Blunt chest wall trauma: Rib fractures and associated injuries

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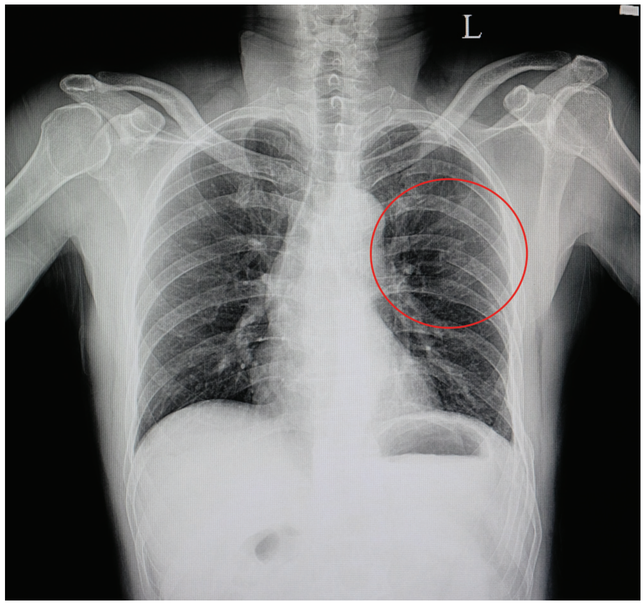
ABSTRACT

Blunt injuries to the chest wall, specifically those related to rib fractures, need to be promptly identified and effectively managed to reduce patient morbidity and mortality. Furthermore, judicious use of multimodal pain management and early identification of patients who will benefit from the surgical stabilization of rib fractures are paramount to optimal outcomes.

Keywords: blunt, chest wall, trauma, rib fractures, surgical stabilization, pneumothorax



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Learning objectives

- Identify and evaluate BCWT-associated injuries.
- Employ effective management strategies for rib fractures associated injuries including pneumothorax, hemothorax, pulmonary contusions, and upper intra-abdominal injury.
- Describe multimodal pain management and treatment options for BCWT.

Blunt chest wall trauma (BCWT) occurs when a direct force impacts the thorax. Injuries associated with BCWT have a mortality of 10% to 20%.[1,2] The primary mechanisms of injury in BCWT include motor vehicle accidents, assault, and falls.[3,4] The incidence of BCWT has been rising, particularly in older adults.[4] BCWT has been reported as the cause of 15% of trauma-related ED visits globally.[5]

BCWT can lead to multiple complications. These include early complications such as pneumonia or lung injury and long-term complications such as chronic pain or respiratory impairment.[3,5] Further, BCWT can lead to life-threatening conditions such as respiratory failure, pneumothorax, and hemothorax if the condition is not promptly identified and treated.[5] Even minor blunt trauma to the chest wall of an older adult with osteoporotic bone can lead to rib fractures.[4] Rib fractures in adults account for 55% of blunt traumatic injuries and are the focus of this article.[6] Additionally, patients with rib fractures can experience a respiratory decline 24 to 72 hours after initial injury, which makes understanding this pathology and its treatments essential.[1,5]

The uncontrolled pain from rib fractures leads to splinting, inadequate breathing, and cough suppression. These factors contribute to about a 30% increased risk in developing pneumonia in these patients.[7] Additionally, associated pneumothorax or hemothorax from rib fractures may require invasive management such as surgery or tube thoracostomy.[8] Long-term complications from rib fractures such as nonunion and intercostal nerve entrapment can lead to chronic pain and disability.[3,4] Surgical stabilization of rib fractures should be considered in patients with a flail chest, severely displaced rib fractures, or those in whom conservative treatment has failed and who have worsening respiratory status.[3,9]

Tignanelli and colleagues reviewed treatments for rib fractures and concluded that clinicians do not adhere to current evidence-based treatment recommendations, even at level I trauma centers.[10] This article reviews current

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Key points

- BCWT can lead to several complications such as lung injury, respiratory failure, and chronic pulmonary compromise.
- A thorough evaluation and early initiation of evidence-based treatments can improve patient outcomes.
- Important rib fracture-associated injuries to consider during evaluation include pneumothorax, hemothorax, lung parenchymal injuries, and upper abdominal soft-tissue injuries.
- Treatments for rib fractures include multimodal pain management, surgical stabilization, and VATS.

