Inpatient management of traumatic rib fractures

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INTRODUCTION

Traumatic rib fractures are the consequence of significant forces impacting the chest wall and are most commonly due to blunt injuries (eg, motor vehicle crash, falls, assault), but penetrating injuries (eg, gunshot) can also fracture ribs. Rib fractures are a marker of more severe injuries and are present in 10 percent of all trauma patients and approximately 30 percent of patients with significant chest trauma [1]. The number of fractured ribs also directly correlates with the presence of intrathoracic injury [2,3].

Multiply fractured ribs or flail chest can significantly compromise respiratory function. Pneumonia is often the common pathway to acute respiratory failure resulting from rib fractures, and prevention offers the best means to avoid potentially preventable deaths [4]. The main goal of treatment is to prevent pneumonia and other complications of rib fractures (eg, nonunion), and conservative treatment includes pain control and aggressive supportive pulmonary care to avoid the need for intubation. For some patients in whom these conservative measures are not adequate, rib fracture stabilization may be beneficial.

Although less common, chronic, forceful coughing, as may be seen in patients with severe asthma, cystic fibrosis, or poorly controlled emphysema, can also result in rib fractures [5]. General considerations for single or nontraumatic rib fractures are discussed separately. (See "Initial evaluation and management of rib fractures".)

This topic review will discuss inpatient management of multiple traumatic rib fractures. Specific techniques for surgical stabilization of rib fractures are reviewed separately. (See "Surgical management of severe rib fractures".)

TRAUMA EVALUATION

The initial resuscitation, diagnostic evaluation, and management of the patient with blunt or penetrating injury is based upon protocols from the Advanced Trauma Life Support (ATLS) program, established by the

American College of Surgeons Committee on Trauma. The initial resuscitation and evaluation of the patient with blunt or penetrating thoracic trauma is discussed in detail elsewhere.

- (See "Initial management of trauma in adults".)
- (See "Initial evaluation and management of blunt thoracic trauma in adults".)
- (See "Initial evaluation and management of penetrating thoracic trauma in adults".)

An increasing number of rib fractures is clearly associated with increased morbidity and mortality [1,2,6-9]. As such, we recommend the following regarding disposition of the patient:

- For limited, isolated traumatic rib injuries (<3 fractures, no associated injuries), outpatient management with oral analgesics and incentive spirometry may suffice. The outpatient management of rib fractures is discussed elsewhere. (See "Initial evaluation and management of rib fractures", section on 'Disposition'.)
- The presence of ≥3 rib fractures suggests the need for hospitalization or transfer to a regional trauma facility.
- Hospital admission should be considered for any older adult (>65 years) patients because of their comorbidities and increased risk for complications related to rib fractures.

In the setting of acute trauma, many patients cannot relate their symptoms or medical history due to altered mental status (eg, neurologic injury, intoxication) or because they are intubated and sedated. Every attempt should be made to identify preexisting medical conditions by contacting the patient's primary care physician or family members. The presence of significant medical comorbidities and medical conditions requiring antiplatelets or anticoagulation should be determined, as these may impact management decisions.

Patients are admitted to a monitored unit or intensive care unit depending upon the number of rib fractures, the nature and severity of associated injuries, and the nature of medical comorbidities. Level of pain, oxygenation and ventilation, and respiratory parameters (eg, incentive spirometry volume) are followed closely with continuous pulse oximetry. (See 'Pulmonary care and support' below.)

Physical exam — Physical findings indicative of a rib fracture include rib pain on palpation, rib step-off on palpation, and crepitus. The patient may also feel a sensation of clicking or movement with deep inspiration or with coughing/Valsalva maneuver. Multiple fractures may cause a visible chest wall deformity, and the presence of paradoxical respiratory motion, an area of the chest wall pulled in with inspiration and pushed out with expiration, is diagnostic for flail chest. (See 'Flail chest' below.)

Pneumothorax and hemothorax are often present initially, and their presence should prompt a careful review of all imaging studies for the presence of rib fractures. (See "Initial evaluation and management of rib fractures", section on 'Clinical presentation and examination'.)

Flail chest — Flail chest (ie, "stoved-in" chest, crushed chest) is defined as fractures of three or more ribs in two or more places, which create a floating segment that loses its mechanical continuity with the remainder of the chest wall [10] (figure 1). Sternal flail occurs when the sternum becomes dissociated from the

hemithoraces because of bilateral, multiple, anterior cartilage, or rib fractures. Sternal fracture may also accompany rib fractures. (See 'Sternal fracture' below.)

Flail chest occurs in 5 to 13 percent of patients with chest wall injury. A review of data from the National Trauma Data Bank noted that flail chest occurred in 1 percent of all admissions to Levels 1 and 2 trauma centers included in the dataset [11].

Flail chest is most commonly due to a blunt mechanism of injury whereby significant force is imparted on the chest. Such scenarios can include a motor vehicle collision where the chest strikes the steering wheel, an automobile accident with a pedestrian or bicyclist, a fall from a height onto the chest, an ejection from a motor vehicle or motorcycle, or an assault with a blunt weapon such as a baseball bat. Although less common, flail chest following penetrating trauma (eg, shotgun blast) has been reported [12]. Because of the severe injury mechanisms associated with flail chest, pulmonary contusion is much more common compared with multiple rib fractures without flail, and these patients have a high risk for acute respiratory failure [13].

Flail chest is clinically diagnosed by the observation of paradoxical motion of the chest wall with respiration [14]. Paradoxical chest wall motion arises from the effect of negative pleural forces acting upon the detached segment. The rib cage normally expands upward and outward during inspiration as the diaphragm contracts and flattens, creating the negative intrathoracic pressure necessary to expand the lungs. With flail chest, the detached segment of the chest wall is pulled into the chest cavity during inspiration and pushed outward during expiration (figure 2). This abnormal motion increases the work of breathing, compromises respiratory function, and may necessitate intubation and ventilatory support. (See "Chest wall diseases and restrictive physiology", section on 'Normal structure and function'.)

A flail chest can be missed early in the clinical course because muscle splinting can conceal motion of the involved segment of ribs. It may also be difficult to diagnose in patients who require immediate mechanical ventilation because ventilatory support may minimize paradoxical chest wall motion. Moreover, the pattern of flail can be affected by differential recruitment of chest wall muscles. (See 'Rib fracture complications' below and 'Pulmonary care and support' below.)

Chest imaging — Computed tomography (CT) of the chest is highly accurate for showing the location and number of rib fractures but is not obtained solely to identify rib fractures. Rather, CT is indicated when there is concern for concomitant injury based upon mechanism of injury or concern for underlying parenchymal injury (eg, aortic injury, pulmonary contusion) or when surgical fracture fixation is being considered. (See "Initial evaluation and management of blunt thoracic trauma in adults", section on 'Chest computed tomography' and 'Intrathoracic injury' below and 'Surgical management' below.)

Although standard plain chest radiography is performed during the initial evaluation of chest trauma (image 1), it usually underestimates the number of rib fractures and may not detect nondisplaced fractures. It will also usually identify significant pneumothorax or hemothorax and, to some extent, pulmonary contusion. Ultrasound has also been used to establish the number of rib fractures, but this approach remains operator dependent and will only become useful if it impacts management [15].

Two-dimensional chest CT demonstrates rib fractures more reliably than plain chest radiographs. Although a three-dimensional CT scan is less sensitive for the detection of rib fractures, it may provide insight on the characteristics of severely displaced fractures and therefore may be useful for operative planning (image 2) [16]. (See "Surgical management of severe rib fractures", section on 'Number of fractures to repair'.)

Rib fractures of the lower rib cage (T8 to T12) can be associated with intra-abdominal injury, and abdominal CT may also be indicated [17]. (See 'Intra-abdominal injury' below.)

ASSOCIATED INJURIES

The most common mechanisms leading to multiple rib fractures are front- or side-impact motor vehicle collisions that cause contact of the victim with the steering wheel or door. As a result, head injury, abdominal injury, and extremity injury are commonly associated with chest wall injury [11]. Ninety percent of patients with rib fractures will have associated injuries [1]. The presence of intrathoracic or intra-abdominal injuries relates directly to the site of impact, with injured organs located directly beneath the fractured ribs. The risk of organ injury increases if two or more rib fractures are present at the same level. Fractures to the first two ribs generally require a severe mechanism of injury due to their relative protection by surrounding muscles and short length. These are associated with increased morbidity and mortality from associated injuries.

