

# BEST PRACTICES GUIDELINES

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# MANAGEMENT OF CHEST WALL INJURIES

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**Endorsed by the Chest Wall Injury Society (CWIS) and the Orthopaedic Trauma Association (OTA).**

BEST PRACTICES GUIDELINES  
**MANAGEMENT OF  
CHEST WALL INJURIES**



# **OVERVIEW OF CHEST WALL INJURIES**



## INTRODUCTION

Thoracic trauma is responsible for over 30% of all trauma-related deaths in the United States, and traumatic rib fractures represent the most frequently encountered thoracic injury.<sup>1</sup> Mortality is estimated to be up to 8% in older adults and 36% in patients with flail chest.<sup>1</sup> For many years, clinicians considered rib fractures to be injuries that would heal over time, requiring no surgical intervention. Over the last 125 years, various modalities of surgical treatment for rib fractures were advocated and then abandoned.

While the treatment of chest wall injuries, including rib fractures, has entered a new era, rib fracture treatment is not a new concept. Open surgical treatment of rib fractures was described almost 2,000 years ago when the Roman surgeon Soranus (78–117 CE) described the resection of depressed rib fractures for the relief of pleuritic pain.<sup>1</sup> Recent chest wall injury treatment efforts focused on the study of surgical stabilization in the context of modern pain control and pulmonary hygiene. Tanaka et al. reported the first randomized study that reviewed the clinical efficacy of surgical stabilization of rib fractures (SSRF) compared with “internal pneumatic stabilization” of patients with severe flail chest injuries who required prolonged ventilatory support.<sup>2</sup> This study sparked a resurgence of the surgical approach in the care of chest wall injuries, including fractures of the sternum. Surgical innovators of the early 21st century examined the ability to treat rib fractures surgically with newly developed and innovative surgical systems. These plating systems for patients with rib and sternal fractures offer surgical options that appear to provide better long-term outcomes with fewer short-term postinjury complications. Despite a logarithmic increase in the number of research papers published dealing with SSRF, not all general/trauma/thoracic surgeons have adopted this practice, possibly concerned that not enough appropriately conducted studies were focused on patients without flail chest.

Organized efforts to study and disseminate best practices for chest wall injuries have multiplied. The multidisciplinary, multinational Chest Wall Injury Society (CWIS), conceptualized in 2016 and formally established in 2017, has significantly aided this work. This society’s specific

mission is optimizing the operative and nonoperative care of the patient with chest wall injury. The CWIS published practice guidelines and educational material for patients with these injuries.<sup>3</sup>

Concomitant with these efforts, an evidence base now exists to support a multimodal and multidisciplinary approach to pain management and rehabilitation for patients with chest wall injury. With the rapid growth of knowledge about the entire spectrum of chest wall injury care, both operative and nonoperative, best practices in the management of chest wall injuries will continue to evolve.

## IMPORTANT NOTE

The intent of the ACS Trauma Quality Programs (TQP) Best Practices Guidelines (BPGs) is to provide healthcare professionals with evidence-based information regarding care of the trauma patient. The BPGs do not include all potential options for prevention, diagnosis, and treatment, and they are not intended as a substitute for the provider’s clinical judgment and experience. Responsible clinicians must make all treatment decisions based upon their independent judgment and the patient’s individual clinical presentation.

This BPG is not intended to be a comprehensive guide to all services, personnel, and processes needed to conduct surgery. The guidance herein does not constitute a standard of care and is not intended to replace the medical judgment of the physician or health care professional in individual circumstances. Although these BPGs have been reviewed with significant care, this resource guide is provided “as is” with all faults. To the maximum extent permitted by law, ACS disclaims any and all express or implied representations and warranties with respect to the materials, including any express or implied warranty of merchantability, fitness for a particular purpose, accuracy, or non-infringement. The entire risk as to the satisfaction, quality, performance, and use of this licensed material shall be with the user. The ACS and any entities endorsing the guidelines shall not be liable for any direct, indirect, special, incidental, or consequential damages related to the use or misuse of the information contained herein. The ACS may modify the TQP BPGs at any time without notice. This ACS TQP *Best Practices Guidelines for the Management of*

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## CHEST WALL INJURIES OVERVIEW

### KEY POINTS

- Chest wall injuries have a negative effect on a patient's long-term functional outcomes and quality of life.
- Flail chest injuries result in chest wall instability that can lead to paradoxical chest wall motion, decreased vital capacity, pulmonary dysfunction, and eventual respiratory failure.
- Sepsis and pneumonia are among the most common causes of mortality.

### Rib Fractures and Flail Chest

Rib fractures are common injuries in trauma patients and are generally caused by blunt chest trauma. Between 1% and 4% of these patients have an anatomic flail segment (see Fracture Characteristics on page 14 for definition), which can lead to a physiologic flail chest with paradoxical chest wall motion.<sup>1-3</sup> Flail chest injuries are associated with high rates of short- and long-term morbidity and mortality.<sup>4</sup> Flail chest may cause chest wall instability affecting the respiratory mechanics, and it is often accompanied by other significant thoracic injuries, such as injury to the lung parenchyma, pulmonary contusion, laceration, and hemorrhage.

The mechanical consequences of chest wall instability can lead to paradoxical chest wall motion, decreased vital capacity, pulmonary dysfunction, and eventual respiratory failure. Patients with rib fractures and flail chest physiology often have significant pain. If not controlled, pain can cause decreased respiratory effort, resulting in atelectasis, cough suppression, and an inability to clear secretions that can lead to respiratory failure.<sup>4-7</sup> A high proportion of patients with flail chest require mechanical ventilation due to poor respiratory mechanics, leading to a prolonged stay in the intensive care unit (ICU) and hospital, increased health care costs, and mortality.<sup>4-9</sup>

Patients with concurrent severe brain injury or pulmonary contusions may require a longer duration of mechanical ventilation and have inferior outcomes.<sup>10</sup> The prolonged mechanical ventilation requirements in these patients are due to concomitant intracranial or lung parenchymal injury, and these patients are more likely to suffer from ventilator-associated complications.<sup>2</sup> Long-term complications

reported for patients with flail chest injuries include chronic pain, dyspnea, abnormal pulmonary function, chest tightness, chest wall deformity, decreased quality-of-life function, and low rates of return to work.<sup>11-17</sup>

### Short-Term Outcomes and Complications

Flail chest injuries are a result of thoracic trauma and can lead to numerous complications in the short and long term. A National Trauma Databank (NTDB) study, including 3,465 adult patients (mean age 52.5 years, 77% male) with flail chest diagnosis over a 3-year period, reported outcomes of patients with flail chest injuries.<sup>2</sup> The mean injury severity score (ISS) was 31, and the mechanism of injury for 79% of patients was motor vehicle crash (MVC). In the cohort, 59% of patients required mechanical ventilation for a mean of 7.1 days. Care in the ICU was required by 82% of patients (mean of 11.7 days), and the mean hospital length of stay (LOS) was 16.6 days. Overall, 21% of patients underwent tracheostomy. Other complications included pneumonia (21%), acute respiratory distress syndrome (14%), sepsis (7%), and mortality (16%). The study also reported that the subgroup of patients with a concomitant severe brain injury (Abbreviated Injury Scale [AIS] head  $\geq 4$ ) had significantly worse outcomes. In patients with severe brain injury, 88% required mechanical ventilation, and the rate of pneumonia and tracheostomy in these patients was nearly double that of patients without a brain injury.<sup>2</sup> Another patient subgroup (54%) had concomitant pulmonary contusion. Compared to patients without pulmonary contusion, this subgroup had slightly worse outcomes, but the difference was not of the magnitude experienced by the severe brain injury subgroup.<sup>2</sup>

A Canadian study reported on 117,204 patients with rib fractures (mean age 60 years, 62% male), over an 11-year period.<sup>1</sup> Injury incidence was single rib fracture (57.9%), multiple rib fractures (40.6%), and flail chest (1.5%). The authors reported on the need for mechanical ventilation, ICU admission, LOS, readmission, pneumonia, and tracheostomy. Patients with multiple rib fractures had significantly worse outcomes compared to those with a single rib fracture. Patients with a flail chest had significantly worse outcomes in all domains compared to those with multiple rib fractures (see Table 1).<sup>1</sup>