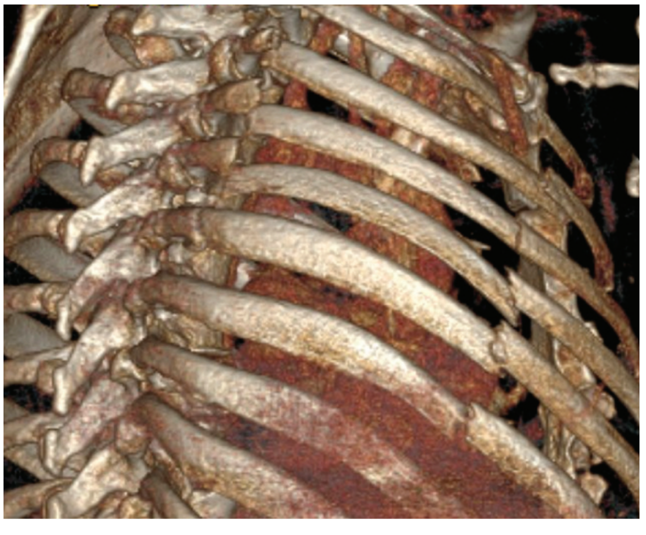
evidence-based recommendations on the treatment of rib fractures and associated injuries from BCWT to educate clinicians on a pathology that has a 48% morbidity.[10]

CHEST WALL MECHANICS

The chest wall is composed of bony structures including the sternum, ribs, and thoracic spine. Additionally, it has supporting musculature including the external intercostal, internal intercostal, innermost intercostal, subcostal, and transverse thoracic muscles.[11] Internally, it is lined with the parietal pleura.

The chest wall has two primary functions: to protect underlying vital organs and to power respirations. During inhalation, intercostal muscles contract along with the diaphragm to elevate the ribs, increasing intrathoracic volume and reducing intrathoracic pressure. This process causes air to be pulled into the lungs. During exhalation, the muscles relax. This reduces intrathoracic volume and increases intrathoracic pressure, expelling the air passively. When ribs are fractured, the natural motion and mechanics of the chest wall are disrupted.[2,11] When three or more ribs are fractured in at least two locations along each rib, it is considered a flail segment (**Figure 1**) and can lead to paradoxical motion of the chest wall.[3,5]

FIGURE 1. Reconstructed imaging of flail chest. The ribs are fractured in multiple locations and are severely displaced posteriorly and laterally.



Disruption of the chest wall, especially in a patient with multiple rib fractures and a flail chest, alters chest wall mechanics and impairs respiration.[11] First, chest wall rigidity is decreased from the broken rib segments and damaged musculature.[5] Next, intrathoracic volume is reduced because of overlapping of displaced rib fractures and space-occupying hemothorax or pneumothorax. Finally, decreased respiratory effort because of pain limits the patient's ability to take full deep breaths, reducing overall vital capacity.[12]

The intercostal bundle consists of the intercostal nerve, artery, and vein that run along the inferior portion of the rib in the costal groove. In a patient with BCWT, the direct force of impact and subsequent fractured rib segment can disrupt underlying structures such as the parietal pleura and the lung parenchyma, causing a pulmonary contusion, laceration, or pneumothorax (**Figure 2**). Further, bleeding from the bone, surrounding tissues, or a severed intercostal artery or vein can lead to hemothorax.[13] Additionally, the upper abdominal organs lie inferior to the lower part of the rib cage. Assess for internal laceration or contusion of the diaphragm and upper abdominal organs including the liver and spleen when a fracture is noted in ribs 9 to 12.[11]

EVALUATION

Advanced Trauma and Life Support (ATLS) provides guidelines on evaluating and treating trauma patients. During the primary survey, many chest wall injuries are identified. The primary survey consists of airway, breathing, circulation, and disability assessments, as these can immediately identify potential life-threatening injuries.[14]

Vital signs and the physical examination are of particular importance in patients with BCWT. First, inspection of the chest can reveal paradoxical motion and crepitus, or ecchymosis can identify the location of an injury. Next, auscultation of the chest evaluates for diminished or absent breath sounds; however, the sensitivity of detecting a pneumothorax or hemothorax in trauma is about 50% and varies depending on clinician experience.[15]

CT imaging is the standard of care in hemodynamically stable patients with chest wall injury, because its sensitivity for detection is more accurate than plain chest radiography alone. Furthermore, CT imaging can identify smaller-volume pneumothoraxes and hemothoraxes, compared with radiography, which misses up to 50% of pneumothoraxes less than 200 mL.[11,16-18] Ultrasound or extended focused assessment with sonography for trauma (eFAST) can be used by a skilled clinician to quickly evaluate for rib fracture-associated injuries such as pneumothorax or hemothorax that require tube thoracostomy.[11,14] Further, eFAST sensitivity is 90.9% for detecting