Intrathoracic injury — Pneumothorax, hemothorax, and pulmonary contusion are common in patients with multiple rib fractures. Hemothorax and pneumothorax are usually apparent upon initial presentation; however, delayed hemothorax or pneumothorax can occur.

Displaced rib fractures can push into the lung, tearing the pulmonary pleura and lung tissue and causing pneumothorax, which occurs in approximately 25 percent of patients with multiple rib fractures [2]. Pneumothorax is suspected on chest auscultation as diminished breath sounds on the affected side but may also manifest as subcutaneous emphysema with crepitus upon palpation of the chest wall. On chest radiograph, pneumothorax is diagnosed as a radiolucent space where the pulmonary parenchyma has separated from the parietal pleura. On supine radiograph, a deep sulcus sign may be more evident than apical separation. The plain film diagnosis of pneumothorax is discussed in detail elsewhere. (See "Imaging of pneumothorax".)

Disruption of the intercostal vessels can lead to bleeding into the chest, particularly when multiple ribs are involved. However, massive hemothorax from intercostal vessel injury alone is rare. When present, significant hemothorax is more likely to be from direct lung parenchymal injury. In the supine position, hemothorax is identified on chest radiograph as a diffuse increase in opacification on the affected side due to the layering of blood posteriorly. The presence of hemothorax in the trauma patient indicates the need for a thoracostomy tube. (See "Initial evaluation and management of blunt thoracic trauma in adults".)

A large volume of initial chest tube drainage or ongoing bleeding may indicate the need for thoracic exploration. In the presence of upper rib fractures, hemothorax should be assumed to be from a major vascular injury until proven otherwise and not solely attributed to the rib fractures. Laceration of the aorta can

occur directly related to the rib fracture [18-22]. Patients with persistent hemorrhage but without injury to the major vasculature may require urgent thoracotomy to ligate the intercostal vessels.

Pulmonary contusion is due to the transmission of blunt force through the chest wall to the underlying lung parenchyma. Hemorrhage and alveolar collapse result, which have the appearance of focal consolidation on chest radiography. The extent of pulmonary contusion is best evaluated on chest CT. The appearance of the injury progresses over time, and follow-up imaging is needed. (See 'Pulmonary care and support' below.)

Sternal fracture — Sternal fracture may accompany rib fractures when there is an anterior blow to the chest, such as an impact with the steering wheel in a motor vehicle collision. A palpable sternal step-off may be appreciated [23]. In one study, sternal fracture occurred in 7 percent of patients with flail chest [24]. The presence of a sternal fracture should raise concern for blunt cardiac injury, and appropriate workup should be initiated. (See "Cardiac injury from blunt trauma".)

Sternal fractures will usually heal without specific intervention but require precautions (limited lifting) once the patient is up and around. Severely displaced sternal fractures may require operative intervention.

Rarely, patients may have an unstable sternum or complete disruption of bilateral costochondral junction leading to a "flail sternum" with paradoxical movement as would be seen in a flail chest (movie 1). In these instances, operative fixation of the sternum and/or costochondral junction may be beneficial (image 3 and picture 1), although there are no large case series upon which to base this recommendation.

Intra-abdominal injury — The spleen and liver are the most commonly injured intra-abdominal organs following blunt trauma, occurring in 2 to 4 percent of patients [24]. Fractures of the right lower ribs lead to hepatic injury, fractures of the left lower ribs to splenic injury, and fractures of the posterior portion of the lower ribs can cause renal injury. (See "Initial evaluation and management of blunt abdominal trauma in adults" and "Management of splenic injury in the adult trauma patient" and "Management of hepatic trauma in adults" and "Blunt genitourinary trauma: Initial evaluation and management".)

Head injury — Head injury is a sign of a severe mechanism of injury. In one study, head injury was present in 25 percent of patients diagnosed with flail chest [24]. Of the three groups studied (flail with head injury, isolated flail, flail plus thoracic/abdominal injury), patients with flail chest and head injury had significantly higher mortality compared with patients without head injury (16 versus 4 and 7 percent). (See "Management of acute severe traumatic brain injury".)

Upper extremity injury — The mechanism of injury that includes a combination of multiple rib fractures and upper extremity injury is typically a side-impact automobile collision. Lateral chest wall fractures, pulmonary contusion, and upper extremity injury including clavicular fracture, scapular fracture, shoulder injury (eg, shoulder dislocation), and long bone fracture can occur. In one study, flail chest was associated with clavicular fracture in 8 percent of patients, and other upper extremity injuries were present in 4 percent of patients [24]. (See "Initial evaluation and management of blunt thoracic trauma in adults" and "Clavicle fractures" and "Proximal humeral fractures in adults" and "Midshaft humeral fractures in adults" and "Tarsometatarsal (Lisfranc) joint complex injuries".)

RIB FRACTURE COMPLICATIONS

Complications of traumatic rib fractures include pneumonia (most common), retained hemothorax or empyema, respiratory failure requiring intubation, and fracture nonunion, which can lead to chronic pain and disability. The probability of pneumonia is directly related to the number of fractured ribs as well as the age of the patient; pneumonia is also a risk factor for developing empyema or respiratory failure. In a review of the National Trauma Data Bank, 59 percent of patients admitted with a flail chest required mechanical ventilation, with a mean duration of 12.1 days and with 54 percent having an associated pulmonary contusion [11]. In-hospital complications included pneumonia in 21 percent, acute respiratory distress syndrome (ARDS) in 14 percent, and sepsis in 7 percent. Death occurred in 16 percent.

Pneumonia — Pneumonia is one of the most common complications associated with rib fractures. Because pneumonia is the common pathway to death from rib fractures, it is imperative that pain is adequately controlled and aggressive pulmonary support is provided to reduce the risk of pneumonia and avoid the need for intubation, and to facilitate extubation as quickly as possible. (See 'Pain control' below and 'Pulmonary care and support' below.)

The probability of pneumonia (and death) is directly related to the number of fractured ribs as well as the age of the patient [6-8,11,25]. The incidence of pneumonia for all patients hospitalized with one or more rib fractures is approximately 6 percent [6]. For patients admitted to a trauma center (presumably with more severe injuries), the incidence is greater [11]. Two retrospective studies reported pneumonia in 11 and 17 percent in patients <65 years old but 31 and 34 percent in older patients [7,26].

In patients with flail chest, the inherent chest wall instability and higher degree of pain associated with deep breathing and coughing lead to a high incidence of acute respiratory failure and need for mechanical ventilation. Pneumonia following intubation for flail chest or multiply fractured ribs is common. The probability of pneumonia is approximately 3 percent for each day the patient is intubated.

Respiratory failure — Pain and loss of chest wall function reduce the ability to move the chest wall upward with inspiration and downward with expiration. The altered pulmonary mechanics increase the work of breathing. As a result, the patient is at risk for respiratory muscle fatigue. Respiratory function is worsened by poor pulmonary hygiene from an inability to cough, which can lead to pneumonia. While respiratory failure can be due to the chest wall injury (eg, flail chest), it is more commonly related to an underlying pulmonary contusion or development of nosocomial pneumonia, particularly if superimposed upon a preexisting pulmonary condition. Atelectasis or underlying pulmonary contusion contribute to impaired oxygen exchange as evidenced by an increased alveolar-arterial (A-a) gradient.

Retained hemothorax — Retained hemothorax refers to the presence of blood/clot in the thoracic cavity that persists in spite of thoracostomy drainage. The risk of empyema is increased in patients with retained hemothorax [27]. (See 'Empyema' below.)

The most accurate means to diagnose a retained hemothorax is with chest CT. Many authors have advocated early video-assisted thoracoscopic surgery (VATS) to provide adequate drainage of the chest in these circumstances. In one trial, patients treated with early evacuation by VATS had a significantly shortened duration of chest tube drainage, fewer hospital days, and lower total hospital costs compared with patients randomized to receive a second thoracostomy tube [28]. In another study, implementation of a clinical pathway (patients with residual hemothorax on postoperative day 2 were drained with VATS) resulted in shorter hospital stay and decreased costs [29]. (See "Overview of minimally invasive thoracic surgery", section on 'Chest drainage/pleurectomy'.)

Empyema — Empyema is an infected pleural fluid collection and is estimated to occur in 3 to 10 percent of patients after the placement of a thoracostomy tube for chest trauma [27,30]. Independent predictors of post-traumatic empyema include prolonged duration of the thoracostomy tube and length of stay in an intensive care unit, the need for laparotomy, and the presence of pulmonary contusion or retained hemothorax [30]. In one study, empyema occurred in 33 percent of patients who had retained hemothorax compared with 2 percent of patients without [27]. (See "Parapneumonic effusion and empyema in adults".)