**Table 1. Outcomes of Patients with Rib Fracture Injuries**

Outcomes	Flail chest n=1708	Multiple ribs n=47611	Isolated ribs n=67884	p-value
<b>Patient Outcomes</b>				
30-day mortality	9.5%	3.4%	1.3%	<0.001
1-year mortality	14%	9%	6%	<0.001
Readmission within 1 year	41%	30%	20%	<0.001
<b>Complications</b>				
Pneumonia	39%	13%	6%	<0.001
Ventilator-associated pneumonia	7%	1%	0%	<0.001
Chest tube insertion	56%	11%	2%	<0.001
Tracheostomy	12%	1%	0%	<0.001
Deep venous thrombosis	38%	13%	6%	<0.001
Acute renal failure	4%	1%	1%	<0.001
Bleeding requiring transfusion	3%	1%	0%	<0.001
<b>Treatment</b>				
Need for mechanical ventilation	43%	7%	2%	<0.001
Ventilator use for >48 hours	46%	7%	2%	<0.001
ICU admission	65%	14%	4%	<0.001

Adapted with permission from Dehghan N, Mah JM, Schemitsch EH, Nauth A, Vicente M, McKee MD. Operative stabilization of flail chest injuries reduces mortality to that of stable chest wall injuries. *J Orthop Trauma*. 2018;32(1):15–21. doi:10.1097/BOT.0000000000000992. ©Wolters Kluwer.

A 2022 Netherlands study identified 14,850 admitted patients with rib fractures (mean age 62 years, 70% male) between 2015 and 2017.<sup>3</sup> Flail chest was present in 3.9%. The median hospital LOS was 9 days, 63% were admitted to the ICU, and the median ICU LOS was 3 days. Only 48% of patients with a flail chest were discharged home, compared with 67% of those who did not have a flail chest injury. The incidence of rib fractures was 29 per 100,000 person-years, and the incidence of flail chest was 1 per 100,000 person-years.<sup>3</sup>

## Quality of Life and Function

Patients with rib fractures and flail chest are reported to have lower quality-of-life outcomes compared with preinjury.<sup>14–17</sup> Choi et al. conducted a quality-of-life assessment in 139 patients with rib fractures (3% had flail chest injury) at 3 months and at 1 year postinjury.<sup>16,17</sup> At 3 months postinjury, 33% of patients had not returned to work at preinjury level.<sup>16</sup> At 1 year postinjury, patients had excellent emotional well-being and functional engagement but poor physical well-being and recovery. Physical limitations included inability to exercise or perform leisure

activities at preinjury levels. About 40% of patients reported some degree of rib pain, and 29% had not returned to preinjury work status.<sup>17</sup> Heindal et al. studied 279 patients with isolated rib fractures and reported functional and quality-of-life limitations 6–12 months after injury. Of these patients, 56% reported limitations with physical functioning, 51% had limitations with exercise capacity, and 28% had not returned to work.<sup>15</sup> In another study from Australia, Marasco et al. evaluated patients with multiple rib fractures and reported significant reduction in quality of life; only 71% had returned to work at 2 years postinjury.<sup>14</sup>

## Cost

It is difficult to calculate the exact cost associated with rib fractures in patients who often have other injuries, complicating the cost estimate of rib fractures in isolation from other injuries. A National Inpatient Sample database, maintained by the Agency for Healthcare Research and Quality, revealed that between 2007 and 2016, the reported 373,053 rib fracture admissions cost an estimated \$3.64 billion.<sup>18</sup> Over the 10-year period, rib fracture hospitalization

costs increased markedly, from \$209 million per year to more than \$469 million per year in 2016.<sup>18</sup> In addition, the incidence of rib fractures has increased over the past 10 years, with these increases related to more injuries and to improvements in the ability to identify injuries with advancements in radiographic technology.<sup>19</sup>

## Mortality

Patients with flail chest injuries have a reported mortality rate between 10–36%.<sup>1–4</sup> Despite the presence of other injuries, sepsis and pneumonia remain two of the most common causes of death in patients with flail chest.<sup>5</sup> While the overall rate of mortality was 16% in the NTDB study, the mortality rate in the patient subgroup with severe brain injury was nearly four times higher (40%) than in the subgroup without a severe brain injury (11%). Pulmonary contusion did not have an impact on mortality.<sup>2</sup> In the Canadian database study, the mortality rate in patients with flail chest was 9.5% in the first 30 days and 14% in the first year. These mortality rates were significantly higher than in patients with multiple rib fractures (3.4% at 30 days, 9% at 1 year [ $p < 0.0001$ ]).<sup>1</sup> In the Netherlands study, the 30-day mortality rate for patients with flail chest was 11.9%.<sup>3</sup>

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BEST PRACTICES GUIDELINES  
**MANAGEMENT OF  
CHEST WALL INJURIES**



**ANATOMIC AND  
PHYSIOLOGIC  
CONSIDERATIONS**

## THORACIC ANATOMY

### KEY POINT

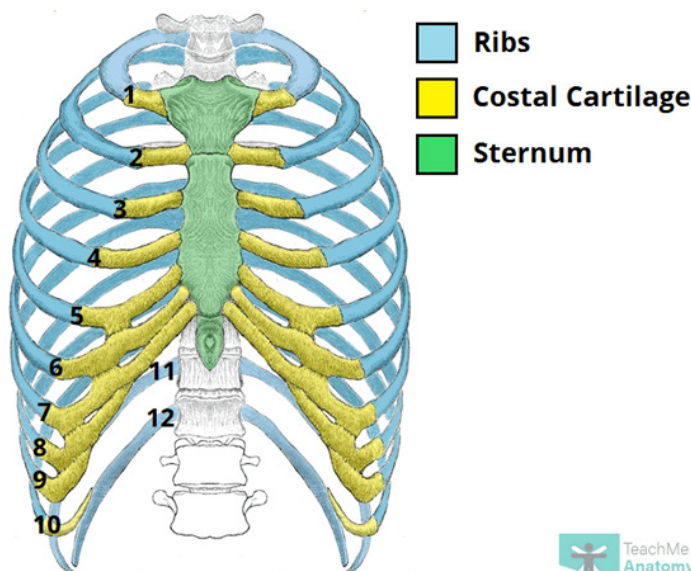
- For safe exposure to perform SSRF and/or administer regional anesthesia, a detailed knowledge of surface landmarks, bone, muscle, and nerve structures of the chest wall is required.

Using surface landmarks, the chest encompasses the area from the sternal notch to the costal margin anteriorly and the area from the base of the neck to the costal margin posteriorly. Intimate knowledge of the bony, muscular, and neurologic structures of the chest wall is required to provide safe exposure for SSRF and regional anesthesia techniques.

### Bones of the Chest Wall

The skeleton of the chest comprises an osteocartilaginous thoracic cage that protects the thoracic organs. It consists of 12 thoracic vertebrae, 12 pairs of ribs and cartilage attachments, and the sternum (manubrium, sternum, and xiphoid).<sup>1</sup> See Figure 1.

**Figure 1. Bones of the Chest Wall**



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### Ribs

The ribs project from the thoracic vertebrae anteriorly and attach to the sternum. The most anterior aspects of the ribs transition from bone to costal cartilage, which contributes to the elasticity of the thoracic wall.<sup>1</sup> The chest wall has three types of ribs.

- Ribs 1 through 7 are true ribs, because they attach to the thoracic vertebra posteriorly and the sternum anteriorly.<sup>1</sup>
- Ribs 8 through 10 are considered false ribs, because they attach to the sternum as a common cartilage rather than having individual sternal attachments.<sup>1</sup>
- Ribs 11 and 12 are free or floating ribs, because the cartilaginous terminus of the ribs results in ligamentous attachments to the abdominal musculature.<sup>1</sup>

### Costal Margin

The costal margin consists of the cartilaginous attachments of ribs 7 through 10 bilaterally. Individuals have significant variability in the attachments and anatomy of the costal margin.<sup>2-4</sup> In a majority of individuals, the 7th rib joins the sternum to form the infrasternal angle. The 8th rib has an independent attachment to the sternum in up to 10% of individuals.<sup>4</sup> The 8th and 9th ribs are often attached to the rib above through an intercondylar joint and have free-floating tips in, respectively, 45% and 60% of cases studied.<sup>4</sup> The 10th rib is a floating rib in 46% to 59% of individuals.<sup>2,3</sup> There may also be intercondylar joints between the ribs before they join the sternum. The incidence of intercondylar joints between ribs 4 and 5 is 0%–3%; between ribs 5 and 6 is 35%–68%; between ribs 6 and 7 is 83%–96%; and between ribs 7 and 8 is 72%–96%.<sup>2,4</sup> These variable attachments of the costal margin may contribute to increased instability of the lower chest wall with rib fractures.

