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Emergency Department Evaluation And Management Of Blunt Chest And Lung Trauma

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Abstract

The majority of blunt chest injuries are minor contusions or abrasions; however, life-threatening injuries, including tension pneumothorax, hemothorax, and aortic rupture can occur and must be recognized early. This review focuses on the diagnosis, management, and disposition of patients with blunt injuries to the ribs and lung. Utilization of decision rules for chest x-ray and computed tomography are discussed, along with the emerging role of bedside lung ultrasonography. Management controversies presented include the limitations of needle thoracostomy using standard needle, chest tube placement, and chest tube size. Finally, a discussion is provided related to airway and ventilation management to assist in the timing and type of interventions needed to maintain oxygenation.

Prior to beginning this activity, see "Physician CME Information" on the back page.

This issue is eligible for 4 Trauma CME credits.

Case Presentations

You are about to start a busy Monday afternoon shift when you hear a radio call from EMS for a high-speed motor vehicle crash. The dispatcher tells you that the patients are 5 minutes away. The first patient that arrives is an unrestrained 23-year-old male driver. The patient has severe right-sided chest pain with moderate respiratory distress. His blood pressure is 102/54 mm Hg, his heart rate is 112 beats/min, and the pulse oximeter reads 92% on room air. You are concerned for a pneumothorax but wonder what else could explain his abnormal vital signs...

The second patient is the unrestrained 27-year-old female passenger from the same accident, with a chief complaint of chest pain, difficulty breathing, and shortness of breath. Her blood pressure is 120/70 mm Hg, her heart rate is 85 beats/min, and the pulse oximeter reads 97% on room air. On exam, the patient has decreased breath sounds on the right side. Again, pneumothorax sounds likely as you wait for the portable x-ray; you wonder if a bedside ultrasound could facilitate making the diagnosis...

A third patient then walks into triage. He is a 79-year-old man who has come in after a fall from standing and is complaining of rib pain. He is in moderate distress. His blood pressure is 140/90 mm Hg, his pulse is 90 beats/min, and his oxygen saturation is 97% on room air. His only complaint is extreme pain to his left chest. He tells you that his medical history is positive for type 2 diabetes mellitus, hypertension, and chronic obstructive pulmonary disease. He takes metformin, metoprolol, and inhaled tiotropium bromide. On physical exam, you see bruises to the left chest wall and can feel crepitus; you suspect multiple rib fractures and get ready to treat a third pneumothorax...

Introduction And Epidemiology

Traumatic injuries continue to be a major health concern in the United States. Unintentional injuries have become the fourth leading cause of death, now exceeding stroke.[1] Trauma is also the leading cause of death, morbidity, hospitalization, and disability in Americans aged 1 year to 45 years. Blunt chest injuries are a particular concern, occurring in 12 persons per 1 million per day, with approximately one-third requiring hospital admission. Blunt thoracic traumatic injuries are responsible for 20% to 25% of all blunt trauma deaths.[2]

Motor vehicle crashes account for 70% to 80% of blunt chest trauma cases.[3,4] Motor vehicle crashes can cause injury both by direct forces of impact as well as rapid deceleration from high speed. Other common causative mechanisms of blunt chest injuries include falls, blast injuries, barotrauma, and physical assault. In a review of 1696 patients with blunt chest trauma, injuries were considered to be minor in 710 patients (42%), intermediate in 740 (44%), and severe in 246 (15%).[3] Global in-hospital mortality was low (5%), but increased to 37% when only patients with multiple severe injuries were considered. Thoracic skeletal fractures were present in 84% of these patients, while flail chest was diagnosed in 8%. Pulmonary contusion was diagnosed in 16% of the patients, diaphragmatic rupture was present in 2%, and tracheobronchial injury in 0.4%.[3]

Rib fractures are identified in up to two-thirds of chest trauma patients who receive radiographic imaging.[4-6] Rib fractures are some of the most common injuries in the elderly, accounting for approximately 12% of all fractures, with increasing incidence as this population gets older.[7] Emergency clinicians must have a low threshold of suspicion for rib fractures and bony skeletal injury in patients with blunt thoracic trauma, as up to 50% of fractures may be undetected radiographically.[6] This is important, as morbidity and mortality can be significant from chest wall injuries alone. One review of 77 elderly patients reported a 38% rate of respiratory complication, with 8% mortality, associated with isolated rib fractures.[8] Mortality associated with a flail chest is as high as 16%.[9]

Sternal fractures occur in approximately 8% of severe blunt chest trauma patients,[10,11] 90% of which are secondary to motor vehicle crashes.[11,12] One study of 200 patients with sternal fracture reported an estimated 30% incidence of concomitant chest injuries.[12] The significance of associated intrathoracic injury associated with sternal fractures is underscored by the fact that fractures of the sternum have been associated with cardiac contusion in 20% to 40% of cases.[13]

Pulmonary contusions, pneumothorax, and hemothorax occur in 30% to 50% of patients with severe blunt chest trauma managed in trauma centers. [4,11,13-17] Diaphragmatic tears secondary to blunt trauma are uncommon, but they have potential for delayed complications (eg, diaphragmatic hernia) if not identified. Up to 6% of patients with blunt abdominal trauma have had traumatic diaphragmatic rupture diagnosed during exploratory laparotomy.[18] Clinically significant tracheobronchial injuries are rarely identified in blunt chest trauma, and are reported in < 1% of cases.[19]

This issue of *Emergency Medicine Practice* provides an evidence-based review of blunt chest trauma with a focus on injuries involving the chest wall, lungs, and pleura. Best-practice recommendations are made to facilitate clinical decision-making and appropriate resource utilization.

Critical Appraisal Of The Literature

PubMed was searched using the following terms: *blunt chest trauma, blunt chest injury, traumatic pneumothorax, traumatic hemothorax, pulmonary contusion, rib fractures, flail chest, clavicle fracture, scapula fracture, sternoclavicular dislocation*, and *sternum fracture*. Articles were selected if they were relevant to emergency care and focused on adult patients. References from the papers were also utilized. Guidelines from the Eastern Association for the Surgery of Trauma (EAST) and the American College of Radiology (ACR) Appropriateness Criteria® were included as found on the National Guideline Clearinghouse site at www.guideline.gov.

Review of the literature clearly demonstrated that there is a paucity of well-designed prospective studies; much of the evidence is based on retrospective analysis of databases and cohort studies. Consequently, much of the literature suffers from selection bias and from being underpowered.

Anatomy And Pathophysiology

Pulmonary Contusion

Pulmonary contusions commonly result from direct impact to the chest wall or from concurrent chest wall injury, such as from a blast.[20] Acute parenchymal lung injury produces multiple physiological effects, all of which have an impact on outcomes.

The mortality associated with pulmonary contusion is difficult to predict, but is estimated to be 10% to 25%.[21,22] The clinical manifestations of pulmonary contusion are variable, ranging from mild dyspnea to acute lung injury and acute respiratory distress syndrome.

The pathophysiology of pulmonary contusion includes alveolar hemorrhage and edema resulting in decreased lung compliance, increased alveolar capillary permeability, and increased intrapulmonary shunting. These processes result in hypoxemia, hypercarbia, and decreased lung compliance. Lung contusions also result in acute local and systemic inflammatory cascades that activate tissue macrophages and the production of inflammatory mediators, cytokines, and chemokines. These result in pathophysiologic changes that clinically manifest as immunosuppression, acute lung injury/acute respiratory distress syndrome, and respiratory failure.[22-25]

Bony Injuries

The bony thoracic skeleton includes the ribs, sternum, clavicles, and scapulae. The thoracic skeleton is vital to respiratory function and protects the vital organs of the chest. Traumatic rib fractures occur most often at the site of direct impact or at the posterolateral angle that is structurally the weakest area of the thoracic cage.[26] Rib fractures can be very painful, causing decreased chest wall excursion/respiratory splinting that results in atelectasis, pneumonia, and possibly hypoxemia. Fractures of the first, second, or third ribs indicate a high-energy mechanism and are associated with vascular thoracic injuries. Fracture of any rib can also cause pneumothorax, hemothorax, or chest-wall hematomas. Simple rib fractures may be a marker of more-severe intrathoracic and intra-abdominal injury. Ziegler et al reviewed 7147 patients in a trauma service database and found that only 6% had isolated rib fractures without other injury.[27]

The most severe form of blunt thoracic wall skeletal injury is a flail chest, defined as 3 or more contiguous rib fractures. It results in a paradoxical movement of a segment of the chest wall. In addition to injury to underlying intrathoracic and intra-abdominal organs, it also causes a mechanical limitation of motion, resulting in respiratory compromise.