Some studies have suggested that prophylactic antibiotics in trauma patients at the time of thoracostomy tube placement reduced the risk of empyema [31]. This issue is discussed separately. (See "Placement and management of thoracostomy tubes and catheters in adults and children", section on 'Antibiotic prophylaxis'.)

Fracture nonunion — A small percentage of rib fractures do not heal even though a fibrous capsule may envelope the fracture ("pseudoarthrosis") (image 4). Although some consider a nonunion to be present three months following injury, most agree that the presence of a pseudoarthrosis six months following injury is pathognomonic of a nonunion. A nonunion usually presents as discomfort with respiration due to movement of the fracture site. Some patients find the respiratory restriction due to pain quite disabling.

A small number of case series describe operative fixation to manage pain and disability in patients with nonunion of traumatic rib fractures [32,33]. The fibrous callous enveloping the nonunion is resected and a plate used to fixate the ribs, limit their motion, and facilitate healing. Patients treated operatively appear to have had good relief of their symptoms. (See 'Surgical management' below and "Surgical management of severe rib fractures".)

Chronic pain and long-term disability — Patients with multiple rib fractures or those with nonunion, and even some who have undergone rib fracture stabilization, are at risk for chronic pain that can lead to long-term disability [34-37]. In an observational study that followed 187 patients with rib fractures for more than two months, 59 percent had prolonged chest wall pain and 76 percent had prolonged disability. Even the subset of patients with isolated rib fractures had high rates of pain (64 percent) and disability (66 percent) at two months [35]. Data for later outcomes are lacking.

MANAGEMENT APPROACH AND INITIAL CARE

For most patients with traumatic rib fractures, we suggest initial conservative management, rather than surgical intervention (algorithm 1) [38]. Surgical rib stabilization remains an option for patients who continue to have acute pain or other problems that interfere with respiratory toilet, those experiencing worsening pulmonary function, or those with rib fractures that do not heal (nonunion) and are causing persistent pain and functional impairment. (See "Surgical management of severe rib fractures".)

Conservative management of rib fractures initially involves thoracostomy drainage for pneumothorax/hemothorax (when present), limiting fluid during trauma resuscitation to reduce edema in contused lung, and appropriate prophylactic therapies.

- Thoracostomy drainage – Patients with hemothorax or pneumothorax following chest trauma generally require thoracostomy tube placement. The techniques for placement and management of thoracostomy tubes are discussed in detail elsewhere. (See "Initial evaluation and management of blunt thoracic trauma in adults", section on 'Hemothorax' and "Initial evaluation and management of chest wall trauma in adults", section on 'Pneumothorax' and "Placement and management of thoracostomy tubes and catheters in adults and children".)

- Fluid management – Judicious fluid resuscitation is also important in the management of patients with multiple rib fractures to limit pulmonary edema in contused pulmonary tissue [39]. Pulmonary contusion may or may not be as evident on initial chest radiograph, and a high index of suspicion for its presence based upon the mechanism of injury allows for prudent fluid administration. (See "Overview of inpatient management of the adult trauma patient", section on 'Pulmonary contusion'.)

- DVT prophylaxis – Trauma patients are at high risk for developing deep vein thrombosis (DVT), and prophylaxis is indicated. The timing of pharmacologic therapy (eg, enoxaparin) early after injury should be coordinated so as not to prevent regional analgesia, when indicated. (See "Prevention of venous thromboembolic disease in adult nonorthopedic surgical patients".)

- Antibiotics – Patients with penetrating chest trauma may benefit from prophylactic antibiotics to limit infectious complications associated with chest tube placement. These issues are discussed elsewhere. (See "Placement and management of thoracostomy tubes and catheters in adults and children", section on 'Antibiotic prophylaxis'.)

Subsequent multidisciplinary management is associated with improved outcomes [40,41]. Multidisciplinary care of the patient with multiple rib fractures includes an acute pain service for pain management, respiratory therapy to improve volume expansion and assist with ventilator management, physical therapy to increase patient mobility, and nutritional support to optimize wound healing. In a prospective study of patients with ≥4 rib fractures, a multidisciplinary clinical care pathway was associated with shorter intensive care unit and hospital stays and lower mortality compared with those who were not in the care pathway [40]. (See 'Pain control' below and 'Pulmonary care and support' below.)

PAIN CONTROL

Patients with rib fractures seek to minimize their chest wall motion by reducing their tidal volume and coughing effort. Pain control is fundamental to decrease chest wall splinting and alveolar collapse. Adequate pain management improves patient tolerance for deep breathing and coughing, which improves lung volume and clears secretions, thereby decreasing the risk for pneumonia. Pain control can generally be achieved with a multimodal regimen. (See 'Pulmonary care and support' below and 'Pneumonia' above.)

Our strategy — Aside from providing pain relief, the strategy for pain control should minimize the need for narcotics, given their respiratory side effects. We use an escalating strategy of analgesia that begins with placing the patient on around-the-clock acetaminophen [42], a cyclooxygenase (COX)-2 inhibitor, and a low-dose demand-only opioid (eg, hydromorphone, morphine, fentanyl). We prefer to use hydromorphone delivered using patient-controlled analgesia (PCA). Alternative opioid agents can be used; however, morphine should not be used in patients with severely impaired renal function due to the potential buildup of its metabolites and resultant adverse effects. Due to its wide volume of distribution, fentanyl can also accumulate. For those with pain that is refractory to pharmacologic agents, additional pain control involves placement of an epidural or paravertebral catheter for continuous infusion of ropivacaine. In centers where placement of epidural or paravertebral catheters is not readily available, intercostal blocks are effective for providing non-narcotic-based analgesia. If pain is still not sufficiently controlled using regional anesthesia, the patient is placed on a ketamine infusion [43]. If pain continues to preclude adequate mobility and the ability to cough or the patient has impending respiratory failure due to pain, we proceed with surgical rib fracture fixation. (See 'Oral and parenteral therapy' below and 'Regional anesthesia' below and "Surgical management of severe rib fractures".)

Our approach is generally consistent with guidelines from the Eastern Association for the Surgery of Trauma (EAST) [44,45]. The involvement of a dedicated pain service is critical to provide tailored therapy and monitor its effectiveness.

Oral and parenteral therapy — Provision of pain relief should begin with use of systemic analgesics that have minimal side effects. These include acetaminophen dosed around-the-clock to achieve a total daily dose of 3 grams as well as nonsteroidal anti-inflammatory drugs (NSAIDs), which can also be initially dosed around-the-clock [42]. COX-2 inhibitors, such as celecoxib, may be safer than the nonselective COX inhibitors, such as ibuprofen, in patients with a history of gastritis or renal insufficiency.

Intravenous narcotics (eg, morphine) are preferred over subcutaneous or intramuscular injection due to a rapid and predictable onset of action. PCA using a demand-only mode is advocated for patients with rib fractures because of more timely access to pain medication by the patients and a reduced risk for excessive sedation. Patients should be switched from PCA narcotics to orally administered narcotics as soon as possible to facilitate timely discharge from the hospital. (See "Management of acute perioperative pain".)

Ketamine can also be used to provide ongoing relief of pain, if needed, in addition to acetaminophen, COX-2 receptor inhibitors, and regional analgesia [46]. This agent can be administered as a continuous infusion at a low (subanesthetic) dose as an opioid-sparing adjuvant. In this setting, the risk of adverse side effects is very low.

If these agents do not provide sufficient analgesia, consideration should be given to use of regional anesthesia. (See 'Regional anesthesia' below.)

Regional anesthesia — Regional anesthesia techniques available for the management of multiple rib fractures include continuous epidural infusion, paravertebral block, intrapleural infusion, and intercostal nerve block, each with its own benefits and risks [47,48]. Interfacial plane block of the chest wall (eg, serratus anterior) has also been described [49,50]. (See "Overview of anesthesia", section on 'Neuraxial (spinal or epidural) anesthesia' and "Nerve blocks of the scalp, neck, and trunk: Techniques", section on 'Thoracic blocks'.)

There are no randomized trials comparing the efficacy of these modalities in patients with rib fractures. The EAST trauma guidelines recommend epidural analgesia for patients with four or more rib fractures and suggest its use in those with fewer fractures who are older than 65 years or who have significant cardiopulmonary disease or diabetes mellitus [45].