### Sternum

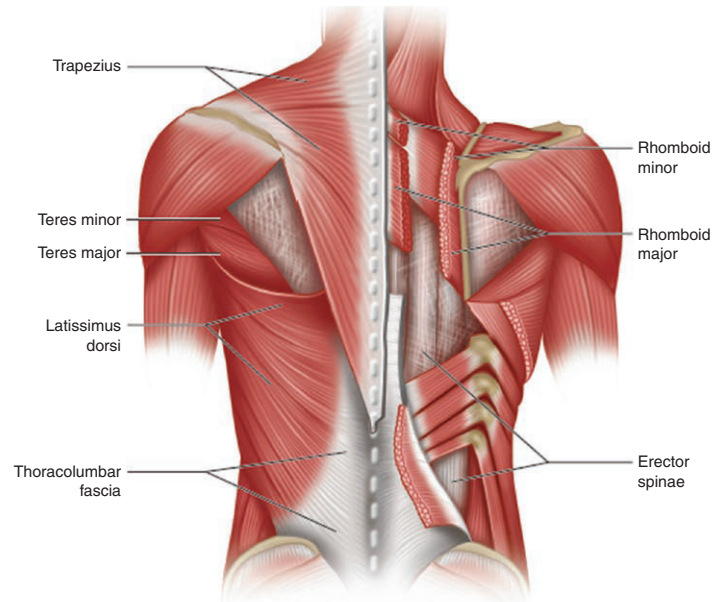
The sternum is composed of three anatomic structures. The *manubrium* is a triangular bone forming the superior aspect of the sternal complex, and it attaches to the clavicles as well as the first rib. Inferiorly, the manubrium attaches to the sternum at the manubriosternal joint.<sup>1</sup> The manubrium and sternum lie in different planes and form the sternal angle.<sup>1</sup> The second rib inserts into the manubriosternal joint, making it a reliable landmark for identifying the location of

the ribs by palpation.<sup>1,2</sup> The *sternal body* is thinner, longer, and narrower than the manubrium. The *xiphoid process* extends from the inferior aspect of the sternum. It is cartilaginous in younger people and becomes ossified in patients over 40 years of age.<sup>1</sup>

## Muscles of the Chest Wall

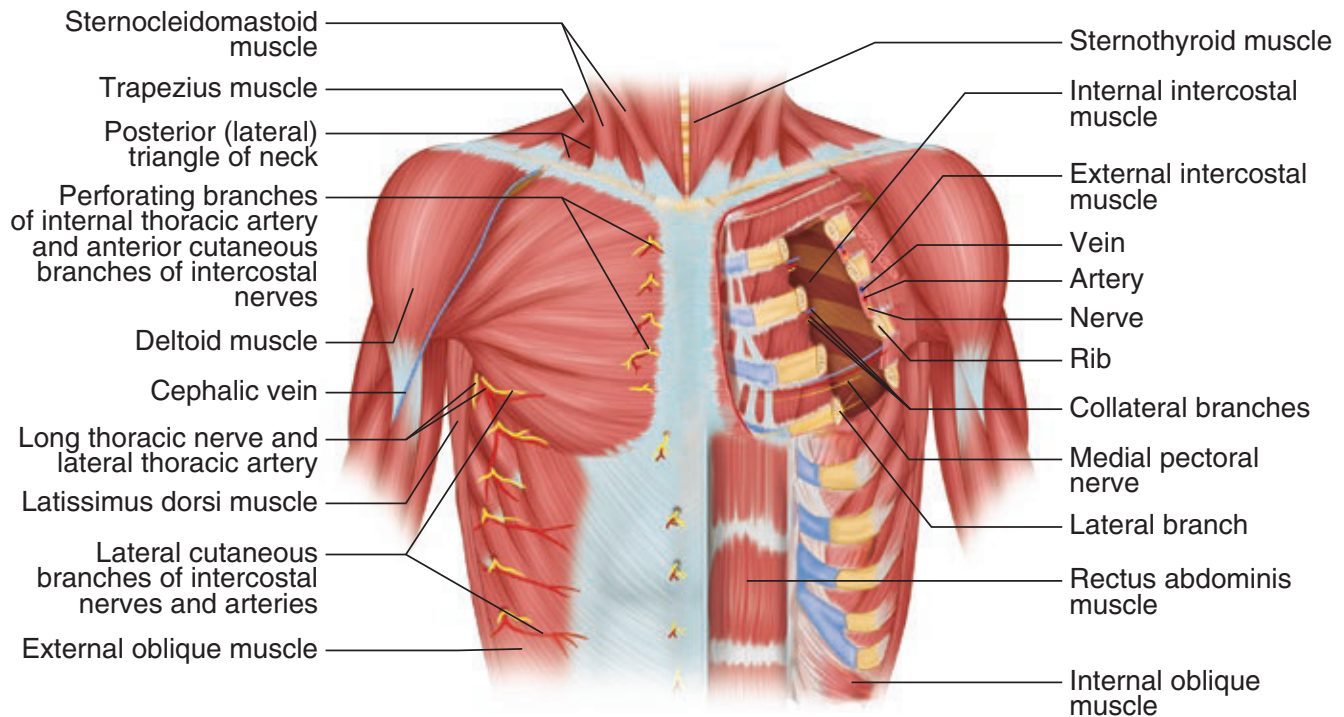
The muscles of the chest wall include the pectoralis major, pectoralis minor, serratus anterior, serratus posterior superior, serratus posterior inferior, trapezius, rhomboid major, rhomboid minor, latissimus dorsi, intercostal muscles, rectus abdominis, external oblique, internal oblique, and transversus abdominis (see Figures 2 and 3). Their proximal and distal attachments, as well as innervation and contribution to respiratory movement, are outlined in Table 2. The intercostal muscles attached between each rib create a wall superficial to the parietal pleura, which helps prevent lung herniation and assists with rib cage elevation during inspiration.

**Figure 3. Muscles of the Posterior Chest Wall**



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**Figure 2. Muscles and Vasculature of the Anterior Chest Wall**



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## Diaphragm

The diaphragm is the primary muscle of respiration. It is attached to the osteocartilaginous thoracic rib cage at the inferior margin, at the L1 vertebral body posteriorly, and at the xiphoid process anteriorly.<sup>1</sup> During inspiration, the diaphragm contracts, pushing the abdominal viscera inferiorly and expanding the volume of the thorax, resulting in negative pressure in the chest to bring air into the alveoli.<sup>1</sup> During inspiration, the diaphragm pushes the costal margin medially and superiorly.<sup>1</sup> This action is counteracted by the serratus posterior inferior muscle and the abdominal musculature.<sup>1</sup> This creates internal tension on the ribs that is important to consider during surgical stabilization of the bony skeleton.