Pneumothorax

Blunt traumatic pneumothorax is defined as air entering the pleural space either directly through the chest wall from rib fracture with pleural penetration or by alveolar rupture due to sudden compression of the chest.[28] The clinical manifestations of a pneumothorax are variable and depend on the degree of lung collapse; decreases in vital capacity cause varying degrees of hypoxemia. If the pneumothorax is large, it can have profound effects on intrathoracic pressure, creating mediastinal shift and hemodynamic instability by preload reduction and markedly reduced diastolic filling of the heart. Tension pneumothorax is life-threatening and manifests clinically as hypotension, elevated jugular venous pressure, hypoxemia, chest pain, and dyspnea, and it can progress to sudden cardiac arrest.

Hemothorax

In addition to air, blood can also enter the pleural space secondary to blunt thoracic trauma and create a hemothorax. The degree of respiratory and hemodynamic compromise is usually predicted by the volume of blood that enters the pleural space as well as how rapidly it accumulates. The pleural cavity of an adult can easily accommodate ≥ 4 liters of blood.

Differential Diagnosis

Many injuries can occur after blunt force trauma to the chest. **(See Table 1, page 4.)** This review is limited to injuries to the ribs and lungs, but there are many other concomitant injuries that must also be considered.

Prehospital Care

The goals in prehospital care are to prevent further injury, initiate resuscitation, provide pain relief, and provide safe and timely transport to an appropriate facility.[29] Early literature suggests that a significant number of trauma-related deaths could have been prevented with appropriate prehospital care.[30-35]

The prehospital management of blunt thoracic trauma, however, remains controversial.[36,37] The approach to civilian prehospital trauma care has been characterized simplistically in the past as "scoop and run" (or "load and go") versus "stay and play," which is the EMS vernacular for field stabilization prior to transport.[38,39] Proponents of the "scoop-and-run" paradigm argue that this approach allows for expeditious transfer to definitive-care trauma centers and limits unnecessary and potentially harmful procedures. However, advocates of the "stay-and-play" paradigm argue that early interventions improve survival and functional outcomes.

Supporting the "scoop-and-run" paradigm, one study demonstrated that on-scene time linearly correlated with a prolonged transport time to the hospital. Mean on-scene time was not significantly different between high and low trauma score groups, although patients with low trauma scores did receive more interventions (more intravenous lines and more-frequent intubation). Patient groups with either a low trauma score or a low Glasgow Coma Scale (GCS) score showed no significant improvement in emergency department (ED) trauma score with increasing on-scene time.[40] The Ontario Prehospital Advanced Life Support (OPALS) Major Trauma Study demonstrated no benefit in trauma-related mortality and morbidity after a system-wide implementation of full advanced life support programs, providing advanced airway management with endotracheal intubation (ETI), and intravenous fluid therapy. They also found that during the advanced life support phase, mortality was greater among patients with GCS scores < 9.[37]

Current evidence does not support paramedic-delivered ETI for acutely ill and injured patients unless they are unable to oxygenate or ventilate without it. A 2008 Cochrane review that examined all randomized controlled clinical trials involving the emergency use of ETI in the injured or acutely ill patient concluded that, "currently there is insufficient high-quality data available to comment on the efficacy of emergency ETI, an intervention often advocated as life-saving."[41] It is difficult to draw conclusions as to the efficacy of ETI in trauma from this Cochrane review, as it included only 3 randomized controlled trials, with 2 trials involving adults with nontraumatic cardiac arrest and 1 pediatric study.

Although the evidence is weak, it may still be prudent to consider ETI in patients who require security of the airway for prehospital transport. The prehospital provider must use his or her judgment and consider multiple variables, including transport time, severity of injury, indication for ETI, and the skill level of the provider when determining whether or not prehospital ETI should be performed.

Prehospital intravenous fluid administration is common in trauma patients, although little evidence supports this practice. In an observational study using the National Trauma Data Bank® (NTDB®), Haut et al demonstrated that patients receiving intravenous fluids were significantly more likely to die, and that this association was identified in nearly all subsets of trauma patients, including blunt chest trauma patients.[42]

Guidelines for prehospital fluid resuscitation in the injured patient established by EAST gives a level II recommendation ("the recommendation is convincingly justifiable by available scientific evidence and strongly supported by expert opinion") that "vascular access should not be performed at the scene of injury as it delays patient transport to definitive care and there is no evidence to demonstrate any benefit to their placement." They do state (level III: "the recommendation is supported by available data but adequate scientific evidence is lacking") that an IV may be placed when vascular access during transport "is feasible."[43] The EAST guidelines state that there are insufficient data to show that trauma patients benefit from prehospital fluid resuscitation and that intravenous fluids should be withheld in the prehospital setting in patients with penetrating torso injuries. "Intravenous fluid administration in the prehospital setting, regardless of mechanism or transport time, should be titrated to palpable radial pulse using small boluses of fluid (250 mL)."[43]

Standard prehospital management of tension pneumothorax is acute needle decompression/thoracostomy. Several studies have challenged the effectiveness of this procedure in relieving tension pneumothorax. Standard intravenous catheters that are used for this procedure do not reach the pneumothorax in up to 65% of the cases, and even when the pneumothorax has been reached, a standard

Table 1. Differential Diagnosis In Blunt Chest Trauma

Visceral Injuries
- Ruptured diaphragm
- Pulmonary contusion
- Pneumothorax
- Hemothorax
- Tracheobronchial injuries
- Esophageal injury
- Pneumomediastinum

Skeletal Injuries
- Flail chest
- Rib fracture
- Sternoclavicular fractures or dislocation
- Scapular fracture
- Clavicular fracture or dislocation
- Vertebral or spinal injury

Cardiovascular Injuries
- Aortic rupture
- Caval injury
- Pericardial effusion/tamponade
- Subclavian artery injury
- Intercostal artery injury
- Commotio cordis
- Cardiac laceration

14-gauge catheter may not be sufficient to relieve the tension.[44-53] See the "Treatment" Section (page 11) for further discussion.

Despite the rapid expansion of the scope of practice and skill set for prehospital EMS personnel, there continues to be insufficient high-quality evidence to justify many of the prehospital interventions some may consider the standard of care for the management of blunt trauma patients.

Emergency Department Evaluation

History

The history obtained from the patient, witnesses, or prehospital providers helps determine which patients with blunt chest trauma are at low versus high risk of intrathoracic injury. Important components in the history include chest pain, dyspnea, the mechanism of injury (eg, fall, direction, and speed of impact), concomitant drug and/or alcohol use, allergies, medical and surgical histories, and use of anticoagulation or antiplatelet therapies. Mechanism alone is predictive and associated with thoracic injury in up to 20% of patients.[54] **(See Table 2.)**

Various components of the history (age of the patient and speed during a motor vehicle crash) are contained in the NEXUS (National Emergency X-Radiography Utilization Study) Chest Decision Instrument.[55] **(See Table 3.)** This instrument was derived from a multicenter prospective study that included 9905 patients aged ≥ 15 years who had sustained blunt chest trauma in the preceding 24 hours. The NEXUS Chest Decision Instrument is 98.8% sensitive but only 13.3% specific for thoracic injuries following blunt trauma.

A history of congestive heart failure and chronic obstructive pulmonary disease (COPD) are known to increase complications in patients with rib fractures.[56] A history of use of anticoagulant and/or antiplatelet therapy is associated with increased morbidity and mortality following blunt trauma.[57,58]

Physical Examination

The physical examination in blunt thoracic trauma requires that the entire chest wall (anterior and posterior) be inspected for penetration, ecchymosis, or deformity and examined for crepitus and point tenderness. Close attention must be paid to the patient's respiratory rate, effort, and use of accessory muscles, as these may signal impending respiratory failure. Look for asymmetry of chest wall movement and excursion during respiration, as this may be due to pneumothorax or hemothorax. Additionally, absent breath sounds with hypotension or tracheal deviation may raise concern for tension pneumothorax, which warrants immediate decompression. Abnormal or paradoxical movement of the chest wall during respiration should also be monitored and may indicate a flail chest.