Proponents of epidural-based analgesia cite that this modality has been studied much more extensively and is of proven benefit following rib fractures [51]. Advocates of paravertebral analgesia cite the following advantages: no need to access the spinal space, thereby lowering the risk of epidural hematoma or infection; less likelihood of sympatholysis with resultant hypotension; and ability to discharge the patient with the catheter in place. In a review of the National Trauma Data Bank (NTDB) in the United States that included a total of 194,766 patients admitted for rib fractures, 1073 patients had epidural analgesia and 1110 had paravertebral block. The remainder had neither [47]. After propensity score matching, there were no differences for in-hospital mortality, length of stay, intensive care admission or length of intensive care unit stay, mechanical ventilation or duration, development of pneumonia, or other complication. Thus, either technique appears to be a reasonable analgesic option for rib pain refractory to oral and parenteral therapy.

Continuous epidural infusion — In patients with multiple rib fractures, epidural analgesia is associated with improved pain control, reduced duration of mechanical ventilation, and a decreased incidence of nosocomial pneumonia in some, but not all, trials. However, some patients who would benefit from epidural placement will not be able to receive one (eg, spine fracture) [52]. The most widely studied approach uses epidural catheters to infuse local anesthetics with or without the addition of narcotic agents. Side effects of epidural combinations of local anesthetic and opioids include pruritus, nausea, urinary retention, and respiratory depression. (See "Neuraxial anesthesia/analgesia techniques in the patient receiving anticoagulant or antiplatelet medication".)

A systematic review and meta-analysis that included eight trials [52-57] comparing thoracic epidural with other forms of analgesia did not find any differences in the need for mechanical ventilation, length of intensive care unit (ICU) stay, or mortality in patients managed with epidural analgesia [58]. However, the duration of mechanical ventilation was less for those managed with thoracic epidural analgesia. Higher rates of hypotension were found with thoracic epidural analgesia compared with no epidural analgesia or epidural analgesia at the lumbar level. Three of the eight included studies found superior pain control associated with epidural use; however, a pooled analysis of all the data was not performed [59]. Other trials not included in

this meta-analysis also found better pain scores for epidural analgesia compared with intravenous narcotics and improved pulmonary function [60-62].

In a registry review of highly selected patients with three or more rib fractures from blunt trauma, mortality up to one year after injury was lower among those who received an epidural catheter compared with those without [63]. Excluded were patients who were not potential candidates for epidural placement, such as patients with significant head and spine injuries, significant neurologic impairment, unstable pelvic fractures, coagulopathy, or those who died within 48 hours. The authors noted that while mortality was reduced, epidural analgesia did not reduce pulmonary complications, raising concern that these results were caused by other factors that may be associated with epidural placement and not a direct benefit (causal relationship) from the regional anesthesia. In this study, the majority of the epidural catheters were placed at Level I trauma centers, which are known to be associated with improved outcomes. However, similarly improved outcomes were also demonstrated in a review of a Level II trauma center registry [64].

The use of epidural catheters in patients with multisystem trauma is often limited because of contraindications to epidural catheter placement (eg, spine fractures, coagulopathy) [65]. All patients, but particularly older patients, managed with epidural analgesic infusion should be closely monitored for side effects. (See "Overview of neuraxial anesthesia", section on 'Adverse effects and complications'.)

Paravertebral catheter infusion — Paravertebral catheter infusion provides regional analgesia to one side of the chest using a local anesthetic, such as ropivacaine. Analgesia administered through a paravertebral catheter is associated with a lower rate of systemic hypotension when compared with epidural infusion, and there may be less urinary retention [59,66]. Furthermore, patients can be discharged to home with a paravertebral catheter in place.

Paravertebral block improves pain, bedside spirometry, and blood gas parameters. One trial and a prospective nonrandomized study reported this technique to be as effective as epidural for controlling pain associated with unilateral rib fractures [59,67]. However, a review of the National Trauma Database (NTDB) found no differences comparing 1073 patients with epidural catheters with 1110 with paravertebral catheters relative to propensity matched controls [47].

Paravertebral blocks can be administered as a single shot or as a continuous infusion. A commercially available infusion system (ie, ON-Q) can provide ongoing continuous delivery of a local anesthetic for up to one week. (See "Nerve blocks of the scalp, neck, and trunk: Techniques", section on 'Thoracic paravertebral block'.)

For clinicians familiar with this paravertebral catheter placement, this technique may also be easier to perform compared with epidural catheter placement. However, the failure rate is as high as 10 percent and vascular puncture occurs in about 4 percent [68]. Other complications include dural puncture and subarachnoid injection [67-70]. An ultrasound-guided technique for placement has been described that may make this technique safer and easier [71-73].

Intercostal nerve blocks — Intercostal nerves can be blocked individually to provide a band-like segment of anesthesia at the chosen level. This block is easy to perform, though multiple blocks are often required. Intercostal nerve blocks have few hemodynamic consequences, though they are associated with pneumothorax, with an increasing risk for a higher number of nerve blocks performed [74]. (See "Nerve blocks of the scalp, neck, and trunk: Techniques", section on 'Intercostal nerve block'.)

Intermittent intercostal nerve block controls pain associated with rib fractures but is limited by the duration of the block and, for patients with multiple rib fractures, the need to perform the procedure at multiple intercostal levels. Repeated blockade is needed for prolonged relief [74-77]. A continuous infusion device is available that requires surgery for placement, which can be performed at the bedside in intubated patients [78]. As such, given other options for pain control and the severe nature of traumatic rib injuries, this approach is generally not applicable to the majority of multiple rib fracture patients.

Intercostal nerve blocks involve injections of the intercostal nerve proximal to the point of injury and at a level above and below the injured rib. Some advocate performing the block proximal to the midaxillary line to ensure blockade of the lateral and anterior cutaneous branches of the intercostal nerve, but this should only be necessary when analgesia of the skin is required [79,80].

Intrapleural infusion — Another approach to analgesia involves infusion of local anesthetics directly into the pleural space. The catheter used to administer the anesthetic can be placed adjacent to a thoracostomy tube at the time of tube placement. (See "Placement and management of thoracostomy tubes and catheters in adults and children", section on 'Tube selection'.)

One placebo-controlled trial study failed to find clear benefit with this approach [81]. Another study, which compared intrapleural with epidural analgesia, found improved pain relief with the epidural approach [55].

PULMONARY CARE AND SUPPORT

Supportive pulmonary measures are aimed at avoiding the need for intubation.

Patients with multiple rib fractures should receive volume expansion treatments regularly. Volume expansion by noninvasive means using incentive spirometry, deep breathing, and coughing are important to reduce secretions and prevent atelectasis. One study reported that every 10 percent increase in vital capacity after injury was associated with a 36 percent reduction in the likelihood of pulmonary complications [82]. However, aggressive pulmonary toilet and chest physiotherapy may be limited by chest wall pain, and adequate pain control is important for success. (See 'Pain control' above.)

Avoidance of intubation altogether and timely extubation for those who require intubation are associated with decreased mortality [83]. Patients who have not already been intubated need to be monitored closely for respiratory fatigue [24]. A trial of noninvasive positive pressure ventilation is warranted in appropriately selected patients to avoid obligatory mechanical ventilation [84]. Intubation may be unavoidable in spite of appropriate pain control and pulmonary care and, when needed, should be done preemptively under

controlled conditions to prevent morbidity associated with sudden respiratory decompensation. (See "The decision to intubate".)

Intubation and ventilatory support are more often needed in patients with flail chest [13]. A review of patients with flail chest from the National Trauma Data Bank reported that 59 percent of patients required mechanical ventilation [63]. It is imperative to determine if the cause for respiratory failure is pain or inherent chest wall instability, in which case a more aggressive pain control strategy or surgical stabilization of the chest wall may be of benefit, or whether respiratory failure is related to lung pathology, such as pulmonary contusion. In the latter case, there is much less of a role for surgical stabilization of the chest wall until the underlying lung parenchyma has healed to a point where extubation is feasible. Patients who fail to wean from mechanical ventilation may ultimately benefit from operative rib fracture fixation. (See 'Surgical management' below.)

SURGICAL MANAGEMENT

Although the majority of patients will heal their rib fractures with conservative measures, it is recognized that selected patients may benefit from surgical rib fracture fixation, and for these patients surgical fixation may be more cost effective [38,85,86]. The indications, techniques, and outcomes for surgical stabilization of rib fractures are discussed separately. (See "Surgical management of severe rib fractures".)

