useful to diagnose pneumothorax and hemothorax. We suggest a chest CT be obtained if any concerning findings are identified on CXR, the patient has persistent chest pain or dyspnea, or the patient is unable to undergo a thorough clinical examination because of an extrathoracic injury. (See 'Ultrasound' above and 'Chest CT' above.)

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