Some 10% to 23% of patients with minimal findings on examination may still have significant thoracic injuries.[54,59] However, it is unclear what percentage of these injuries is clinically important. Point tenderness and ecchymosis on the chest wall should raise the concern for intrathoracic injury; however, these findings are nonspecific.[55] Injuries to the lower ribs may also indicate the presence of intra-abdominal injuries. In a 2005 prospective observational study, 3% of patients with "isolated" subjective pain or point tenderness to the lower left ribs as the only indication for computed tomography (CT) had splenic injuries. If patients had other indications for CT (hypotension, abdominal or flank tenderness, pelvic or femur fractures, or gross hematuria) the rate of splenic injury was 9.4%.[60]

Diagnostic Studies

Chest X-Ray

Chest x-ray (CXR) is used in most chest trauma patients because it is fast, inexpensive, and can be diagnostic of life-threatening injuries such as pneumothorax, hemothorax, pulmonary contusion, aortic injuries, and rib fractures. The ACR recommends CXR as "usually appropriate" (the highest recommendation) and complementary to CT in patients with high-energy mechanisms of injury.[61] There is also a recommendation that CT or CT angiography (CTA) "may be appropriate" in patients with a normal CXR and low probability of significant thoracic injury.

CXR has a low sensitivity for detecting thoracic injuries following blunt trauma. It misses up to

Table 2. Mechanisms Predictive Of Significant Thoracic Injury[54]

- Motor vehicle crash at > 35 mph
- Fall from > 15 ft
- Automobile hitting a pedestrian with pedestrian being thrown > 10 ft
- Assault with depressed level of consciousness without any other evidence of trauma

Table 3. NEXUS Chest Decision Instrument[55]

Patients are considered very low risk and unlikely to benefit from chest imaging if they have none of the following characteristics:

- Age > 60 years
- Rapid deceleration (fall from > 20 ft or motor vehicle crash > 40 mph)
- Chest pain
- Intoxication
- Abnormal mental status
- Distracting injury
- Tenderness to palpation of the chest wall

Abbreviation: NEXUS, National Emergency X-Radiography Utilization Study.

36% of thoracic injuries when compared to CT **(see Figure 1)**, though only a small percentage of those injuries are clinically significant.[62-64] Obtaining a dedicated rib series can augment the sensitivity of plain x-rays for the detection of rib fractures.[65,66]

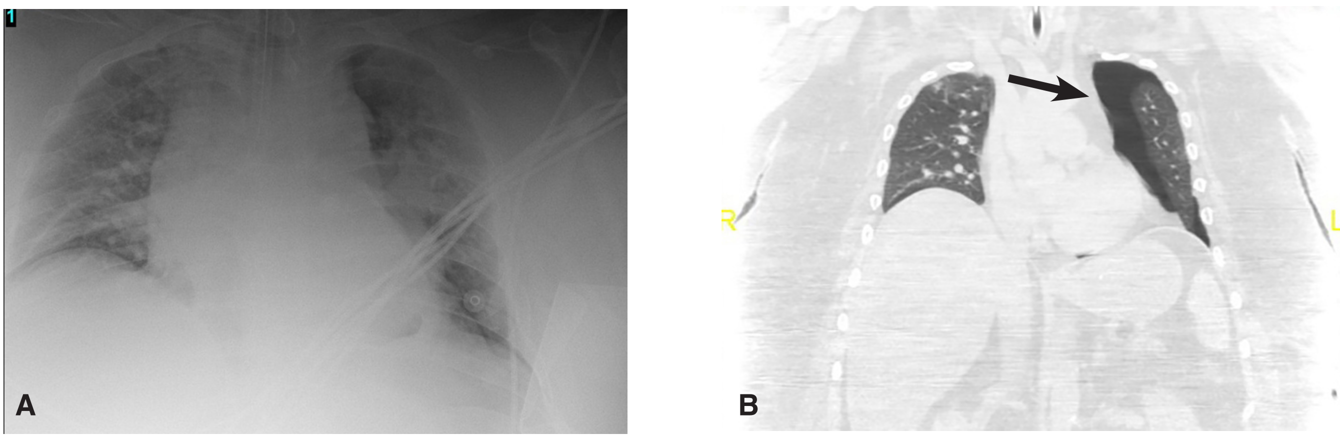
Pneumothorax is diagnosed on CXR by visualizing a separation between the visceral and parietal pleura. On supine CXR, hyperlucent lung bases, deep and radiolucent costophrenic sulcus (deep sulcus sign), and outlining of the anterior and posterior portions of the hemidiaphragm (double diaphragm sign) can be seen.[67] **(See Figure 2.)** Hemothorax can be detected on CXR as layering of fluid and blunting of the costophrenic angle, similar to a pleural effusion.[67] **(See Figure 3.)**

Ultrasound

Ultrasound is a noninvasive, safe, and portable test that can be performed at the bedside while the patient is undergoing other diagnostic and therapeutic procedures. Two systematic reviews found ultrasonography to be 86% sensitive and 98.2% specific for the detection of pneumothorax.[68,69] CT results or air present on chest tube insertion were the gold standards applied in these systematic reviews.

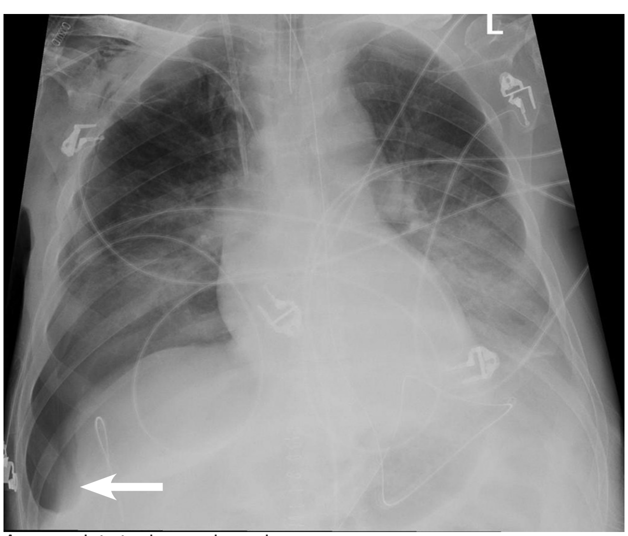
Lung ultrasound is more accurate than CXR for the diagnosis of pulmonary contusion and hemothorax.[70,71] Bedside ultrasound is also useful in detecting pericardial effusion and assessing cardiac function. The major limitation to bedside ultrasound

Figure 1. Pneumothorax On Chest X-Ray And Computed Tomography



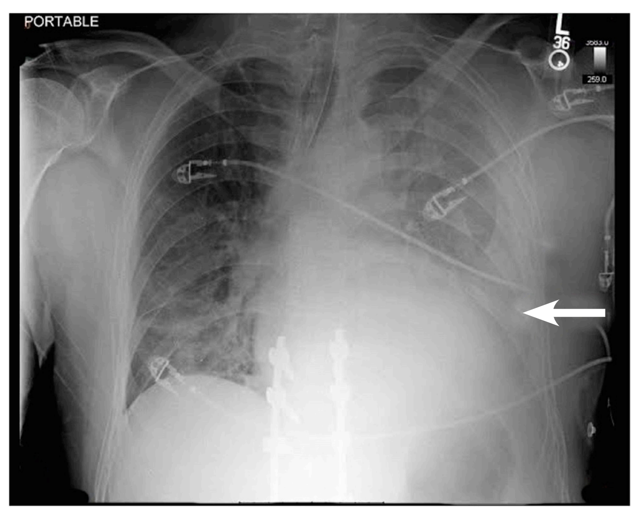
Suspected pneumothorax on View A chest x-ray is clearly defined on View B chest CT. The arrow in View B points to the pneumothorax on CT.
Abbreviation: CT, computed tomography.
Images reprinted courtesy of Stony Brook Medicine, Stony Brook, NY.