MORBIDITY AND MORTALITY

An increasing number of rib fractures is clearly associated with increased morbidity and mortality [1,6-9,35,87]. The presence of six or more rib fractures significantly increases the risk for death, often due to associated injuries [1,8]. Flail chest in isolation is associated with a mortality rate of 16 percent [88]. A review of data from the National Trauma Data Bank confirmed an increasing risk of pulmonary complications with increasing number of rib fractures but identified age and Injury Severity Score (ISS) as the primary predictors of death [6,9,11]. For each fractured rib, the odds ratio of death increased by 19 percent and the risk of pneumonia increased by 27 percent, in one study [7]. Conversely, the odds ratio of death decreases by 40 percent with adequate pain control. Thus, pain control, adequate pulmonary hygiene, and early mobility are the goals of care for patients with severe rib fractures. (See 'Management approach and initial care' above and 'Pain control' above and 'Pulmonary care and support' above.)

An increased number of rib fractures is more common in older patients who are clearly at a higher risk for complications [7,26,89-92]. In one study, patients over age 45 with ≥4 rib fractures had a significantly longer duration of mechanical ventilation and longer hospital stay compared with younger patients [90]. These data are likely driven by an increased incidence of infectious complications in older patients. For patients <65 years, pneumonia occurs in 11 to 17 percent, whereas for patients ≥65 years, rates up to 34 percent are reported [7,90]. One other study found that for each additional rib fracture in patients >65 years, the risk of pneumonia increased by 27 percent, and mortality increased by 19 percent. Thus, although outcomes following rib plating have not been studied in patients grouped by age, it may be logical to offer operative

intervention more frequently to older patients and to those with a higher number of rib fractures than to younger, less injured patients. (See 'Pneumonia' above and "Surgical management of severe rib fractures", section on 'Indications'.)

Patients with uncomplicated rib fractures can have significant short-term disabilities [36,93,94], and in one study these patients lost an average of 70 days of work [36]. Patients with crush injury associated with severe chest deformities are likely to have significant long-term disability without surgical stabilization of the chest [14].

INFORMATION FOR PATIENTS

UpToDate offers two types of patient education materials, "The Basics" and "Beyond the Basics." The Basics patient education pieces are written in plain language, at the 5th to 6th grade reading level, and they answer the four or five key questions a patient might have about a given condition. These articles are best for patients who want a general overview and who prefer short, easy-to-read materials. Beyond the Basics patient education pieces are longer, more sophisticated, and more detailed. These articles are written at the 10th to 12th grade reading level and are best for patients who want in-depth information and are comfortable with some medical jargon.

Here are the patient education articles that are relevant to this topic. We encourage you to print or e-mail these topics to your patients. (You can also locate patient education articles on a variety of subjects by searching on "patient info" and the keyword(s) of interest.)

- Basics topics (see "Patient education: Rib fractures in adults (The Basics)")

SUMMARY AND RECOMMENDATIONS

- Multiple rib fractures are the consequence of significant forces impacting the chest wall and are most commonly due to blunt injuries (eg, motor vehicle crash, falls, assault), but penetrating injuries (eg, gunshot) can also fracture ribs. (See 'Introduction' above.)
- Physical findings indicative of a rib fracture include rib pain with palpation, palpable rib step-offs, and crepitus. Patients may also complain of feeling a "clicking" or movement with deep breathing or Valsalva techniques. Multiple fractures may cause a visible chest wall deformity. The presence of paradoxical respiratory motion, an area of the chest wall pulled in with inspiration and pushed out with expiration, is diagnostic for flail chest. (See 'Physical exam' above.)
- Flail chest is present when three or more ribs are fractured in two or more places. It occurs in 5 to 13 percent of patients with chest wall injury. Sternal flail occurs when the sternum becomes dissociated from the hemithoraces. Pulmonary contusion is common with flail injuries, and these patients are at high risk for acute respiratory failure. (See 'Flail chest' above.)

- For limited, isolated rib injuries (<3 fractures), outpatient management with oral analgesics and incentive spirometry may suffice. The presence of ≥3 rib fractures suggests the need for hospitalization or transfer to a regional trauma facility. Older patients are at increased risk for complications associated with rib fracture, and hospital admission should be considered for any older adult (>65 years) patient. Such patients may benefit from admission to a center with dedicated resources and expertise in management of multiply fractured ribs. (See 'Trauma evaluation' above.)

- Standard plain chest radiographs may show the rib fractures but usually underestimate the number of fractures. The presence of pneumothorax or hemothorax on plain radiographs should prompt re-review of all imaging studies for rib fractures or sternal fracture. Although computed tomography (CT) of the chest is highly accurate for showing the location and number of rib fractures, CT should be reserved for when there is concern for concomitant injury (eg, pulmonary contusion, empyema, aortic injury) or when intervention is being considered. Rib fractures of the lower rib cage (T8 to T12) can be associated with intra-abdominal injury (eg, spleen, liver), and abdominal CT may also be indicated. (See 'Chest imaging' above.)

- Complications of traumatic rib fractures include pneumonia (most common), retained hemothorax or empyema, respiratory failure requiring intubation, and fracture nonunion, which can lead to chronic pain and disability. The probability of pneumonia is directly related to the number of fractured ribs as well as the age of the patient; pneumonia is also a risk factor for developing empyema or respiratory failure. (See 'Rib fracture complications' above.)

- For most patients with traumatic rib fractures, we suggest initial conservative management rather than surgical rib fracture stabilization (**Grade 2C**). Conservative management of rib fractures initially involves thoracostomy drainage for pneumothorax/hemothorax (when present) and judicious fluid resuscitation to reduce edema in contused lung. Subsequent management includes aggressive pain control, supportive pulmonary care, and early mobility for volume expansion and managing secretions. A multidisciplinary approach to patients with multiple rib fractures is associated with improved outcomes. (See 'Management approach and initial care' above.)

    - Adequate pain management is fundamental for tolerating deep breathing and coughing. The involvement of a dedicated pain service is important for providing tailored therapy and for monitoring its effectiveness. Pain control can generally be achieved with a multimodal regimen. We use an escalating strategy to control pain. (See 'Pain control' above.)

    - Altered pulmonary mechanics increase the work of breathing and the risk for respiratory failure. Supportive pulmonary measures are aimed at avoiding the need for intubation and include volume expansion using incentive spirometry, and deep breathing and coughing to reduce secretions and prevent atelectasis. Patient who are not intubated need to be monitored closely for respiratory distress. (See 'Pulmonary care and support' above.)

    - In spite of appropriate pulmonary support, respiratory fatigue or failure may occur. Intubation may be unavoidable and, when needed, should be performed preemptively under controlled conditions. A

trial of noninvasive positive pressure ventilation is warranted for appropriately selected patients in an attempt to avoid mechanical ventilation. Avoidance of intubation altogether and timely extubation among those for whom intubation is required decrease mortality. (See 'Pulmonary care and support' above.)

- Surgical rib stabilization is an option for patients who continue to have acute pain or other problems that interfere with respiratory toilet, those experiencing worsening pulmonary function, or those with rib fractures that do not heal (nonunion) and are causing persistent pain and functional impairment. (See 'Surgical management' above and "Surgical management of severe rib fractures".)

- Mortality from multiple rib fractures is directly related to the number of ribs fractured, injury severity (ie, associated injuries), and age. Mortality for patients over the age of 65 approaches 25 percent. A more aggressive approach to pain control, including operative fixation of rib fractures, may be warranted in older patients with severe rib fractures. (See 'Morbidity and mortality' above.)

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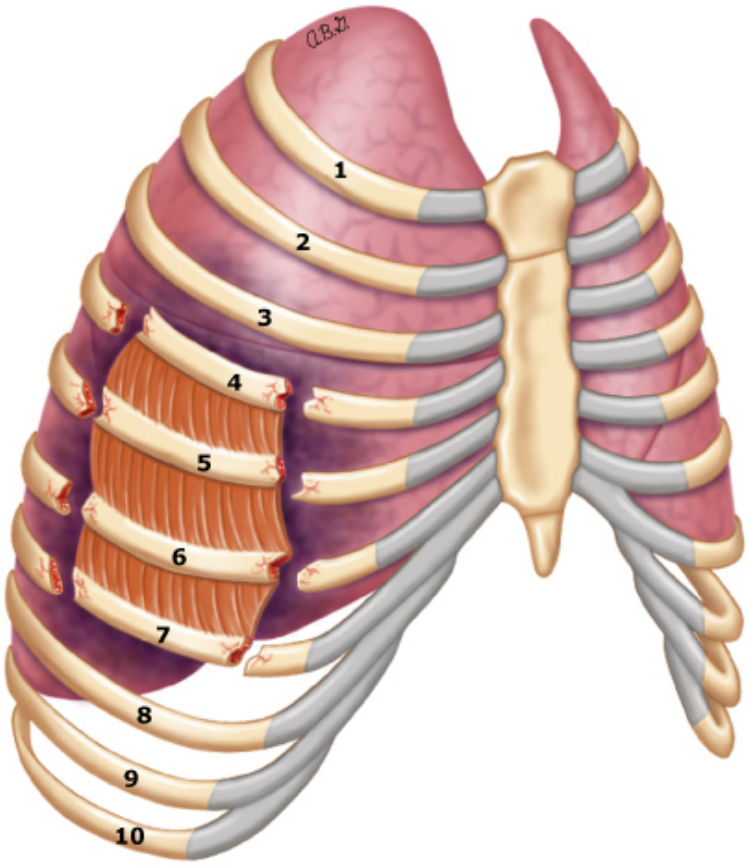
Topic 15152 Version 16.0