FIGURE 2. CT scan of a moderately displaced posterior rib fracture and bilateral hemothorax

pneumothorax, significantly higher than a plain chest radiograph.[7]

Baseline pulmonary function tests including incentive spirometry and forced vital capacity (FVC) can help predict a higher risk of respiratory failure. Patients with an incentive spirometry volume less than 1,000 mL on admission and those with a predicted FVC of 55% or less demonstrate higher respiratory complication rates.[2,17] According to the American Association for Respiratory Care, the proper use of incentive spirometry includes inspiration over 5 seconds, followed by a breath hold and natural unforced exhalation.[4] The current recommendation for the use of incentive spirometry as a therapeutic modality after trauma or surgery remains mixed, because studies have not supported its benefit.[4] However, this has not been extensively studied in patients with rib fractures. Further, deviation from baseline incentive spirometry level can be a predictor of worsening respiratory decline and indicate the need for more aggressive interventions such as surgery.[4]

In addition to monitoring pulmonary function with FVC and incentive spirometry, scoring systems such as the RibScore and Sequential Clinical Assessment of Respiratory Function (SCARF) can help identify patients who are at increased risk of pulmonary decompensation.[12,19,20] The RibScore uses radiographic findings from a CT scan to identify patients who are at greater risk of complications. A RibScore (**Table 1**) of 4 or greater is more than 90% specific for respiratory failure, pneumonia, and need for tracheostomy.[12,19] The SCARF score (**Table 2**) is based on clinical assessments, including incentive spirometry value, pain score, respiratory rate, and strength of cough. The SCARF score should be assessed in the ED and each time routine vital signs are obtained after admission. An increase in SCARF score by 1 point from admission has been shown to occur before detrimental pulmonary outcomes.[20] Like the RibScore, the SCARF score has been used to predict adverse outcomes and can be used to guide treatment decisions.[12,20]

TABLE 1. RibScore[12,19]

A score of 4 or more indicates respiratory failure, pneumonia, and need for tracheostomy.

Radiologic finding	Score
First rib fracture	1
Flail chest	1
Bilateral fractures	1
Six or more fractures	1
Three or more severely displaced fractures	1
One or more ribs fractured anteriorly, laterally, and posteriorly	1
Total	6

TABLE 2. SCARF score

Reprinted with permission from Hardin KS, Leasia KN, Haenel J, et al. The Sequential Clinical Assessment of Respiratory Function (SCARF) score: a dynamic pulmonary physiologic score that predicts adverse outcomes in critically ill rib fracture patients. *J Trauma Acute Care Surg*. 2019;87(6):1260-1268.

Assessment	Score
Analog pain score of 5 or greater	1
Incentive spirometry less than 50% of predicted	1
Respiratory rate of 20 or greater	1
Poor cough effort	1
Total	4

The Western Trauma Association recommends ICU admission for patients over age 65 years with more than two significant rib fractures.[2] Consider ICU admission for patients with preexisting respiratory dysfunction, anticoagulant use, flail chest, or evidence of severe pulmonary contusion on CT.[1,2,12]

PULMONARY PARENCHYMAL INJURIES

Acute injury to the lung parenchyma has a mortality of 40% and increases the patient's chance of developing pneumonia or acute respiratory distress syndrome (ARDS).[8,16] Pulmonary parenchymal injury can occur from a transfer of kinetic energy from the rigid chest wall in an adult to the lung tissue or by direct impact from a fractured rib segment. Laceration of the lung tissue can be the underlying cause of pneumothorax or hemothorax. In a pulmonary contusion, the alveoli can rupture, causing hematoma and atelectasis. This damage from capillary leakage and pulmonary edema directly impairs lung function, leading to reduced gas exchange and reduced lung compliance.[1] These changes increase the patient's risk for hypoxia and severe respiratory distress.