Figure 2. Pneumothorax On Chest X-Ray With Deep Sulcus Sign



Arrow points to deep sulcus sign.
Case courtesy of Dr. Hani Al Salam, Radiopaedia.org, rID: 13262. www.radiopaedia.org.

Figure 3. Hemothorax On Chest X-Ray



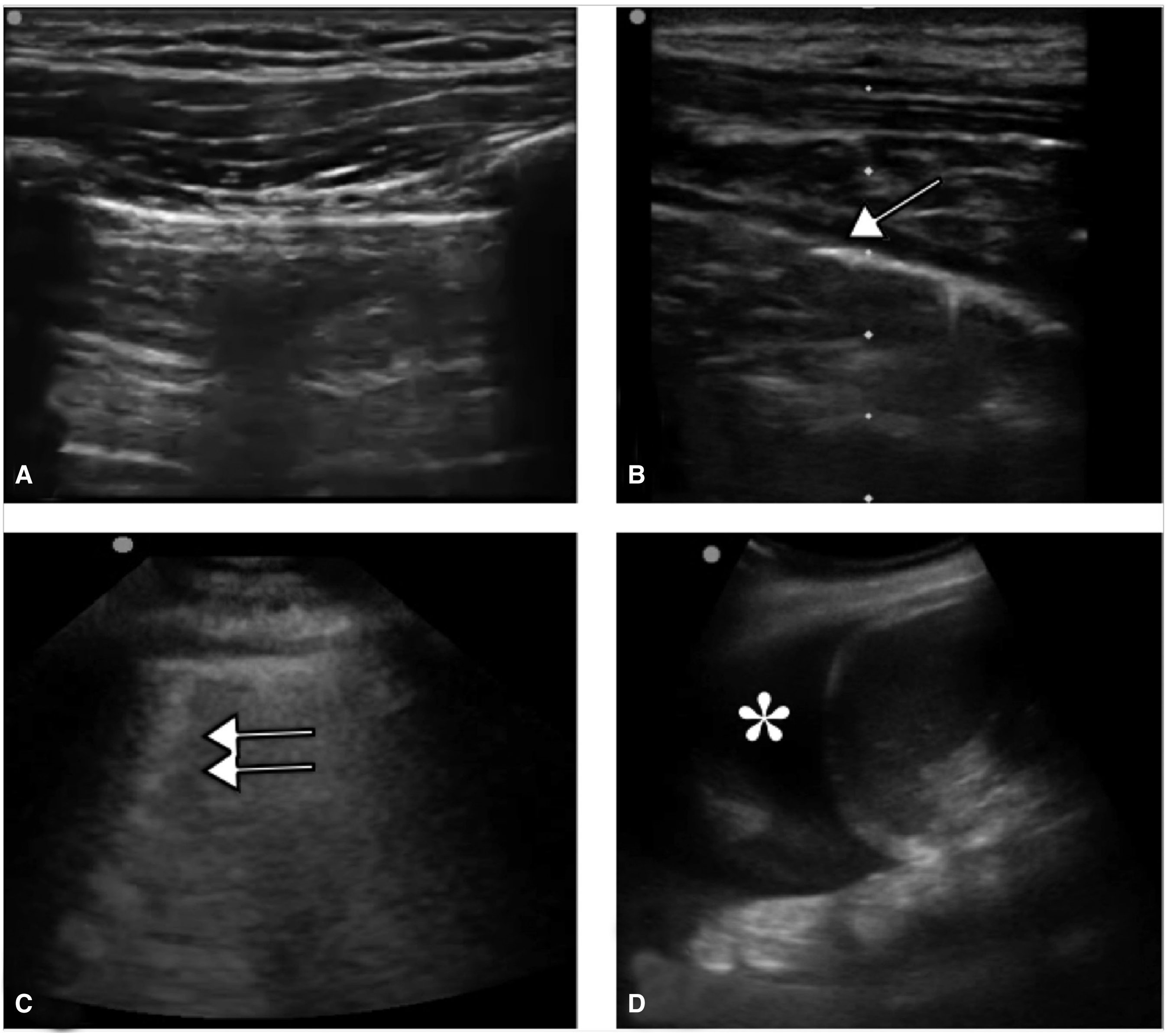
Arrow indicates pleural fluid that, in this patient, is a hemothorax.
Image reprinted courtesy of Stony Brook Medicine, Stony Brook, NY.

is that it is highly operator-dependent. **Figure 4** shows examples of a normal and an injured lung on bedside ultrasound.

Computed Tomography

CT is the preferred modality for imaging most intrathoracic blunt injuries. It detects many injuries that are not identified on CXR, including pleural, parenchymal, osseous, and vascular injuries.[62-64] However, there are disadvantages to obtaining an intravenous contrast-enhanced CT of the chest, including the risk for contrast-induced nephropathy and exposure to ionizing radiation (median 8 mSv for a chest CT).[72-75] **See Table 4 (page 8)** for the estimated risk of radiation-induced cancer. These are important considerations, given the low percentage of clinically significant injuries detected by CT.[62-64,76] Finally, CT is expensive; it is estimated that the cumulative cost to detect 1 clinically major thoracic injury with CT is $44,232 (≈ 12 patients need to be scanned); this cost increases to $203,467 for CTs performed after normal CXR (≈ 80 patients need to be scanned).[77]

Figure 4. Ultrasound Of A Normal Versus An Injured Lung



View A shows a normal lung.
View B shows a lung with a transition point (single arrow) pathognomonic for a pneumothorax.
View C shows a lung with B lines (double arrow) indicative of interstitial fluid that represents a contusion in the setting of trauma.
View D shows free pleural fluid seen as a hypoechoic area between the diaphragm and lung (asterisk).
Images courtesy of Eric J. Morley, MD.

Laboratory Testing

A complete blood count, chemistry panel, coagulation profile, and type and screen are generally recommended in major trauma. However, these tests typically have a low yield for finding clinically significant abnormalities.[78-80] Age > 50 years, a history of hypertension, and a depressed GCS score (≤ 10) are associated with clinically significant serum chemistry abnormalities.[79] Despite this, large prospective studies are needed to determine which patients should undergo extensive laboratory testing in the setting of blunt trauma. It is the authors' opinion that a baseline hemoglobin, creatinine, and type and screen are important tests in the moderately to severely injured patient.

There are a large number of studies evaluating the use of serum lactate as a predictor of mortality in trauma. However, the majority of data comes from retrospective studies, and none were performed specifically in the setting of blunt chest trauma. There is no cutoff for lactate level that can safely exclude significant trauma.[81-83] However, serum lactate levels > 2 mg/dL (and certainly > 4 mg/dL) are associated with higher mortality.[81,82,84,85] Additionally, lactate clearance of 20% to 30% in the first hours predicts lower mortality.[81,85,86]

Troponin testing may be considered in the setting of blunt chest trauma. A 2012 EAST guideline provides a level III recommendation (based on retrospective data) to obtain troponin in patients who have suspected blunt cardiac injury.[87] There is no recommendation regarding the determination of who is at risk.

There is a level II recommendation that all patients with suspected blunt cardiac injury receive an electrocardiogram (ECG), and that blunt cardiac injury can be ruled out if both ECG and troponin testing are negative. Unfortunately, the guideline does not make a specific recommendation for determining who meets suspicion for blunt cardiac injury.

Treatment

Airway Management

The goals of trauma airway management are to protect the airway and to ensure appropriate oxygenation/ventilation. With trauma to the thorax, oxygenation may be impaired by pulmonary contusion and/or abnormal respiratory mechanics (rib fracture, flail chest, and pneumothorax). The patient should be given supplemental oxygen and/or noninvasive positive-pressure ventilation (NIPPV) via nasal or face mask if hypoxic or showing excessive work of breathing.

ETI should be considered whenever any of the following are present: (1) hypoxia (arterial oxygen saturation [SaO_2] < 90%); (2) impending airway obstruction (ie, hemorrhage or swelling); (3) severe traumatic brain injury (GCS score < 9); (4) severe chest trauma with respiratory failure; and (5) hemodynamic instability (systolic blood pressure < 90 mm Hg) related to trauma.[88] The use of a lung-protective ventilation strategy is particularly important for patients who have or who are at risk for developing acute lung injury or acute respiratory distress syndrome.