GRAPHICS

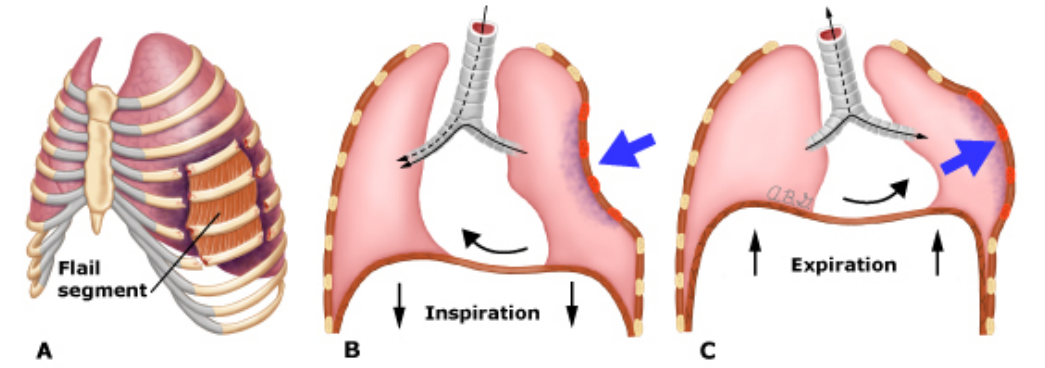
Flail chest injury



A 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.

Graphic 61518 Version 3.0

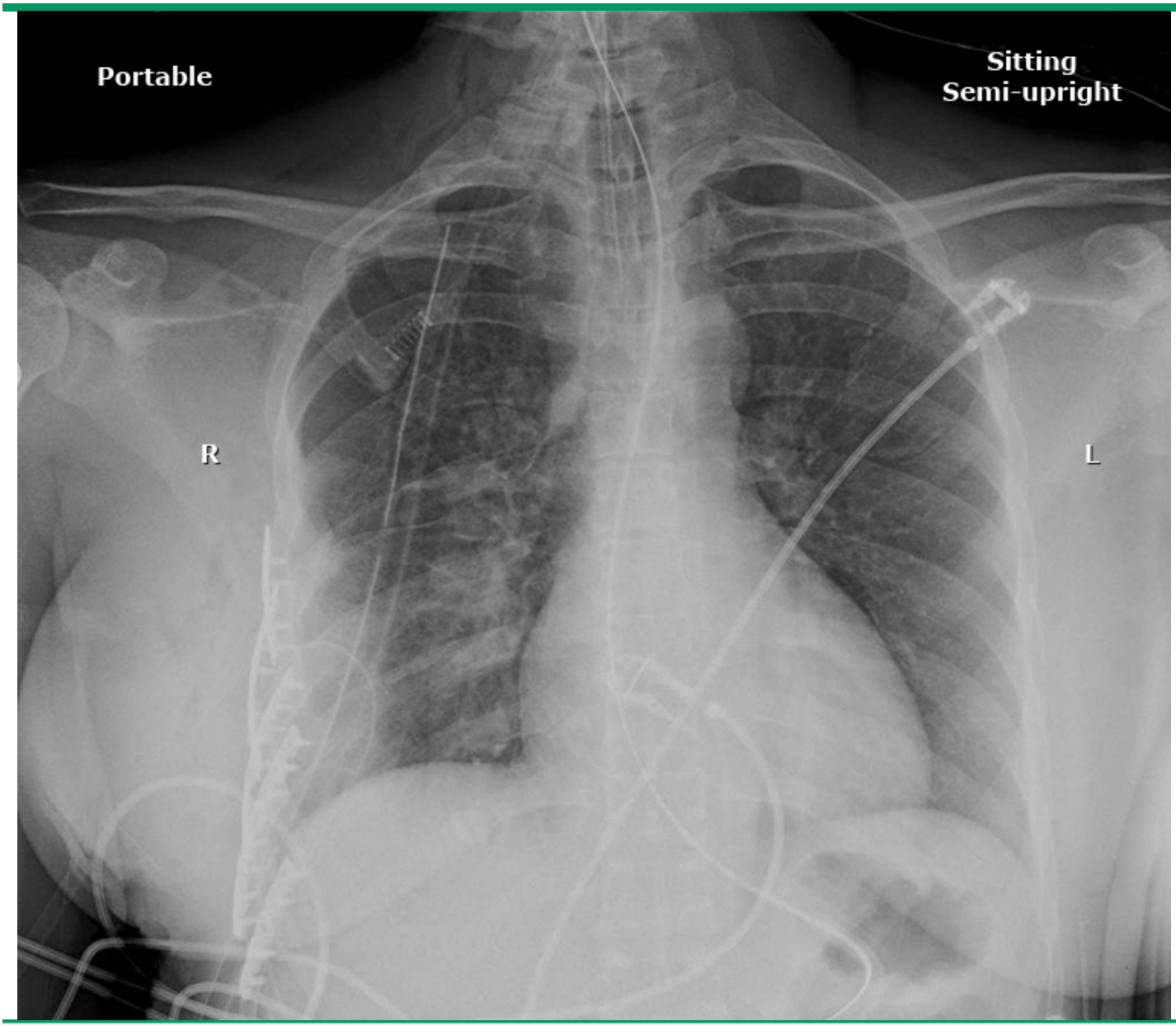
Flail chest



(A) Flail chest occurs when multiple rib fractures result in a loss of stability of the chest wall. The loss of continuity with the remainder of the rib cage causes the flail segment to move paradoxically.
(B) Pressure within the chest is negative during inspiration, causing the flail segment to retract.
(C) With expiration, intrathoracic pressure becomes positive and the flail segment bulges.

Graphic 79746 Version 3.0

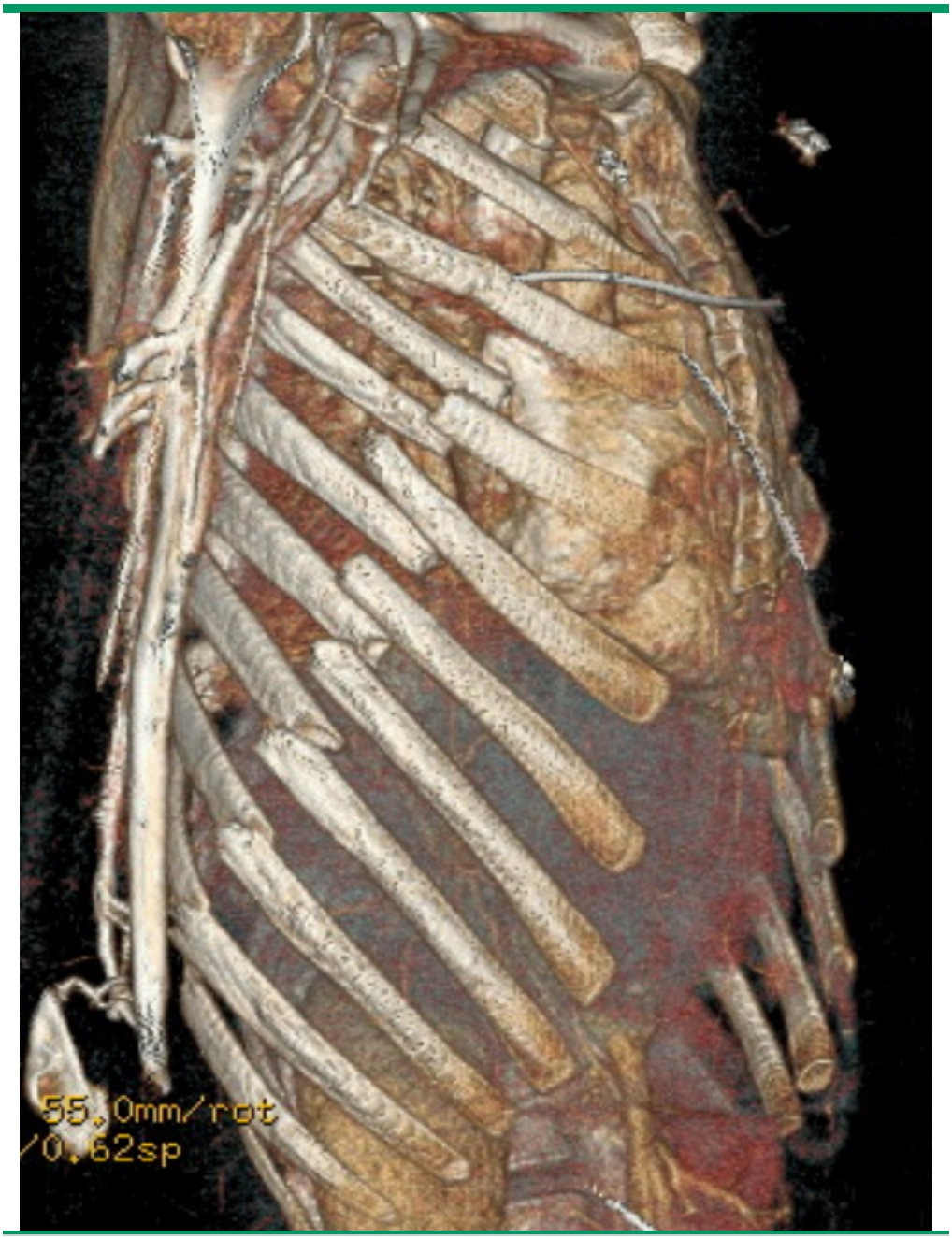
Postoperative chest radiograph motorcycle collision