## Vasculature

Anteriorly, the subclavian artery and vein branches give rise to the internal thoracic artery and vein.<sup>1</sup> The internal thoracic artery and vein course deep to the cartilaginous portions of the ribs.<sup>1</sup> The internal thoracic artery and vein give rise to the anterior intercostal artery and vein branches at the level of each rib; to perforating branch arteries and veins that extend through the intercostal musculature into the pectoralis major muscle; and to the musculophrenic artery and vein at the level of the diaphragm.<sup>1</sup> Inferiorly, the internal thoracic artery and vein extend into the abdomen and become the superior epigastric artery and vein.<sup>1</sup>

**Table 2. Muscles of the Chest Wall, Their Attachments, Contribution to Respiratory Movement, and Innervation**

Muscle	Proximal Attachments	Distal Attachments	Respiratory Movement	Innervation
Pectoralis major	Clavicle, sternum	Humerus	Accessory muscle of respiration, elevates ribs	Lateral and medial pectoral nerves
Pectoralis minor	Ribs 3–5 near costal cartilage junction	Coracoid process of scapula	Accessory muscle of respiration, elevates ribs	Medial pectoral nerve
Serratus anterior	Ribs 1–8 anterior	Anterior surface of the medial border of the scapula	Accessory muscle of respiration, elevates ribs	Long thoracic nerve
Serratus posterior superior	Spinous process C7–T3	Superior border of ribs 2–4	Elevates ribs	Intercostal nerves
Serratus posterior inferior	Spinous process T11–L2	Inferior border of ribs 9–12	Depresses inferior ribs	Intercostal nerves
Trapezius	Occiput, spinous process C1–T12	Lateral third of the clavicle, acromion, spine of the scapula	None	Spinal accessory nerve
Rhomboid major	Spinous process T2–T5	Medial border of scapula	None	Dorsal scapular nerve (C4–C5)
Rhomboid minor	Spinous process C7–T1	Medial border of the scapula	None	Dorsal scapular nerve (C4–C5)
Latissimus dorsi	Spinous process T7–L5, iliac crest	Humerus	None	Thoracodorsal nerve
Intercostal muscles (external, internal, innermost)	Inferior border of the rib above	Superior border of the rib below	External intercostal muscles elevate the ribs for inspiration. Internal intercostal muscles depress the ribs for expiration.	Intercostal nerves
Rectus abdominus	Pubic symphysis, pubic crest	Xiphoid process, costal cartilages 5–7	Flexes trunk, compresses viscera	Intercostal nerves T5–T11, subcostal nerve
External oblique	External surface of ribs 5–12	Linea alba, pubic tubercle, anterior half of iliac crest	Depresses ribs, compresses viscera, rotates thorax	Intercostal nerves T5–T11, subcostal nerve
Internal oblique	Thoracolumbar fascia, iliac crest, inguinal ligament	Inferior border of ribs 10–12, costal margin of linea alba, conjoined tendon	Depresses ribs, compresses viscera	Intercostal nerves T5–T11, subcostal nerve, L1
Transversus abdominus	Internal surface of costal cartilages 7–12, thoracolumbar fascia, iliac crest, inguinal ligament	Linea alba, iliac crest, conjoined tendon	Depresses ribs, compresses viscera	Intercostal nerves T5–T11, subcostal nerve, L1

Abbreviations: C, cervical; L, lumbar; T, thoracic.

Contributed by Evert A. Eriksson, MD, FACS, FCCP, FCCM. Medical University of South Carolina.

Posteriorly, the aorta gives rise to the posterior intercostal artery at the level of each rib bilaterally.<sup>1</sup> The venous drainage of the intercostal veins posteriorly enters the azygous vein on the right side and the hemiazygos vein on the left side.<sup>1</sup> The intercostal arteries and veins, as well as the intercostal nerves, run along the ribs at the inferior aspect of the rib in a costal groove.<sup>1</sup>

## Nerves

Twelve pairs of thoracic spinal nerves extend from the spine out along each rib within the costal groove.<sup>1</sup> These nerves exit the spine and interact with the sympathetic trunk and sympathetic ganglions, which are located near the head of the ribs.<sup>1</sup> The nerves then extend laterally within the costal groove between the internal intercostal muscle and the innermost intercostal muscle.<sup>1</sup> From the intercostal groove, the nerves proceed anteriorly, innervating the intercostal muscles.<sup>1</sup> The intercostal nerves of ribs 7–12 also innervate the following muscles: intercostal, external oblique, internal oblique, transversus abdominis, and rectus abdominis of the abdominal wall, as well as the diaphragm.<sup>5,6</sup> Additionally, they give rise to the lateral cutaneous and anterior cutaneous branches to provide innervation of the skin.<sup>1</sup>

Other important nerves in the thoracic area include the long thoracic nerve anteriorly and the thoracodorsal nerve posteriorly. Injury to these nerves is possible from trauma, or they might be injured during surgical fixation of the chest wall. The long thoracic nerve is a motor nerve that innervates and runs along the outer surface of the serratus anterior muscle. Injury to this nerve can cause scapular winging. The thoracodorsal nerve is a motor nerve that provides innervation to the latissimus dorsi muscle and is located at that muscle's lower border.

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## FRACTURE CHARACTERISTICS

### KEY POINTS

- Flail chest results from multiple rib fractures at multiple levels and causes paradoxical chest wall motion, leading to pulmonary dysfunction.
- Pneumonia is the most common cause of morbidity and mortality with rib fractures.

### Rib Fracture Characteristics and Locations

When evaluating fractures of the 27 bones of the thoracic rib cage, carefully consider the location and characteristics of the fractures. The type of fracture, degree of displacement (if present), and location of the injury will guide patient management and reconstruction options. Rib fractures can be characterized as simple, wedge, complex, and displaced (see Figures 4 and 5).

### Multiple Rib Fractures

When a rib has multiple fractures, the result is a floating rib segment. When multiple fractures occur on multiple rib levels, physiologic changes in the respiratory effort may result in paradoxical chest wall motion (on inspiration, the chest wall falls into the hemithorax rather than increasing excursion and volume). This is referred to as a *flail chest*. Flail chest can exist in two different anatomic regions:<sup>1</sup>

- A lateral flail chest, where three or more ribs are fractured in two or more locations in the lateral chest wall.
- An anterior flail chest, where three or more ribs are fractured bilaterally with the sternum between the fracture lines.

These two types of flail chest can result in paradoxical chest wall motion of the lateral chest wall or anterior chest wall, respectively.

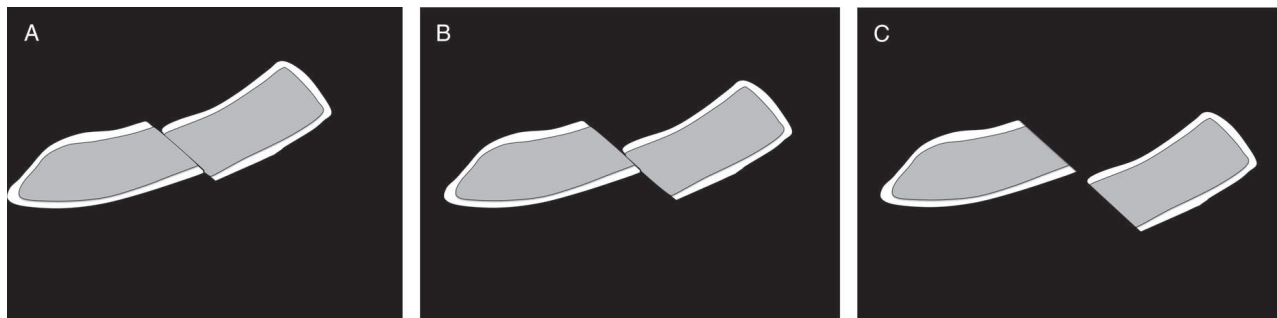
**Figure 4. Nondisplaced Rib Fracture Types**



Key: (A) simple; (B) wedge; (C) complex.

Borrowed with permission from Edwards JG, Clarke P, Pieracci FM, et al. Taxonomy of multiple rib fractures: Results of the Chest Wall Injury Society international consensus survey. *J Trauma Acute Care Surg.* 2020;88(2):e40–e45. doi:10.1097/TA.0000000000002282. ©Wolters Kluwer.

**Figure 5. Displaced Rib Fractures**



Key: The degree of displacement also factors into patient management. These fractures can be characterized as (A) a nondisplaced rib fracture with greater than 90% cortical contact; (B) an offset fracture with cortical contact but less than 90%; or (C) a displaced rib fracture with no cortical contact.

Borrowed with permission from Edwards JG, Clarke P, Pieracci FM, et al. Taxonomy of multiple rib fractures: Results of the Chest Wall Injury Society international consensus survey. *J Trauma Acute Care Surg.* 2020;88(2):e40–e45. doi:10.1097/TA.0000000000002282. ©Wolters Kluwer.