Rib Fracture And Flail Chest Management

Physiologic breathing relies on the ability to create negative pressure within the thoracic cavity. Flail chest causes the disruption of this integrity, resulting in paradoxical motion of a portion of the chest wall during respiration. This, in turn, may result in increased respiratory effort, dyspnea, and hypoxemia. Therefore, pain control and adequate ventilation are crucial to prevent respiratory failure.[20] Systemic administration of pain medications or regional nerve blocks can help control pain. Epidural analgesia is another method of pain control that has helped improve ventilation. It is associated with decreased risk of pneumonia, duration of ventilation, and length of stay.[6]

A trial of NIPPV may facilitate breathing by overcoming the need to create negative pressure during inspiration.[20] Any decompensation (hypoxia or increased work of breathing) or lack of improvement in ventilatory function may be an indication for intubation. Due to poor ventilatory effort with flail chest, patients are at risk for complications such as atelectasis and pneumonia. This may require further chest physiotherapy. In severe cases of unstable thorax, surgical stabilization may be indicated.[20,89] However, the 2012 EAST guidelines do not recommend any specific type of surgical approach.

Pulmonary Contusion Management

The management of pulmonary contusion is mainly supportive. Supplemental oxygen and positive-pressure ventilation should be initiated and titrated to support oxygen saturation and respiratory effort; however, for some patients with pulmonary contusion, this method may not be enough. Therefore, patients can either receive NIPPV (discussed below) or invasive positive pressure ventilation.[20,90]

Patients with pulmonary contusion are at high risk for acute respiratory distress syndrome and pneumonia, especially elderly patients. This is seen particularly in the first 24 to 48 hours after the initial injury. Therefore, a ventilation strategy should

Table 4. Estimated Number Of Chest CTs Needed To Cause 1 Radiation-Induced Cancer[74]

Patients, by Gender	Age, 20 y	Age, 40 y	Age, 60 y
Male	1020	1538	2040
Female	380	720	1070

Abbreviation: CT, computed tomography.

be initiated to improve oxygenation and ventilation while ensuring the lung is protected. The goal should focus on trying to re-expand atelectatic regions in a contused lung through high positive end-expiratory pressure (PEEP) and recruitment maneuvers. One needs to be careful with these methods, as the elevated peak airway pressures can lead to over-distension of alveoli in a normal lung, resulting in ventilator-induced lung injury. Over-distension can also cause compression of pulmonary capillaries, reducing alveolar perfusion, and consequently resulting in increased dead space.[90]

The ideal ventilation strategy should include: (1) low tidal volume, at 4 to 8 mL/kg of predicted body weight (not actual body weight); (2) limited plateau pressure < 30 mm Hg, which is associated with less tidal hyperinflation and end-tidal collapse; (3) a fraction of inspired oxygen (FiO_2) level that is as low as possible (FiO_2 should be adapted to obtain $SaO_2 \geq 90\%$); and (4) optimal PEEP, incrementally added to optimize oxygenation. Elevated partial pressure of carbon dioxide ($PaCO_2$) levels can be tolerated if inadequate ventilation is not possible, as long as the pH is > 7.2.[90]

NIPPV, which includes continuous positive airway pressure (CPAP) and bilevel positive airway pressure (BiPAP), can be used in select groups of patients with pulmonary contusion and hypoxemia that are refractory to supplemental oxygen. NIPPV should be used in patients who are able to protect their own airway and do not have any contraindications to NIPPV, such as inability to tolerate the mask, uncooperativeness, hemodynamic instability, facial injuries, inability to cough or manage their own secretions (to reduce risk of aspiration), or profound metabolic acidosis.[89,90] A 2013 meta-analysis including 5 studies and 219 patients showed that NIPPV in chest trauma improves oxygenation while decreasing the need for ETI and leads to lower rates of complications and infections.[91] However, there was no mortality benefit seen.

Pain Management

Pain related to rib fractures may result in hypoventilation and lead to pneumonia. The major goal in the management of rib fractures is pain control and the identification of patients who are likely to develop complications. (See the "Rib Fractures In Geriatric Patients" section, page 12.) The EAST guidelines give a level III recommendation that opioids may be given to low-risk patients. EAST gives a level II recommendation that epidural anesthesia be provided to any patient with ≥ 4 rib fractures, especially in patients aged > 65 years.[6] That said, a systematic review from 2009 showed no benefit on mortality or intensive care unit (ICU) length of stay in patients who received epidural anesthesia.[92] Despite this, pain control should be optimized for the suffering patient, regardless of the effect on mortality.

As of 2005, EAST could not make any recommendations regarding intrapleural and paravertebral analgesia. However, the literature on this topic is evolving, and both intrapleural and paravertebral techniques have been used successfully more recently.[93-95] A simpler approach to regional anesthesia available to the emergency clinicians is the intercostal nerve block. For a comprehensive review of traumatic pain management, refer to the August 2012 issue of *Emergency Medicine Practice*, "An Evidence-Based Approach To Traumatic Pain Management In The Emergency Department" at www.ebmedicine.net/TraumaPain.[96] Surgical fixation of rib fractures may be appropriate in selected patients.[97]

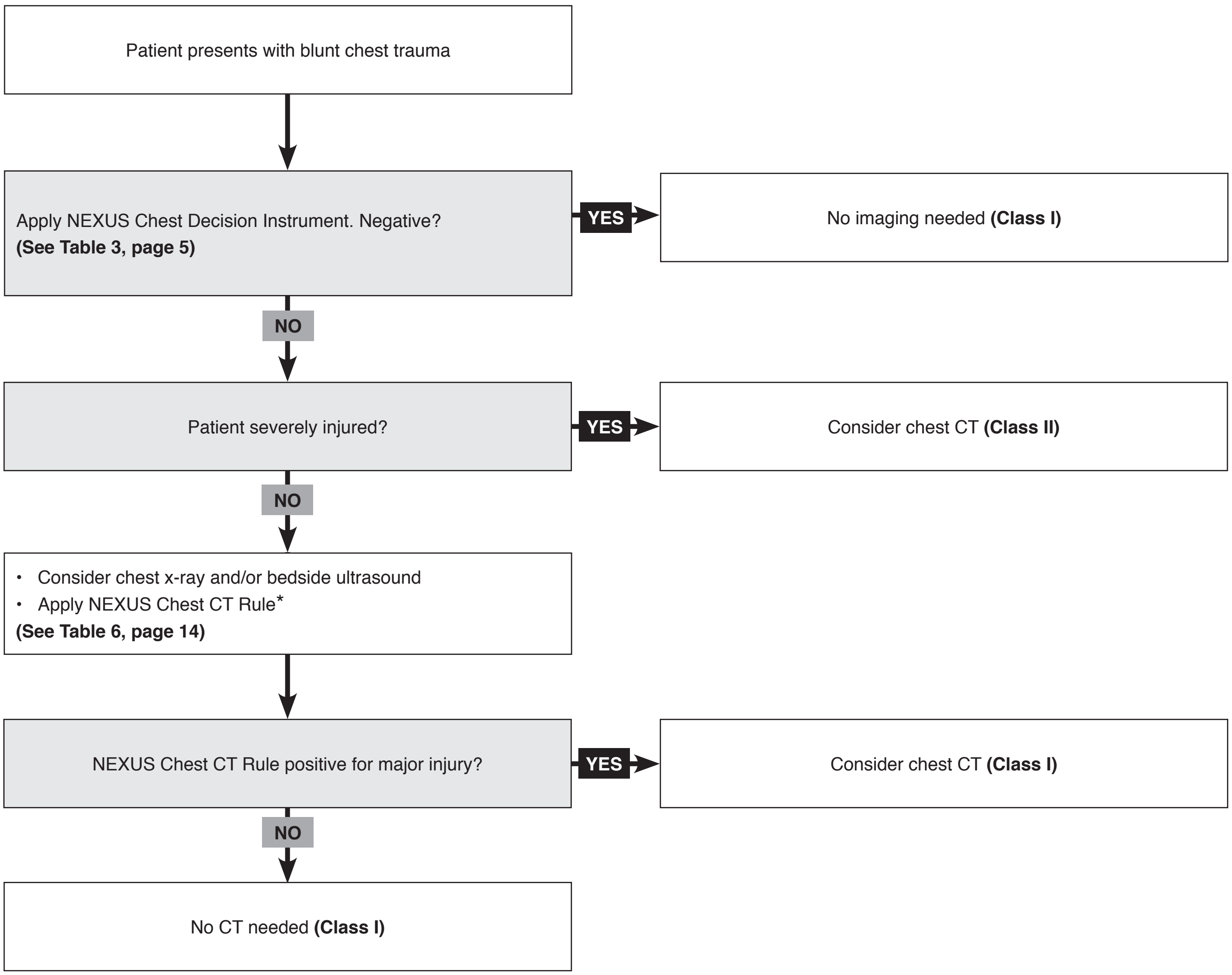
Sternal And Scapular Fracture Management