After initial injury, the edema and inflammatory response of the contused lung can worsen for 24 to 72 hours, further impairing ventilation and oxygenation. Hypoperfusion of the damaged segment of the lung can lead to reflex vasoconstriction, worsening hypoxia, and hypercapnia.[2,16] Aggressive respiratory therapy is paramount for reducing complications related to rib fractures. Ideally, patients should take long, slow breaths to help expand the lung, reduce pleural pressure, and improve overall gas exchange. One method to achieve this is by frequent pulmonary hygiene and incentive spirometry.[4]

In patients with pulmonary trauma, keep the overall fluid status euvolemic to mildly hypovolemic.[8] This can be achieved by monitoring vital signs, laboratory values, and urine output. Furosemide can benefit patients with a pulmonary contusion by not only acting as a diuretic, but by reducing pulmonary vascular resistance and intracapillary pressure.[16]

In patients with severe respiratory distress, including ARDS requiring mechanical ventilation, use low tidal volumes (6 to 8 mL/kg of ideal body weight) and higher levels of pressure support to prevent further lung damage and promote alveolar recruitment.[16] Long term, patients can develop reduced residual capacity and have labored breathing for months to years after injury.[9,16]

PNEUMOTHORAX

A traumatic tension pneumothorax occurs when air becomes trapped between the lung parenchyma and the chest wall after an injury. This can occur from a lung tissue laceration or from air entering through a hole in the chest wall. A tension pneumothorax is life-threatening and requires immediate treatment.

ATLS recommends immediate decompression of a tension pneumothorax. If left untreated, pneumothorax can lead to hypotension from decreased venous return to the heart.[14] Clinical features of a tension pneumothorax include a deviated trachea, distended neck veins, hyperresonance to percussion, and reduced or absent breath sounds. Once pneumothorax is identified, quick intervention via needle decompression or tube thoracostomy can provide a quick resolution by releasing the pressurized air and allowing blood return to the heart.[13]

Complications of ventral needle decompression of the chest include inadequate decompression, especially in larger patients if the needle is not long enough to reach the pleural space.[7] Additionally, ventral decompression in trauma patients carries an increased incidence of lung laceration and parenchymal damage.[7] These complications have led to changes in the most recent ATLS recommendation from the American College of Surgeons. ATLS now recommends that clinicians perform a thoracostomy for decompression of a tension pneumothorax at the mid-axillary line at the fourth to fifth intercostal space.[14]

In addition to a tension pneumothorax, other types of pneumothorax may need to be treated once identified. However, with increased use of CT technology, smaller pneumothoraxes may be identified and may not have clinical significance. An occult pneumothorax is identified on CT but not visible on radiograph.[17] The current recommendation for an occult pneumothorax is monitoring vital signs with close interval follow-up radiographs. Repeat chest radiographs can help clinicians monitor for expansion of an initial occult pneumothorax that may subsequently need more invasive treatment.[17]

The decision to perform tube thoracostomy for a pneumothorax or hemothorax is not without risk. Tube thoracostomy has a complication rate of 22% and increases length of hospital stay.[17] Recent studies have looked at the size of chest tubes and found adequate treatment with a 14-Fr pigtail chest tube with less reported pain than with use of a 28-Fr silicone chest tube.[7]

After a tube thoracostomy, the chest tube is connected to a thoracic drainage system that allows for a pneumatic seal and drainage of fluid and air. The drainage system can be connected to suction in order to enhance air and fluid removal from the extrapleural space. This process allows the lung to expand and adhere back to the chest wall.

Management of a chest tube includes obtaining follow-up radiographs to ensure pathology resolution and conducting an air leak test (observing the fluid level chamber in the thoracic drainage system while the patient coughs). If the patient has a lung laceration, intraparenchymal air will leave the lung tissue and fill the extrapleural space.[7] This air will travel through the chest tube and into the drainage system. Air bubbles seen in the drainage system's fluid chamber are noted as a positive air leak. If an air leak is present, the patient is at increased risk of pneumothorax reaccumulation after chest tube removal. Additionally, evaluate the chest tube, the insertion site, and the chest tube drainage system to eliminate external sources for a positive air leak.

HEMOTHORAX

A hemothorax can occur from laceration of the intercostal artery or vein, bleeding bone, or tissue damage. A massive hemothorax is one that is greater than 1,500 mL on initial placement or output greater than 200 mL/h for the first 2 to 4 hours.[13] In the case of a patient with a massive hemothorax, consider surgery to address the source of hemorrhage. In contrast, a small hemothorax can be monitored. Some blood can be reabsorbed by the body, though patients are at risk of developing an empyema or a trapped lung with retained hemothorax. Management and removal of a chest tube for a hemothorax is similar to a pneumothorax, but daily output volume should be taken into consideration with a hemothorax to ensure fluid production is declining to a manageable level for the body to reabsorb, typically less than 200 mL in 24 hours.[21]

INTRA-ABDOMINAL INJURY

The lower ribs (9 to 12) help to protect the upper abdominal organs, specifically the liver and spleen. When rib fractures are noted in the lower segment, obtain an abdominal CT angiogram to rule out laceration or contusion of the underlying organs including the diaphragm, liver, and spleen.[11,22] The American Association of Surgery of Trauma Organ Injury Scale grades liver and spleen injuries on a scale of I to V.[23] If a patient is hemodynamically unstable with evidence of splenic or liver injury, emergency operative intervention via an exploratory laparotomy is indicated to control hemorrhage.[14] If the patient remains stable, consult an interventional radiologist for possible embolization or closely monitor the patient with serial serum hemoglobin and hematocrit.