Clinical flail chest is defined as paradoxical movement of the chest wall during respiration. This differs from radiographic flail chest, which is defined as three or more ribs broken in two or more places as visualized on an imaging study. It is possible to have radiographic flail chest without clinical flail chest, but the opposite does not occur.

It is important to consider the anatomic location of the rib fractures when managing patients. Authors have proposed differing anatomic regions to guide fracture management. Edwards et al. described the following anatomic regions for fractures of the chest: anterior, lateral, posterior, and costal cartilage.<sup>1</sup> No consensus exists with respect to paraspinous fractures.<sup>1</sup> Other authors have divided the chest wall into the following five regions: anterior (corresponding to the costal cartilage), anterior lateral, lateral, posterior lateral, and posterior.<sup>2</sup> Consensus on the anatomic locations of fractures has been challenging, as the lower ribs (8–12) do not exist in all anatomic regional groupings.

Multiple rib fractures may progressively displace over time. Bauman et al. reported that fractures of ribs 1–10 will show progressive displacement on repeat computed tomography (CT) imaging after 6 days.<sup>3</sup> Head et al. demonstrated that some rib fractures are more likely to become progressively displaced, including the following: ribs 4 through 6; multiple fractures per rib; and rib fractures in the lateral, posterior lateral, and lateral locations.<sup>2</sup>

## Pathophysiologic Considerations

The most common cause of morbidity and mortality after rib fractures is pneumonia that results when pain precludes appropriate pulmonary hygiene. With rib fractures, the sensation of movement and periosteal nerve stimulation frequently results in significant pain for the patient. In turn, patients avoid the deep breathing and coughing needed to adequately move secretions. This decrease in breathing depth leads to atelectasis and eventual alveolar collapse, and it can progress to a ventilation/perfusion mismatch and pneumonia. Severe rib fractures can also impede normal chest wall movement. The most classic example is flail chest with paradoxical wall motion.<sup>4</sup>

A combination of pain, which limits deep breathing, and poor chest wall excursion due to volume loss or instability of the chest wall will progress to respiratory failure. Even in what might appear to be a minor injury, progressive lung volume loss and poor ventilatory capacity are common over the initial 72 hours after injury. This condition worsens with inadequate pain management and pulmonary hygiene.

Complications after 72 hours are strong contributors to the overall morbidity and mortality of patients with rib fractures. Progression of poor respiratory function results in retained secretions and pneumonia if not corrected, which is the most common cause of death in patients with isolated chest wall injury. This is particularly true in patients older than 65 years.<sup>5</sup>

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BEST PRACTICES GUIDELINES  
**MANAGEMENT OF  
CHEST WALL INJURIES**

**ASSESSMENT OF  
PATIENTS WITH CHEST  
WALL INJURIES**



## INITIAL ASSESSMENT CONSIDERATIONS

### KEY POINTS

- Have a high index of suspicion for chest wall injury in patients injured in a MVC, in a fall, as a pedestrian struck by a vehicle, or by other traumatic mechanism.
- Upper extremity, intrathoracic, and traumatic brain injuries (TBIs) have the highest correlation with the number of rib fractures.

### Mechanism of Injury

Assessment of trauma patients for potential chest wall injury begins with a high index of suspicion. Of patients who sustain trauma, 10%–40% have some degree of chest wall injury.<sup>1</sup> The mechanism of injury often includes MVCs, falls, pedestrians struck by vehicles, or after any traumatic mechanism.<sup>2</sup> MVCs are linked to worse outcomes after chest wall injury.<sup>3</sup> Clinical flail chest is also an independent risk factor for adverse outcomes, even when compared to multiple fractures without flail.<sup>3</sup>

### Comorbid Conditions

Comorbid conditions can increase the risk of associated morbidity and mortality after chest wall injury. The presence of cardiopulmonary disease (history of significant cardiac or pulmonary diagnosis or operation) has a mortality odds ratio of 2.86.<sup>4</sup> In a study of patients with chest wall injury and concomitant cardiopulmonary comorbidity, those with an ISS  $\geq 16$ , a fluid and electrolyte disorder, or new-onset paralysis (odds ratio 2.37,  $p < 0.001$ ) were particularly vulnerable to having an adverse event.<sup>3</sup> This study defined an adverse event as a composite outcome of death, pneumonia, need for tracheostomy tube, or discharge to a short-term acute care facility.

## Associated Extrathoracic Injuries

Chest wall injury is strongly associated with increasing overall injury severity, as it commonly accompanies severe extrathoracic injuries. In a retrospective cohort study of 564,798 traumatic rib fracture patients in the NTDB, 44.9% had evidence of polytrauma, defined as an ISS of  $\geq 16$ .<sup>5</sup> The frequency of injuries remote from the chest wall correlates with the number of rib fractures. The strongest correlations with the number of rib fractures were the following other injury types: upper extremity, intrathoracic, and brain injuries.<sup>6</sup> TBI was significantly associated with an increased number of rib fractures.<sup>7,8</sup> First rib fractures, in particular, were associated with an increased rate of serious TBI (head AIS  $\geq 3$ ) (28.9% vs. 12.5%,  $p < 0.001$ ), cervical spine injuries (6.6% vs. 1.5%), and thoracic spine injuries (6.7% vs. 2.9%) when compared with other rib fractures.<sup>9</sup> First rib fracture was also associated with significant cardiac injuries (1.6% vs. 0.5%) and intrathoracic vascular injuries (2.3% vs. 0.8%,  $p < 0.001$ ).<sup>9</sup>

### Older Adult Considerations

Geriatric trauma patients are at significantly increased risk for a higher number of rib fractures (65% vs. 56% in adults under 65), and mortality is doubled.<sup>14</sup> Patients over 65 years with chest wall trauma have a higher mean number of ventilator days (4.3 vs. 3.1), ICU LOS (6.1 vs. 4.0 days), hospital LOS (15.4 vs. 10.7 days), and incidence of pneumonia (31% vs. 17%).<sup>1–3</sup> Mortality rates increase as the number of rib fractures increase, with a mortality odds ratio of 1.19 for each additional rib.<sup>10</sup> In the already at-risk older adult population, comorbid heart failure or diabetes increases the mortality risk.<sup>11</sup> The presence of more than nine comorbidities and medications in patients with chest wall injury leads to nearly five times higher risk of mortality.<sup>6</sup>

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## INITIAL ASSESSMENT

### KEY POINTS

- Obtain an initial chest radiograph to rule out life-threatening injuries, following the recommendations of Advanced Trauma Life Support® (ATLS®).<sup>1</sup> Use standard cross-sectional imaging for thoracic evaluation, as chest radiographs do not have enough sensitivity to appropriately diagnose most injuries.
- Assess patients with chest wall and thoracic injuries by physical examination, radiographic evaluation, and physiologic monitoring to determine the severity of injury and risk for decompensation.
- Consider using one of the triage and assessment scoring systems to assist in the evaluation of patients.
- Develop trauma-center-specific protocols that account for individual resource management and optimization of patient outcomes.

### Physical Exam

**Inspection.** Features of chest wall injury are often notable on physical examination. During inspection, assess for ecchymosis, laceration, obvious deformity, symmetrical motion of the chest, and extremes in respiratory rate and effort. Impaired respiratory effort (increased or diminished) can lead to acid-base derangements, poor secretion clearance, and respiratory failure.<sup>2,3</sup> Assess the respiratory mechanics by examining for use of accessory muscles or areas of paradoxical inward movement of the chest wall during inspiration. Paradoxical motion is a sign of clinical flail chest, which limits chest expansion and vital capacity.<sup>4,5</sup>

**Palpation and Auscultation.** A best practice is to perform palpation and auscultation during the physical exam. Palpation of the chest wall and upper abdominal wall can identify areas of tenderness and deformities in the chest wall architecture that reduce intrathoracic volume and limit respiratory effort.<sup>4,6</sup> Palpation can also identify subcutaneous emphysema or crepitus, likely indicating an underlying pneumothorax. Auscultation is sensitive and specific for chest wall injury after blunt chest wall trauma. Assess for both the presence and symmetry of breath sounds. Auscultation has greater positive and negative predictive value than tachypnea or pain/tenderness.<sup>6</sup>

### Laboratory Testing

Arterial blood gas studies to determine the arterial oxygen saturation and carbon dioxide levels may be useful in assessing ongoing or impending respiratory failure.