Blunt trauma to the thorax sometimes results in fractures of the sternum, clavicle, and scapula. Sternal fractures require a significant force to occur. Concomitant injuries are common in these patients, including rib fractures (58%); lung contusion (34%); pneumothorax/hemothorax (33%); thoracic vertebrae fracture (22%); lumbar vertebrae fracture (17%); concussion (4%); and blunt cardiac injury (4%).[98]

Sternal fractures occurred in 2% of the 14,553 patients included in the NEXUS Chest and Chest CT studies; 94% of those fractures were seen on chest CT only and not on CXR.[99] One patient (0.4%) required surgical intervention for the fracture, and cardiac contusion was diagnosed in 7 patients (2.4%). Mortality in patients with sternal fracture was not statistically different from patients without fractures. In another retrospective study, none of the 88 patients with isolated sternal fractures had clinically significant cardiac injury identified.[100] The 2012 EAST guidelines give a level II recommendation that "the presence of sternal fracture alone does not predict the presence of cardiac injury and thus should not prompt monitoring in the setting of normal ECG results and troponin I level."[87] Considering these together, we recommend that patients who have sternal fractures undergo thoracic CT, ECG, and troponin I testing.

Scapular fractures also require significant force and are therefore associated with other intrathoracic injuries. A retrospective review of the NTDB® found a high number of associated intrathoracic injuries, including rib fractures (53%), clavicle fractures (25%), spinal fractures (29%), pneumothorax (33%), and heart/great vessel injuries (2.2%).[101] In another retrospective review that included 392 patients with scapular fracture, 99% were found to have other associated injuries within and outside the thorax.[102] Blunt thoracic aortic injury occurred in 1% (4 of 392) of these patients with scapular fracture. Given the high rate of associated injuries, we recommend thoracic CT for patients with scapular fractures seen on CXR or suspected on examination.

Clinical Pathway For Imaging Patients With Blunt Chest Trauma



*Consider clinical gestalt in low-risk patients or patients with minor mechanism of injury to avoid any imaging.

Abbreviations: CT, computed tomography; NEXUS, National Emergency X-Radiography Utilization Study.

Class Of Evidence Definitions

Each action in the clinical pathways section of *Emergency Medicine Practice* receives a score based on the following definitions.

Class I
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Nonrandomized or retrospective studies: historic, cohort, or case control studies
- Less robust randomized controlled trials
- Results consistently positive

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate
- Continuing area of research
- No recommendations until further research

Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

Sternoclavicular Dislocation Management

Sternoclavicular dislocations are rare and typically require a high-energy mechanism of injury. Anterior dislocations require minimal interventions and can be followed on an outpatient basis by orthopedic specialists. In a systematic review comprising 24 case studies (251 patients), 44% were treated nonoperatively; 21% were treated with closed reduction; and 38% by open reduction.[103]

Posterior dislocations may cause life-threatening injury to the underlying pulmonary, mediastinal, and vascular structures. Up to 30% of patients with posterior dislocation will have symptoms of mediastinal compression.[103] We recommend all patients with posterior dislocations receive prompt orthopedic and surgical evaluations. Additionally, consider CT angiography of the chest in these patients, given the likely high force applied to the chest and the risk to underlying structures from the injury itself.

Pneumothorax Management

Needle Versus Finger Decompression

Immediate decompression is indicated in patients with suspected tension pneumothorax. The classically taught technique of emergent needle decompression is insertion into the second or third intercostal space in the midclavicular line of a large 14- or 16-gauge, 2.25-inch peripheral venous catheter. However, a recent meta-analysis found that a 5-cm (1.97-in) catheter would be sufficient length in only 72% of patients, and a 6.44-cm (2.54-in) catheter would be required to match the chest wall thickness of 95% of patients.[104] Location of the needle decompression may be important as well. Based on CT analysis of chest wall thickness in normal patients, it is expected that a 5-cm catheter would fail 42.5% of the time at the second intercostal space in the midclavicular line, whereas failure would be expected in only 17% when inserted at the fifth intercostal space in the anterior axillary line.[48] Use of an 8-cm catheter, placed perpendicular to the chest wall, may be safe (< 9% injury rate) and leads to a higher rate of decompression.

Many patients will require tube thoracostomy after needle decompression. Tube thoracostomy should be done emergently if the patient remains unstable despite needle decompression with suspicion for pneumothorax. Not all patients who receive prehospital needle thoracostomy need emergent tube thoracostomy. If the patient is stable, this decision should be based on CXR and/or CT results.[105]

Finger (simple) thoracostomy can be considered after traumatic arrest or in an unstable patient.[106-108] Finger thoracostomy includes the first steps of a complete tube thoracostomy procedure. An incision is made in the fifth intercostal space in the lateral chest wall and forceps are used to enter the pleural space. If a rush of air or release of hemothorax occurs, the procedure can be completed as a tube thoracostomy. Due to the immediate availability of necessary materials (ie, scalpel) in most EDs, finger thoracostomy can often be performed just as quickly as needle decompression, but with a much higher success rate. For a video demonstration, refer to the QR code and URL link in **Figure 5**.

Tube Thoracostomy For Pneumothorax

After a patient has had rapid decompression, chest tube insertion is required, generally at the fourth or fifth intercostal space between the anterior and midaxillary line. Ensuring safe placement in the pleural space is more important than precise positioning of the tube within the thorax.[109] Ultrasound or palpation may be used help find the fifth intercostal space. The size of the chest tube depends on the size of the patient and the indication (ie, pneumothorax vs hemothorax). Traditionally, larger tubes (36-40Fr) are placed in order to facilitate rapid drainage, prevent air leaks, and drain blood, but this practice has been questioned. Larger tube diameters are limited by the intercostal space, so a larger tube may produce more pain without providing any additional drainage. Additionally, endogenous anticoagulants in the pleura tend to prevent coagulation, which may allow drainage from a smaller diameter thoracostomy tube. Multiple studies have supported the use of smaller chest tubes.[110-114]

Not all pneumothoraces require decompression or tube thoracostomy. Selected patients with small or occult pneumothoraces (ie, seen on CT but not CXR) may be observed without tube thoracostomy.[115,116] This may also be possible with patients on positive pressure ventilation.[117] The decision to place a chest tube for an occult or small asymptomatic pneumothorax should be made with trauma or cardiothoracic consultants, as there is evidence that observation is a safe option in some of these patients.[118] Once a chest tube is placed, prophylactic antibiotics are not necessarily indicated; current EAST guidelines state that there is insufficient evidence for or against their use.[108]

Hemothorax Management

Tube Thoracostomy For Hemothorax

Management of hemothorax is tube thoracostomy, performed similarly to the procedure described for pneumothorax. Insertion allows for evacuation

Figure 5. Link To Finger Thoracostomy Video

For a video link of a finger thoracostomy demonstration, scan the QR code above with a smartphone or tablet or go to: http://emcrit.org/podcasts/needle-finger-thoracostomy/.

of blood from the pleural space, allowing the lung to re-expand. Inadequately drained hemothoraces can lead to complications that can prolong hospital stay, including clotted hemothorax, empyema, and fibrothorax.[90] As with a small pneumothorax, some hemothoraces may be managed expectantly without tube thoracostomy; however, larger trials are needed before this becomes standard practice.[119]