This postoperative chest radiograph is from a patient in her late thirties who was ejected off a motorcycle, sustaining multiple right-sided rib fractures. The implanted plates can be seen laterally and are stabilizing ribs 5 through 9. Even though nearly all the ribs laterally on the right were fractured, operative fixation of the ribs of the mid-chest was sufficient to stabilize the entire chest wall.

Graphic 112078 Version 1.0

3D CT severe rib fractures



The image shows chest CT 3D reconstruction of a flail chest in a patient in her late thirties who was ejected off a motorcycle. She arrived with complaints of severe chest pain precluding her ability to speak in full sentences or take a deep breath. The CT scan confirmed displaced fractures of nearly all the ribs on the right side. She underwent operative rib fixation of ribs 5 through 9 on postinjury day 1 and was extubated the following day.

CT: computed tomography; 3D: three-dimensional.

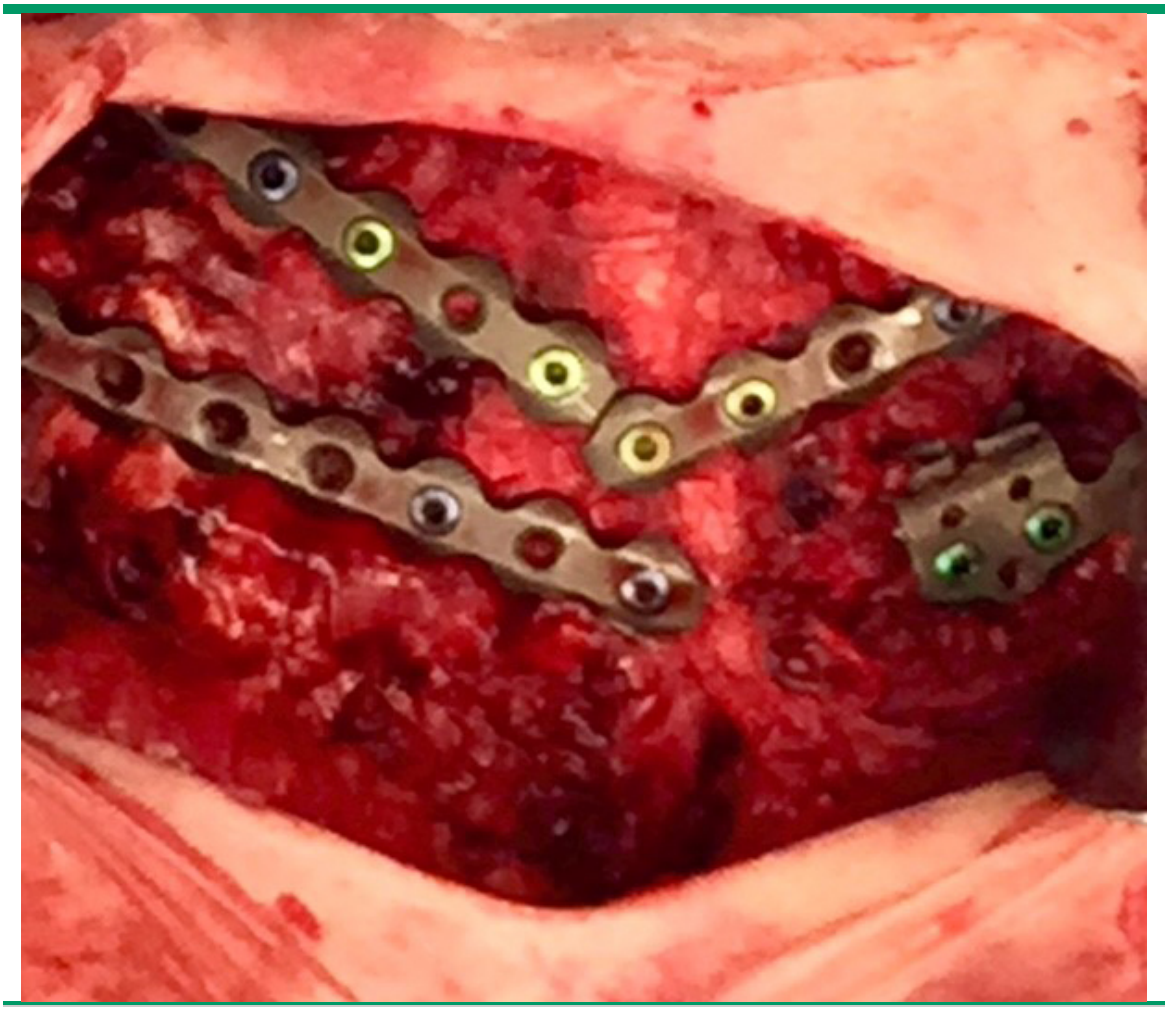
Graphic 110952 Version 3.0

Rib plating on plain chest radiography

The chest radiograph shows multiple rib plates placed for fixation of severe traumatic rib fractures.