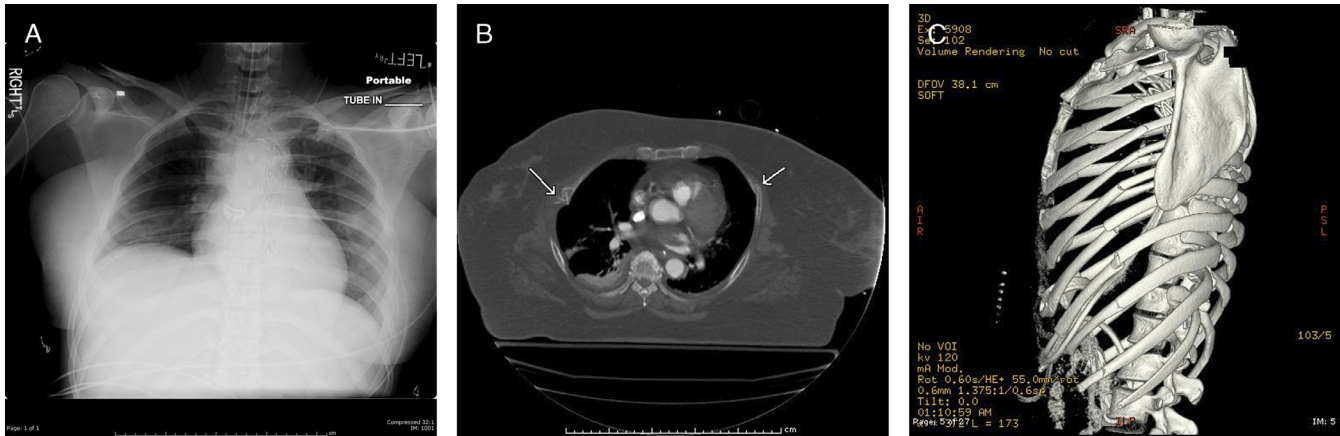
### Imaging

Judicious use of imaging modalities is key to early identification of chest wall trauma and associated injuries. A chest radiograph is a routine adjunct of the primary survey, following the recommendations of ATLS®.<sup>1,3,7</sup> It screens for potential life-threatening injuries such as hemo-/pneumothoraces (with or without tension physiology), pulmonary contusions, and thoracic aorta injuries.<sup>4,8</sup> However, a chest radiograph has a low sensitivity for detecting rib fractures (61.3%) and aerodigestive or mediastinal injuries.<sup>3,4,9</sup> Use cross-sectional imaging (e.g., CT scan) for thoracic evaluation, because plain radiographs do not have enough sensitivity to appropriately diagnose most injuries.

CT scanning is the modality of choice in evaluating for evidence of thoracic injury in blunt trauma patients. An estimated 81% to 93% of rib fractures are only visible on CT scan, and CT scans can simultaneously identify other concomitant injuries.<sup>4</sup> In one study, clinical management was altered in 34.5% of patients due to additional findings on a chest CT, following a chest radiograph.<sup>3</sup> Compared with chest radiographs, CT scans can also better delineate the severity of injury, such as with occult pneumothoraces, which are present in up to 22% of blunt trauma patients.<sup>3</sup> Studies have found that more than 50% of trauma patients with flail chest injuries have associated pulmonary contusion.<sup>3</sup>

CT scans are vital for taxonomic and periprocedural planning purposes. Curved planar and multiplanar reformats of chest CT scans show some benefit with regard to sensitivity, but their use is variable.<sup>10</sup> Whereas 2D axial images are very useful for diagnosis of rib fractures and for measuring degree of displacement, 3D reformatted images may be useful for operative planning (see Figure 6).<sup>11</sup>

Radiographic findings are a part of most chest wall injury scoring systems (see Table 3), and they are a feature of most taxonomic criteria.

**Figure 6.** Representative Images from a Patient Chest Radiograph and CT

Key: (A) chest radiograph; (B) single slice from an axial chest CT; (C) 3D reformat of CT rotated axially.

Borrowed with permission from Pulley BR, Taylor BC, Fowler TT, Dominguez N, Trinh TQ. Utility of three-dimensional computed tomography for the surgical management of rib fractures. *J Trauma Acute Care Surg.* 2015;78(3):530-534. ©Wolters Kluwer.

## Physiologic Considerations

**Incentive Spirometry.** An incentive spirometer is frequently recommended for patients with rib fractures to enhance lung expansion and to potentially lower the risk of pulmonary complications. Incentive spirometry plays a role in risk assessment by incorporating its parameters into scoring systems such as SCARF and RIG (Table 3).<sup>16,17</sup> Incentive spirometry volumes under 1 liter are associated with increased odds of acute respiratory failure.<sup>19</sup> A small randomized controlled trial indicated that patients who used incentive spirometry every hour for at least 8 hours daily had improved pulmonary function tests (PFTs).<sup>20</sup>

**Pulmonary Function Tests.** Various PFTs were evaluated as predictors of respiratory complications. Forced vital capacity (FVC) below 1 liter correlates with a higher risk for hospital readmission and adverse outcomes.<sup>21,22</sup> The percentage of predicted forced expiratory volume (%FEV) may offer a better prediction by factoring in age, height, and ethnicity.<sup>23,24</sup> While PFTs are vital for risk stratification, more research is necessary to help clinicians apply these measurements to patients with chest wall injuries.

**Oxygen Saturation.** SaO<sub>2</sub> is crucial in risk assessment; however, a low SaO<sub>2</sub> can be a late indicator of hypercapnic respiratory failure. Selective use of a high-flow nasal cannula may decrease ICU utilization; however, limited evidence exists to support this practice.<sup>25</sup>

**Pain Assessment.** Pain scores are subjective but are considered a useful tool for measuring the effectiveness of a treatment.<sup>26</sup> The value of pain scores in predicting outcomes remains questionable. Nevertheless, several scoring systems integrate pain scores, including the SCARF and RIG scores (Table 3).<sup>15,16</sup> It is *not* recommended to use a pain score as the sole factor in determining disposition or management decisions.

## Older Adult Considerations

**Functional Capacity/Mobility.** Frailty is recognized as one of the most important predictors of clinical outcomes in trauma patients, especially for older adults.<sup>27-29</sup> Its role in the outcomes of older adult patients with rib fractures, however, remains under investigation. Although studies have failed to show correlation of frailty with clinical outcomes, it appears to consistently predict unfavorable disposition to a long-term setting.<sup>30-32</sup>

Among older adult patients on the day of admission, the %FEV in 1 second was the strongest predictor of discharge to home; when %FEV in 1 second was greater than 60% of predicted, it was associated with a hospital LOS of fewer than 5 days.<sup>33</sup>

**Table 3. Selected Scoring Systems for Assessment of Patients with Rib Fractures**

Scoring System	Factors
Thoracic trauma severity score <sup>12</sup>	Age PaO <sub>2</sub> /FiO <sub>2</sub> Pulmonary contusion Pleural involvement Number and laterality of rib fractures
Chest trauma score <sup>13</sup>	Age Pulmonary contusions Number of rib fractures Bilateral rib fractures
STUdy of the Management of BLunt chest wall trauma (STUMBL) Score <sup>14</sup> (also known as <i>Battle Score</i> )	Age Number of rib fractures Chronic lung disease Preinjury anticoagulant use Oxygen saturation (SaO <sub>2</sub> ) level
RibScore <sup>15</sup>	≥6 fractures Bilateral fractures Flail chest ≥3 severely (bicortical) displaced fractures First rib fracture ≥1 fracture in all three anatomic areas (anterior, lateral, and posterior)
Sequential Clinical Assessment of Respiratory Function (SCARF) Score <sup>16</sup>	Incentive spirometry <50% of predicted Respiratory rate >20 breaths/min Numeric pain score ≥5 Cough inadequate to clear respiratory secretions
Rib Injury Guidelines (RIG) <sup>17</sup>	Age ≥60 years Incentive spirometry <750 mL Severe pulmonary contusions on CT Rib fractures ≥5 Chronic obstructive pulmonary disease (COPD), asthma, or current smoker status Hemo-/pneumothorax or presence of chest tube Pain score ≥6 Weak or absent cough
Pain, Inspiratory Effort, Cough (PIC) Score <sup>18</sup>	Pain—severe, moderate, controlled Inspiration—Unable to perform incentive spirometry, below alert volume, goal to alert volume, above goal volume Cough—absent, weak, strong

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## PATIENT DISPOSITION

### KEY POINTS

- Use clinical tools and scoring systems to aid disposition decisions, because symptoms and radiographic findings in isolation are poor predictors of both early and delayed patient outcomes.
- Continuous evaluation of trauma-center-specific disposition pathways is considered a best practice for trauma centers to minimize readmissions and complications.
- A best practice is for each trauma center to develop a protocol to aid in the diagnosis and evaluation of patients with chest injury.