Aside from evacuation of blood from the pleural space via tube thoracostomy, a chest tube is also inserted to quantify the amount of blood that has been evacuated, which helps to determine whether operative intervention is needed. Operative management is indicated if there is an initial blood loss of 1500 mL or 300 to 500 mL/h for 2 to 4 hours.[89,90,120]

Disposition

Disposition for patients after blunt thoracic trauma must consider the risk for delayed sequelae (eg, pneumothorax or acute respiratory distress syndrome). For seriously ill or elderly patients, it is more likely that they will require inpatient hospitalization and admission for continued monitoring.[121-127] The Battle score is a scoring system that has been developed and validated for predicting complications from blunt chest trauma.[128] In this study, complications were defined as mortality, pneumonia, hemothorax, pneumothorax, pleural effusion, empyema, ICU admission, or prolonged length of stay. The score is comprised of 5 components, with points assigned for each risk factor, with complication risk based on the total. **(See Table 5.)**

Table 5. The Battle Score For Prediction Of Complications From Rib Fracture[128]

Scoring	
Risk Factor	**Points**
Age	1 point for each 10 years of age
Number of rib fractures	3 points per rib fracture
Chronic lung disease	5 points
Preinjury anticoagulant use	4 points
Oxygen saturation levels	2 points for each 5% decrease in oxygen saturation, starting at 94%
Total Score	____________________
Score Probability For Complications	
Total Risk Score	**Probability Mean ± SD**
0 to 10	13% ± 6
11 to 15	29% ± 8
16 to 20	52% ± 8
21 to 25	70% ± 6
26 to 30	80% ± 6
31+	88% ± 7

Abbreviation: SD, standard deviation.

Rib Fractures In Geriatric Patients

Elderly patients are at increased risk for complications from rib fractures. Patients aged > 65 years with rib fractures are approximately twice as likely to develop pneumonia (31% vs 17%) and die (22% vs 10%).[127] Comorbid conditions also play an important role in the risk assessment of these patients. A 2015 retrospective study was performed to derive a prediction model for intubation and pneumonia following rib fractures in elderly patients.[56] Chronic obstructive pulmonary disease (odds ratio [OR], 3.92), protein calorie malnutrition (OR, 2.97), need for an ambulatory assist device (OR, 2.9), congestive heart failure (OR, 1.93), tube thoracostomy (OR, 2.36), spinal fracture (OR, 1.78), lower extremity fracture (OR, 1.78), additional rib fractures (OR, 1.13 per additional fracture) were all associated with increased risk of intubation and/or pneumonia. This is similar to the prediction instrument described in **Table 3 (page 5)**.[128] A low threshold should exist for admission in this population. Additionally, elderly patients with multiple rib fractures, frailty, and comorbidities should be considered for ICU monitoring.

Discharge

Patients with minimal injuries, younger age, and minimal preinjury illness are generally safe to be discharged home with adequate pain control if rib fractures are present. An initial trial with oral analgesics in the ED may be warranted to assure adequate pain control. Incentive spirometry should be considered at home to help prevent atelectasis. All patients with rib fractures should receive close medical follow-up.[125,126]

More seriously injured patients, especially elderly patients, require a coordinated discharge plan in order to ensure safety for discharge. Early engagement of physical/occupational therapy and social workers can be helpful. Getting the patient's family involved early in decision-making generally facilitates the process. All patients discharged with rib fractures should be given explicit instructions to return immediately for any difficulty breathing, fever, productive cough, worsening pain, or changes in mental status (indicating hypoxia).

Admission

Patients with pulmonary contusions generally require admission for monitoring. Rib fractures in the elderly have increased mortality and risk for pneumonia, and, therefore, admission should be considered in this population.[123,124,126,127] Severe rib fractures associated with pulmonary contusions and flail chest may require ETI and positive pressure ventilation and ICU admission. Pneumothorax and hemothorax often require chest tubes and admission.

Risk Management Pitfalls In Managing Blunt Chest Trauma

1. **"My patient feels fine. There's no way he had a thoracic injury."**
   Serious injury is less likely in a well-appearing patient with no complaints. However, significant mechanism of injury alone should raise suspicion for intrathoracic injury. Consequently, a high index of suspicion should be maintained after high-speed motor vehicle collisions (> 35 mph) or falls from > 15 feet.

2. **"The CXR was normal, so I was certain he didn't have an intrathoracic injury."**
   Many injuries are missed on plain CXR that are later seen on CT. Although these injuries are often not clinically significant, it is important to discuss the potential for missed injuries with your patient if you will not be performing additional evaluation. A CT should be strongly considered for severely injured patients or those in whom a missed injury would have severe consequences (eg, the elderly, patients with COPD, etc).

3. **"She couldn't have had a tension pneumothorax because there was no rush of air after needle decompression."**
   The failure rate after needle decompression is quite high. If suspicion for tension pneumothorax remains in the traumatic arrest patient despite needle decompression, an immediate, simple (finger) thoracostomy should be performed. This procedure could also be considered as a first-line intervention in the ED in the traumatic arrest patient.

4. **"He looked so stable; I never thought he would decompensate at home."**
   More seriously injured patients (especially elderly patients) require a low threshold for admission. Early engagement of physical/occupational therapy and social workers can be helpful, based on clinical situations. Getting the patient's family involved early in the decision-making for evaluation of safety at home and establishing support for the patient is a must if and when the patient is to be discharged home.

5. **"I admit all my elderly patients to the floor if they have stable vital signs."**
   Consider admitting elderly patients with multiple rib fractures to a monitored setting such as a step-down unit or ICU. There is a potential for respiratory failure and these patients require close attention.

6. **"I thought he would be fine; it was just a rib fracture."**
   Many patients with isolated rib fractures will do quite well with appropriate pain management. However, some groups are at increased risk of complications (eg, pneumonia) and subsequent respiratory failure. It is prudent to consider admission for the elderly, patients with chronic respiratory disease (COPD or congestive heart failure), 3 or more rib fractures, or patients with respiratory compromise. If not admitting these patients, a careful discussion should take place regarding the signs of pneumonia and instructions to return for worsening symptoms. Patients should understand the risk and be willing and able to return immediately, if necessary.

7. **"I didn't get a CT because I was worried about radiation."**
   Medical radiation is clearly a concern, and conscientious physicians seek to limit the potential danger. However, it is important to not exaggerate the risk and to use shared decision making with patients, when possible. In these discussions, it is important to emphasize that the exact risk is not known, but is based on models.

8. **"I always use a 36Fr chest tube in trauma patients."**
   Although a 36-40Fr chest tube has classically been used for traumatic hemothorax and pneumothorax, this large-sized tube has some drawbacks. Smaller tubes are less painful and easier to pass in patients with smaller intercostal spaces. Additionally, there is evidence that smaller tubes may even be adequate for hemothoraces.

9. **"I scan the chest of all my trauma patients. Why not?"**
   Imaging should be done when there is concern for thoracic injury. However, patients ruled out by NEXUS Chest CT Rule and patients at low risk of serious injury should not receive a CT. This will avoid unnecessary radiation, risks of intravenous contrast, and inappropriate resource utilization.

10. **"I used a 5-cm needle for needle decompression. It should have worked."**
    A CT study showed that the chest wall at the second intercostal space in the midclavicular line is > 5 cm in 42.5% of patients. Consider finger thoracostomy as an alternative procedure.

Controversies

Thoracic Imaging In Blunt Trauma

Imaging of the injured patient remains controversial. A prospective study published in 2011 showed significant disagreement regarding which imaging studies trauma and emergency physicians thought were appropriate for specific patients.[129] In this study, 324 CT chest studies were done. Of these, 40% were desired by the trauma surgeon only (ie, the most senior emergency medicine physician treating the patient did not think a CT was indicated) and 23% percent of the undesired scans had abnormalities on CT. While emergency physicians in this study would have missed a large number of injuries, most of the injuries did not have clinical significance. Management decisions remain a complicated process, and the desire to diagnose injuries that are not clinically significant must be balanced with potential harms, including resource utilization, ionizing radiation exposure, risk of contrast reactions, and potential false-positive findings.