Graphic 112075 Version 1.0

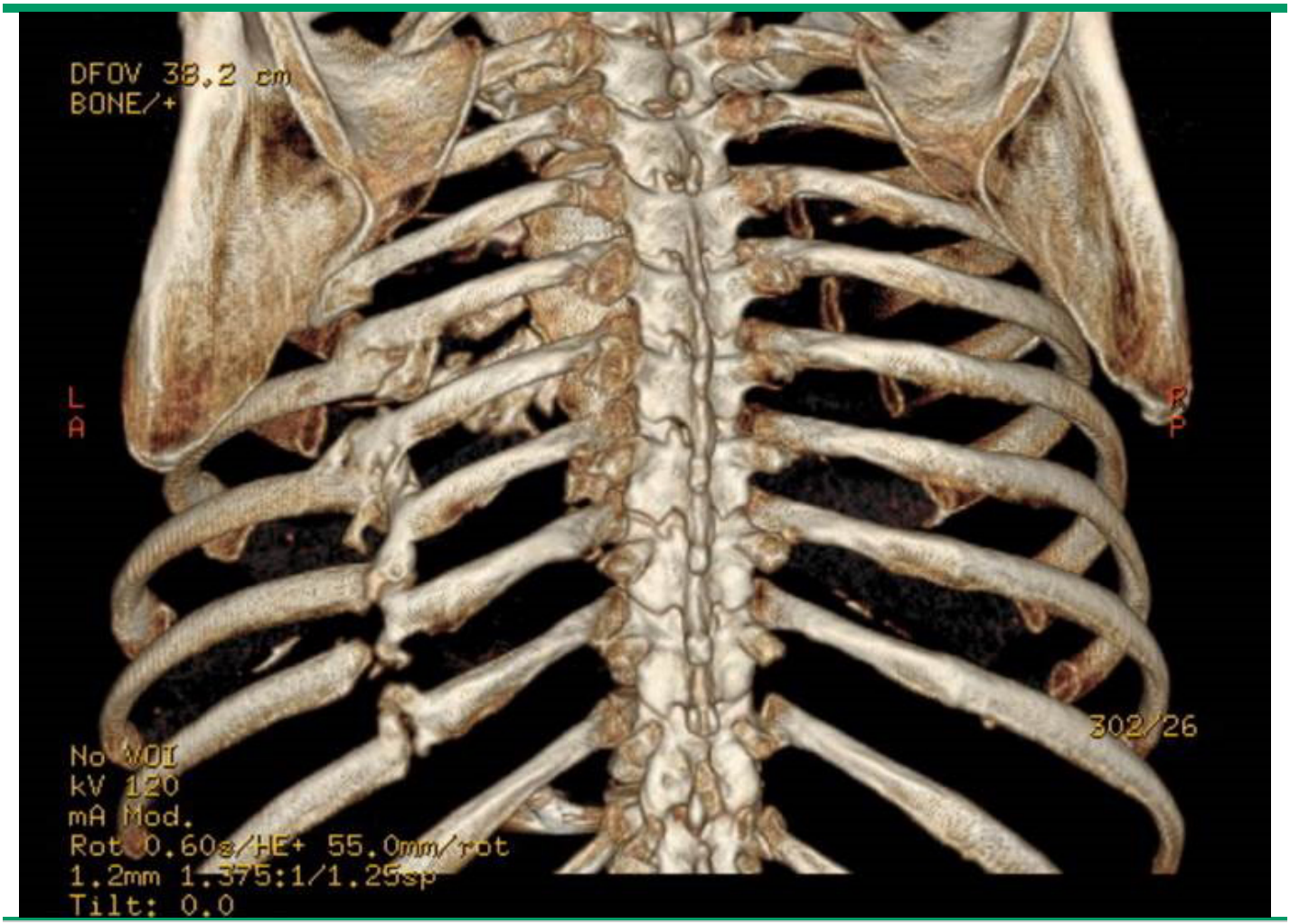
Intraoperative appearance of rib plating



The picture shows the intraoperative appearance of rib plates used for fixation of severe rib fractures.

Graphic 112076 Version 1.0

3D reconstruction of flail chest from collision at eight months

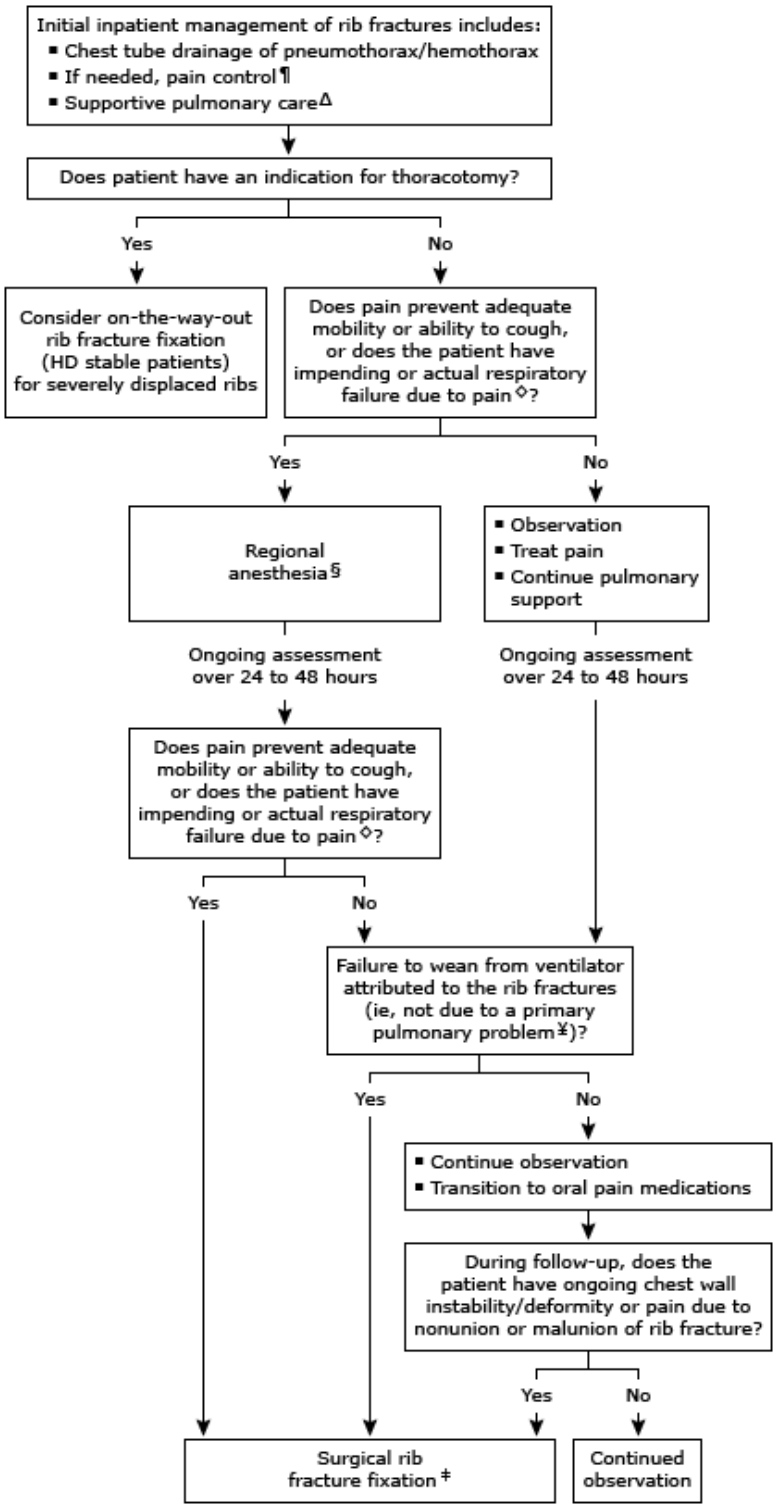


3D reconstruction of the chest wall of a patient involved in a motorcycle collision eight months following injury. The patient presented with severe, constant pain. On the right, there are multiple areas of nonunion as well as several areas of malunion with perifracture callous.

3D: three-dimensional.

Graphic 110953 Version 1.0

Algorithm management of severe rib fractures*



HD: hemodynamically; COPD: chronic obstructive pulmonary disease; COX: cyclooxygenase.

* Admit adults with rib fractures and any of the following: ≥3 rib fractures, age >65, underlying pulmonary disease (eg, pulmonary contusion, COPD), displaced rib fracture(s), multiple trauma. Patients are typically cared for in an intensive care unit or other monitored setting.

¶ We use an escalating strategy of analgesia starting with around-the-clock acetaminophen, a COX-2 inhibitor, and a low-dose opioid delivered by using demand-only patient-controlled analgesia. Other medical adjuncts such as ketamine infusion or lidocaine infusion can be given in any combination based upon the degree of pain per hospital protocol.

Δ Supportive pulmonary care includes pain control, incentive spirometry, aggressive pulmonary toilet, and chest physiotherapy, if tolerated. Severely injured patients may require initial intubation.
◇ Patients with flail chest may benefit from earlier rather than later surgical rib fixation.
§ Options include placement of an epidural or paravertebral catheter for continuous infusion of ropivacaine. An alternative is intercostal nerve blocks.
¥ Examples include pulmonary contusion, ventilator-associated pneumonia, COPD, neurologic disease.
‡ The best supporting evidence for surgical fixation is in patients with flail chest.

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Contributor Disclosures

Babak Sarani, MD, FACS, FCCM Consultant/Advisory Boards: ACUTE Innovations, LLC [Thoracic surgery (Rib Plating System)]; Acelity [Thoracic surgery (Open Abdomen Negative Pressure Therapy Device)]. **Eileen M Bulger, MD, FACS** Grant/Research/Clinical Trial Support: Atox Bio [Necrotizing soft tissue infections (AB103)]. Consultant/Advisory Boards: Hemanext [Transfusion therapy (Anaerobic storage system for blood products)]; Opticyte [Shock (Direct cellular oximeter)]. Equity Ownership/Stock Options: Opticyte [Shock (Direct cellular oximeter)]. **Joseph S Friedberg, MD** Nothing to disclose **Kathryn A Collins, MD, PhD, FACS** Nothing to disclose

Contributor disclosures are reviewed for conflicts of interest by the editorial group. When found, these are addressed by vetting through a multi-level review process, and through requirements for references to be provided to support the content. Appropriately referenced content is required of all authors and must conform to UpToDate standards of evidence.

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