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### Admission versus Discharge from the Emergency Department

The decision to admit patients with rib fractures, in the absence of other indications for hospitalization, hinges on predicting the risks of pulmonary complications and mortality. Consider age and the number of rib fractures as primary factors for this decision. Other significant factors include fracture location(s), PFTs, and frailty assessments for geriatric patients. The multiple scoring systems available (see Table 3 on page 21), in conjunction with clinical judgment, can inform medical decision-making regarding disposition, as well as escalation or de-escalation of care. Although the threshold value predicting complications is unique to each score, no head-to-head studies exist that can be used to choose one scoring system over another.

Evaluation of FVC is increasingly important in determining need for hospital admission, with data suggesting that patients with FVC above 45% can be safely discharged.<sup>1,2</sup> Continuous evaluation of facility-specific disposition pathways is considered a best practice for trauma centers to minimize readmissions and complications. Counsel patients discharged from the emergency department (ED) that their pain and respiratory function may worsen in the first 2–3 days. Educate patients about recovery expectations, provide clear instructions about how to perform pulmonary hygiene, and discuss follow-up care to help reduce unnecessary ED visits. See Monitoring Pain Medication Requirements (page 58) for pain management and patient education guidance.

### ICU Admission versus Ward Admission

The decision to admit patients with rib fractures to the ICU is based on their risk of developing respiratory failure. Various scoring systems can help identify high-risk patients. Guidelines adopted by trauma centers aim to streamline ICU admission criteria, often resulting in better resource utilization without compromising clinical outcomes. One such guideline suggests admitting patients with at least two of the following factors: age over 65 years, four or more rib fractures, significant pulmonary comorbidities (e.g., COPD or congestive heart failure), incentive spirometry values below 50% of predicted, and assessment of “poor pain control.”<sup>3</sup> This approach led to decreased ICU admissions and pulmonary complications without affecting mortality.<sup>3</sup> Scoring systems also exist to assist in decisions for admission to the ward versus the ICU (see Table 3 on page 21). As previously noted, no head-to-head studies exist to help choose one scoring system over another.

While some advocate the routine admission of geriatric patients with three or more rib fractures to the ICU due to their high morbidity risk,<sup>4</sup> this may lead to overutilization of ICU resources. A more selective approach incorporating pre-established trauma-center-specific guidelines for management of pain, pulmonary hygiene, mobility, and clinical judgment may improve resource allocation without adversely affecting outcomes. Geriatric patients with no comorbidities, well-controlled pain, and good pulmonary function might be able to avoid ICU admission but would require very close observation for any signs of clinical deterioration.

### Patient Transfer

There must be a low threshold to transfer patients with rib fractures who are at high risk for morbidity and mortality to a trauma center that has the resources and expertise to manage these injuries and to potentially offer surgical or other specialized interventions. Although the available scoring systems were not developed to support transfer decisions, they are readily available and, in conjunction with the accepting facility, may assist in determining the need for transfer to a specialized facility.

## Importance of a Practice Management Guideline

No universally accepted guideline exists for determining the management of patients with rib fractures. Development of a standardized guideline is particularly challenging for the following reasons:<sup>5</sup>

- The common association of rib fractures with other injuries
- The impact of the patient's underlying comorbid conditions on the risk of morbidity and mortality
- The progressive nature and delayed onset of complications

It is best practice for each trauma center to develop its own evidence-based protocol to aid in the diagnosis and evaluation of patients with chest wall and pulmonary injuries. Standardizing these evaluations can help to stratify patients with rib fractures based on their risk of morbidity and mortality. A multidisciplinary, trauma-center-specific practice management guideline is recommended to guide these decisions. Given the multitude of factors that may have to be considered for these decisions, each trauma center needs to account for its own resources and available skills.

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BEST PRACTICES GUIDELINES  
**MANAGEMENT OF  
CHEST WALL INJURIES**



# **INITIAL PATIENT MANAGEMENT FOR CHEST WALL INJURIES AND RIB FRACTURES**



## MULTIMODAL PAIN MANAGEMENT

### KEY POINTS

- Multimodal pain management is essential for the patient with chest wall injuries. Consider an acute pain service consultation when available.
- Regional anesthesia improves respiratory function and pain control and decreases prescribed oral morphine milligram equivalents (MME).
- The choice of epidural analgesia and paravertebral blocks (PVBs) needs to be individualized based on patient-specific factors such as age, anticoagulation status, and the presence of spinal column/cord injuries or positioning limitations.
- Reassess the efficacy of the multimodal therapy multiple times per day and adjust the regimen as needed.

### Systemic Analgesia

Opioid-sparing, multimodal pain control is essential for effective pain management in the trauma patient. Important clinical considerations when administering systemic analgesia are discussed. Early consultation by an acute pain service, when available, may help improve patient outcomes.<sup>1</sup> The effects of multimodal therapy need to be reassessed by the trauma team multiple times per day to optimize pain control and delineate the effectiveness of the current regimen. Assessments are suggested at least three times per day. Refer to Table 4 for a summary of commonly used multimodal pain medications.

#### Acetaminophen

Acetaminophen is a nonopioid, nonsalicylate analgesic and antipyretic used in conjunction with opioid therapy. It can be administered orally, rectally, and intravenously (IV). In patients with rib fractures, there may be no significant differences in efficacy of oral versus IV acetaminophen with regard to pain scores, LOS, and daily opioid need.<sup>2</sup> It is recommended that patients who can tolerate oral medications receive enteral acetaminophen. *Do not exceed a dosage of 4 g in 24 hours.*<sup>3</sup> *Use with caution in patients who have end-stage liver disease or altered hepatic function.*

## Nonsteroidal Anti-Inflammatory Adjuncts

### Nonselective Nonsteroidal Anti-Inflammatory Drugs (NSAIDs).

Ibuprofen is an NSAID commonly used in conjunction with opioid therapy. It can be administered orally with varied dosing, often three to four times daily for the best effect. Some historical concerns about bone healing in patients with musculoskeletal trauma receiving these medications were addressed with recent consensus guidelines between trauma and orthopaedics societies, reflecting that such concerns are outweighed by the beneficial effect on pain relief.<sup>4-6</sup>

**Selective NSAIDs, COX-1 and COX-2 Inhibitors.** COX-2 inhibitors are more commonly used in this setting, and they act by antagonizing the COX enzyme that produces prostaglandins. These agents are very effective selective NSAIDs with little to no impact on platelet function. They are associated with a lower risk of gastrointestinal (GI) hemorrhage as compared with nonselective NSAIDs such as ibuprofen; however, they do carry a higher risk of GI hemorrhage in high-risk groups. *Use with caution in patients with impaired renal function and patients with history of peptic ulcers and past upper GI bleeding.*

**Ketorolac.** Ketorolac is a nonnarcotic COX-1 NSAID. Its use in patients with chest wall injury is reported to be associated with a decreased risk of pneumonia, without an increased risk of acute kidney injury, fracture nonunion, or GI bleed.<sup>7</sup> It is associated with mild platelet dysfunction. *Ketorolac can be administered orally (not to exceed 40 mg/day) and IV (not to exceed 120 mg/day).*<sup>8</sup> *Use with caution in patients with impaired renal function.*