The decision to image is challenging in the well-appearing patient with a concerning mechanism or intermediate examination. Approximately 20% of patients with no physical evidence of chest trauma but a concerning mechanism will have injuries on thoracic CT. Alternatively, patients with a NEXUS chest score of 0 **(see Table 2, page 5)** have a much lower incidence of significant findings on CT.[55] The ACR Appropriateness Criteria® state that a CT of the chest "may be appropriate" after normal CXR in patients with a normal examination, normal mental status, and no high-energy mechanism of injury.[61] A 2015 study found 25% of moderately injured blunt trauma patients had occult injuries seen on chest CT but not on the original CXR, and 14% of those occult injuries were deemed major.[130]

In 2015, the NEXUS Chest CT Rule was derived and validated in more than 11,000 patients.[131] The authors of the NEXUS Chest CT Study validated separate rules for detecting all injuries and major injuries. **(See Table 6.)** The NEXUS Chest CT-ALL Rule has a sensitivity of 95.4% and a specificity 25.5% for major and minor injuries. The NEXUS Chest-Major Rule has a sensitivity of 99.2% for major injuries and specificity of 37.9% for major and minor injuries.

Table 6. NEXUS Chest CT Major Rule[131]

1. Abnormal chest x-ray
2. Distracting injury
3. Chest wall tenderness
4. Sternum tenderness
5. Thoracic spine tenderness
6. Scapula tenderness

Abbreviation: CT, computed tomography.

Nonselective, or "pan-scanning," may be warranted in severely injured patients. A 2014 systematic review including 7 studies (5 retrospective and 2 prospective) showed that severely injured patients who underwent whole-body CT had better outcomes than those who underwent selective CT following blunt trauma.[132] This held true despite the whole-body CT group having a higher injury severity score at baseline. However, not all deleterious outcomes were quantified (eg, cost, long-term effects of radiation exposure, etc).

It is reasonable to perform chest CT in severely ill trauma patients and patients with a high likelihood of multiple injuries. A recent Cochrane review found no randomized controlled trials evaluating the diagnostic value of thoracic CT specifically in blunt trauma.[133] Based on the limited data above, it is our opinion that thoracic CT be strongly considered if the patient is stable enough to leave the ED.

The selection of blunt trauma patients for imaging remains a complex and controversial issue despite an increasing body of literature. We suggest that no imaging is indicated if the NEXUS Chest Rule is negative or physician pretest probability, based on clinical gestalt, is low enough. Alternatively, we suggest that critically ill patients or patients with multiple severe injuries should have a chest CT performed as part of their initial workup if they are stable enough leave the ED. For intermediate patients, we suggest a liberal use of CXR and use of the NEXUS Chest-Major Rule. If the NEXUS Chest CT-Major score is 0, then CT imaging of the chest is unlikely to alter management. If 1 of the NEXUS Chest-CT Major criteria is positive, a risk-benefit analysis can be performed, factoring both physician and patient tolerance for missed injuries and risk of radiation harm to the patient based on age and gender.

Summary

Blunt chest trauma is a commonly encountered problem in the ED, and imaging decisions can be complicated. Clinical decision rules and new studies have helped to define best practice. If the NEXUS Chest Rule is negative, patients do not require imaging; if the NEXUS Chest CT Major Rule is negative, then CT can be avoided. In that the physical examination may be misleading, a chest CT should be considered in patients with severe chest trauma. Life-threatening injuries such as tension pneumothorax and hemothorax need to be addressed immediately with a tube thoracostomy; however, new literature supports the use of smaller-sized chest tubes than once used. When a needle thoracostomy is used, it is important to ensure that the needle is sufficiently long to enter the chest cavity and decompress the pneumothorax. The decision to admit patients with rib fractures can be difficult, and the Battle Score may be helpful in predicting prognosis and guiding disposition. Finally, adequate pain control and incentive spirometry are fundamental to the management of patients with blunt chest trauma.

Case Conclusions

The 23-year-old driver in the motor vehicle crash had a CXR suggesting a hemothorax. After 2 large-bore IVs were established and fluid resuscitation was begun, you placed a 36Fr large-bore chest tube in his right chest and 1.5 liters of blood were immediately put out. You started resuscitation with blood products, and he was taken emergently to the operating room, where a pulmonary vessel laceration was repaired, and then he was admitted to the surgical ICU.

The 27-year-old passenger presented with decreased breath sounds on the right, which was concerning for a pneumothorax without signs of tension. A bedside ultrasound demonstrated pneumothorax, which was confirmed on CXR, showing > 50% collapse of the right lung. You treated her with fentanyl and had an urgent chest tube placed after anesthesia with local infiltration of lidocaine. The patient's workup for other injuries was negative, and she was admitted to the trauma service for continued monitoring.

The 79-year-old gentleman with multiple comorbidities who had fallen remained hemodynamically stable. A CXR showed multiple left-sided fractures in the fourth, fifth, and sixth posterior ribs and left-sided pneumothorax. You placed a chest tube, and a chest CT showed a localized opacity consistent with an early pulmonary contusion. He maintained his hemodynamic stability and oxygen saturation with nasal cannula, and was admitted to the trauma service for continuous cardiac and respiratory monitoring. Twelve hours after admission, he developed worsening respiratory distress and desaturation to 90% on 4 liters nasal cannula. Repeat CXR showed a decrease in the pneumothorax, but a worsening pulmonary contusion, with no pneumothorax. The patient was placed on NIPPV, his work of breathing improved, and his oxygen saturation improved to 98%. He was moved to the ICU for more monitoring, and was discharged home to his family 6 days later.

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Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study are included in bold type following the reference, where available. In addition, the most informative references cited in this paper, as determined by the authors, are noted by an asterisk (*) next to the number of the reference.

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1. **What is the estimated overall mortality from pulmonary contusions?**
   a. 3% to 5%
   b. 5% to 10%
   c. 10% to 25%
   d. 25% to 40%

2. **What percentage of patients will have thoracic injuries on CT with no physical examination findings but with a significant mechanism of injury alone (ie, motor vehicle crash at > 35 mph, fall from > 15 ft, automobile hitting a pedestrian with pedestrian being thrown > 10 ft, and assault with depressed level of consciousness)?**
   a. 10%
   b. 20%
   c. 30%
   d. 40%

3. **A 62-year-old man with a history of hypertension and COPD slipped and fell in the shower and came in complaining of pain to the left side of his rib cage. On examination, he is tender over the fifth and sixth ribs in the anterior axillary line. Plain films confirm nondisplaced fractures of ribs 5 and 6. Which factors increase the patient's risk of pneumonia and respiratory failure?**
   a. Age > 60
   b. Hypertension
   c. COPD
   d. a and b
   e. a and c

4. **All of the following are part of the NEXUS Chest Decision Instrument EXCEPT:**
   a. Motor vehicle crash > 40 mph
   b. Age > 50
   c. Intoxication
   d. Chest pain

5. **Which is the approximate number of chest CTs needed to cause 1 radiation-induced cancer?**
   a. 20-year-old female: 720 chest CTs
   b. 40-year-old male: 1070 chest CTs
   c. 20-year-old female: 380 chest CTs
   d. 40-year-old male: 2040 chest CTs

6. **For needle decompression of a tension pneumothorax, a 5-cm (1.97-in) catheter inserted at the second intercostal space would be sufficient in what percentage of patients?**
   a. 42.5%
   b. 51%
   c. 65%
   d. 72%

7. **What is an indication for immediate operative management of a traumatic hemothorax?**
   a. Immediate return of 800 mL of blood on chest tube insertion
   b. 300-500 mL of blood draining per hour
   c. Immediate return of 1500 mL of blood on chest tube insertion
   d. b and c
   e. a and b

8. **All of the following are considered risk factors for developing complications after blunt thoracic trauma EXCEPT:**
   a. Pulse oximetry of 95%
   b. Being on anticoagulants
   c. Age > 65 years
   d. Chronic lung disease
   e. 3 rib fractures

9. **Calculate the Battle score for a patient with the following factors: (1) 70 years old, (2) 6 rib fractures, (3) COPD, (4) on warfarin for atrial fibrillation, and (5) pulse oximetry, 89%.**
   a. 12
   b. 22
   c. 36
   d. 42

10. **In the 2015 paper by Langdorf et al,[130] what percentage of occult injuries seen on CT but not seen on CXR were clinically significant?**
   a. 8%
   b. 14%
   c. 23.2%
   d. 40%

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