MULTIMODAL PAIN MANAGEMENT

Patients with chest wall injuries are at increased risk of pneumonia and respiratory failure. Uncontrolled pain can cause splinting and guarding, leading to low overall tidal volumes, reduced mobility, and inability to cough and clear secretions. The best approach for these patients is multimodal pain management. This includes nonopioid interventions, which are crucial in avoiding delirium and oversedation that could lead to reduced cough and respiratory effort.[1,13,22]

Multimodal pain management includes addressing different causes of pain. In addition to acetaminophen, anti-inflammatories have shown benefit in reducing pain in patients with rib fractures.[5] Clinicians also should consider prescribing a muscle relaxant to address pain produced from spasms of the injured muscle and the muscles attempting to stabilize the fractured ribs. Additionally, a nerve modulation medication such as gabapentin can be prescribed because the rib is innervated by intercostal nerves that can be damaged directly by the fracture. If further pain control is needed, ketamine, IV lidocaine infusions, and topical lidocaine patches also are effective nonopioid, noninvasive pain management adjuncts to consider.[4,13,18]

Early intervention with anesthesia lets patients participate in respiratory therapy and can reduce the risk of pulmonary compromise, including atelectasis, pneumonia, and ARDS. Epidural catheter placement for anesthesia has been highly effective for patients with rib fractures; however, contraindications such as use of anticoagulants, neurotrauma, and hypotension can limit its use.[2,5] Myofascial plane blocks such as an erector spinae plane block can be used to provide more localized analgesia and cause fewer adverse reactions than epidural anesthesia.[5,24] Patients can maintain these catheters for several days; the catheters typically are managed by the anesthesia team.[13,18,22]

SURGICAL INTERVENTION

Surgical stabilization of rib fractures involves open reduction and internal fixation of fractured rib segments. Surgical stabilization has been shown to improve outcomes, including reduced duration of mechanical ventilation, incidence of pneumonia, and overall mortality in patients with displaced rib fractures and flail rib segments.[4,9,18] Extensive rib fractures can lead to chronic issues, including pain and reduced pulmonary function.[8,9] Most recently the Chest Wall Injury Society NONFLAIL trial studied the outcome of surgical stabilization of three or more displaced rib fractures.[25] Patients who underwent surgical stabilization had a significant reduction in pain at 2 weeks postoperative, eliminated pleural space complications including retained hemothorax, and had improvement in their quality-of-life scores.[25] Further, 38% of patients with rib fracture nonunion experienced prolonged pain from intercostal nerve entrapment.[4]

Consider surgical stabilization for all patients with a flail chest or with three or more severely displaced ribs.[25] Ongo-

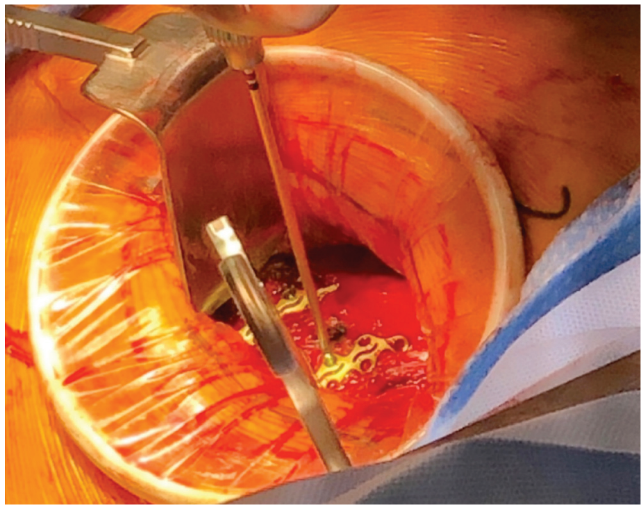


FIGURE 3. Surgical stabilization of lateral rib fractures. After the ribs are reduced and realigned, they are secured in place with a thin titanium plate that is locked in position with multiple screws.

FIGURE 4. Completed surgical stabilization of lateral ribs with restored chest wall bony structure and increased stability

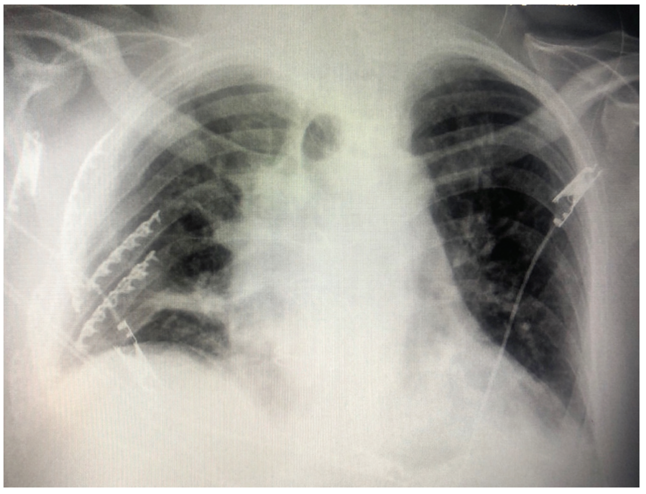


FIGURE 5. Postoperative chest radiograph demonstrating realignment of previously displaced fractures and hardware placement

ing evaluation of a patient's performance with respiratory therapy and pain management, such as a decline in trending SCARF scores, also is a reason to consider surgical stabilization.[20] Additionally, intervene with surgery early if indicated, as the benefits are greatest when it is performed within the first 72 hours postinjury.[22,25]

Location of the rib fracture also determines if surgical stabilization is a feasible option. Ribs 4 to 10 provide the primary stability for the chest wall and are the most common candidates for surgical stabilization.[3,22] Posterior fractures that are in close proximity to the thoracic spinous process do not leave enough room for the surgical plate. Further, fractures to ribs 1 and 2 often are inaccessible because of their close proximity to vital structures such as the subclavian artery and vein. Another structure to consider for anterolateral rib fractures is the long thoracic nerve, which innervates the serratus anterior muscle.[26]

Advancement in minimally invasive and muscle-sparing techniques have reduced the morbidity and mortality associated with surgical stabilization of rib fractures.[26] At the time of surgery, the rib fractures are reduced and realigned. These segments are then fixed in place with a metal plate (**Figures 3** through **5**). After chest wall stability and alignment are reestablished, the thoracic cavity is washed out of any hemothorax, and a wide-bore chest tube is placed. By performing tube thoracostomy intraoperatively, ideal placement to evacuate a pneumothorax and hemothorax can be achieved.[25]

Video-assisted thoracic surgery (VATS) is an additional surgical procedure sometimes performed for persistent pneumothorax, retained hemothorax, or trapped lung.[7] During a VATS procedure, small ports are placed in the chest wall after the lung has been collapsed. Then a camera is used to facilitate interrogation of the chest wall. The thorax can be irrigated, removing retained hemothorax or air.

Surgical stabilization has been shown to improve rib fracture recovery and reduce overall complications associated with rib fractures.[25] However, postoperative pain can limit recovery. Intercostal nerve cryoablation is one newer method to further improve pain management and can be conducted at the same time as surgical stabilization via a VATS approach.[6]

Intercostal nerve cryoablation uses nitrous oxide to cool a probe to –60° C to cause axonotmesis of the intercostal nerves.[6] During axonotmesis, the myelin sheath of the nerve is destroyed, but the internal nerve structures remain intact.[6] This process eliminates pain signal conduction distal to the cryoablation and results in numbness along the nerve. The nerve regenerates at a rate of 1 to 3 mm daily. During the time of rib healing, the patient needs a lower level of opioid analgesics; research has demonstrated that nerve sensation eventually returns to normal.[6]

CONCLUSION

Patients with BCWT have increased morbidity and mortality with rib fractures and associated injuries. Prompt diagnosis using chest radiograph, CT, or eFAST followed by a proper physical examination and classification on a RibScore and SCARF score can improve patient outcomes. Management techniques for a pneumothorax or hemothorax include observation with serial imaging and possible tube thoracostomy.

Patients with rib fractures should first be optimized with respiratory therapy and multimodal pain management. Finally, consider surgical stabilization if conservative therapy fails or the patient has continued respiratory decline. If the patient is a surgical candidate, surgical stabilization can restore chest wall mechanics, expedite recovery, and improve patients' long-term prognosis. **JAAPA**

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