### Opioids

Opioids are essential, especially in the early management of chest wall injury, but use them judiciously. Opioids act by binding to the opioid receptors in both the central and peripheral nervous systems. *While very effective in pain management, special considerations include risks for cough suppression and respiratory depression, tolerance and dependence with chronic or prolonged use, and use in patients currently prescribed buprenorphine.*

**Table 4. Commonly Used Multimodal Pain Medications, Routes, and Considerations**

Class	Examples	Dosing	Route	Side Effects/Other Considerations
Opioids	Codeine Fentanyl Hydromorphone Methadone Morphine Oxycodone Tramadol	Varies from mcg (fentanyl) to mg	PO, IV, SC, Transcutaneous	Respiratory depression Morphine contraindicated in patients with renal failure
Acetaminophen		mg	PO, PR, IV	Acetaminophen: caution using in patients with end-stage liver disease, altered hepatic function. Do not exceed 4g/24 hours
NSAIDs - nonselective	Ibuprofen Ketorolac	mg	PO, IV, IM (ketorolac)	Ibuprofen/Ketorolac: caution using in patients with impaired renal function
NSAIDs - selective	COX-1 and COX-2 inhibitors	mg	PO	Caution using in patients with impaired renal function and patients with history of marginal ulcers/risk of GI bleed
NMDA Antagonists	Ketamine	mg	PO, IV, IM, intra-nasal	At high doses it acts more as sedative than an analgesic agent
Alpha-2 adrenoreceptor agonist	Dexmedetomidine	mg	IV	May cause bradycardia in moderate-high doses
Anesthetic infusion and topicals	Lidocaine	mg	IV, SC, Transcutaneous	Lipid emulsion 20% should be readily available in case of lidocaine toxicity Potential risk of arrhythmias
Muscle relaxants	Methocarbamol Baclofen Diazepam	mg	PO, IV, IM	Methocarbamol: caution in patients with renal impairment. Share anti-cholinergic properties and should be used with caution in patients at risk for fall, geriatric patients Diazepam: caution in geriatric patients, patients at risk for delirium

Abbreviations: IM, intramuscular; IV, intravenous; PO, per os (by mouth); PR, per rectum; SC, subcutaneous.

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It is important to understand oral morphine MME when calculating for differences in opioid drug type and strength. MME is the potency of an opioid dose relative to morphine. When evaluating and prescribing opioids, consider using MME to assure dose equivalency as the patient is transitioned from one opioid form to another. Commonly prescribed opioids include morphine, hydromorphone, hydrocodone, oxycodone, and fentanyl in parenteral, enteral, and subcutaneous modes.

## Systemic Analgesia Adjuncts

**Ketamine.** Ketamine is a dissociative anesthetic and N-methyl-D-aspartate (NMDA) receptor antagonist. At high doses it acts more as a sedative than an analgesic agent. While it can be administered by oral, IV, intramuscular (IM), intranasal, and rectal routes, it is most commonly administered IV and IM in the acute setting.

*Ketamine bolus doses are not to exceed 0.35 mg/kg, and infusions for acute pain generally do not exceed 1 mg/kg/hour in settings without intensive monitoring.*<sup>9</sup> Ketamine is generally used as an adjunct to opioid and NSAID therapy. Though data are limited on its efficacy in isolation, it has not been found to be significantly associated with a reduction in daily oral MMEs or pain scores in patients <65 years old with three or more rib fractures.<sup>10</sup>

**Dexmedetomidine.** Dexmedetomidine is an alpha-2 adrenoreceptor agonist and a short-term sedative that has been associated with reduction in anesthetic and opioid requirements. It also has the added benefit of minimal respiratory depression compared with opioids. *Caution: Dexmedetomidine may cause cardiovascular depression, most notably bradycardia.*

## Anesthetic Infusions and Topicals

**Intravenous Lidocaine.** IV lidocaine can be effective for short-acting therapy.<sup>11</sup> *Do not exceed the recommended initial dose of 1.5 mg/kg, calculated by using the patient's ideal body weight. Infuse over 10 minutes.*<sup>17</sup> This one-time dose can be followed by another infusion not to exceed a maximum dose of 1.5 mg/kg/hour for no longer than 24 hours. Recent studies demonstrated a decrease in total MMEs and pain scores, as well as increased satisfaction, for patients receiving lidocaine when compared with traditional pain management therapy.<sup>12,13</sup>

**Caution:** IV lidocaine may cause dysrhythmia or seizures. Be alert for early signs of lidocaine toxicity, such as agitation, confusion, dizziness, drowsiness, slurred speech, perioral numbness, and metallic taste. Lipid emulsion 20% must be readily available for treatment.<sup>14</sup>

The total daily dose of IV lidocaine must take into account any additional amine class analgesic being administered, as may be the case with regional catheters.

Anesthetics can be delivered as single bolus or, preferably, by continuous infusion through a catheter with the help of pumps.

**Transcutaneous Patches and Creams.** Lidocaine (up to 5% concentration), administered by patches and creams, is often used with mixed results in terms of efficacy. Several studies demonstrated no difference in IV opioid usage, pulmonary complications, or LOS.<sup>15,16</sup> A decrease in opioid MME was reported.<sup>16</sup> Opioids (namely fentanyl) can also be prescribed as a patch.

## Muscle Relaxants

Methocarbamol is a centrally acting skeletal muscle relaxant typically prescribed for muscle spasms. Diazepam, a long-acting benzodiazepine, is also typically prescribed to treat muscle spasms. Both methocarbamol and diazepam are available in oral and IV forms. Their use may reduce LOS, as well as opioid MME duration and dosage.<sup>17</sup> Both drugs are associated with sedation, and diazepam is associated with delirium in older adults. *Use with caution in older adults and patients with renal impairment or who are at risk for falling.*

## Regional Anesthesia

Regional anesthesia is a specialized form of pain management that provides analgesia to a specific area of the body. In cases of traumatic rib fractures, regional anesthesia improves respiratory function and pain control with a decrease in MME.<sup>18</sup> This approach encompasses both neuraxial blocks and fascial plane blocks, with each method offering distinct benefits for specific patient populations.

Both epidural analgesia and PVBs provide effective pain relief, but the choice of technique must be individualized based on patient-specific factors such as age, anticoagulation status, and the presence of spinal or positioning limitations. The use of fascial plane blocks, such as the serratus anterior block (SAB) and the erector spinae plane block, provide additional safe and effective alternatives for specific rib fracture patterns and patient conditions.

### Neuraxial Block Techniques

Neuraxial blocks, such as epidural and paravertebral catheters, involve the administration of local anesthetics near the spinal cord to relieve pain. Commonly used medications include bupivacaine and ropivacaine, often in combination with opioids.

**Special Considerations:** Use with caution in patients with coagulopathy and spinal malformations and consider relative contraindications in patients with spinal fractures or restrictive conditions that hinder safe placement. For deep vein thrombosis (DVT) prophylaxis, the American Society of Regional Anesthesia Regional Anesthesia Guidelines recommend a 12-hour interval between last low-molecular-weight heparin (LMWH) dose and epidural placement/removal. Subsequent LMWH dosing should occur at least 4 hours after catheter removal.<sup>19</sup>

### Epidural Analgesia

Epidural analgesia involves injecting an anesthetic into the space between the spinal canal and the outer covering of the spinal cord. It is particularly beneficial for the following patients:

- Patients with multiple rib fractures ( $\geq 3$  ribs), including patients with flail chest<sup>20</sup>
- Older adults ( $\geq 65$  years) at higher risk due to age-related vulnerability<sup>17</sup>

Benefits of epidural analgesia include the following:<sup>20,21</sup>

- Reduced mortality and pneumonia
- Shortened duration of mechanical ventilation, because improved respiratory function contributes to shorter ventilator dependence
- Optimized pain management and improved ventilatory performance that enhances respiratory function

**Caution:** Special considerations for patients treated with epidural analgesia include the following:

- Risk of hypotension from sympatholytic effect of the administered agent
- Epidural hemorrhage
- Infection
- Penetration of the thecal sac, leading to cerebrospinal fluid leak and/or severe headache
- Need for ongoing hospitalization

### Paravertebral Block

PVB involves a unilateral injection near the spinal column where the spinal nerves exit the vertebrae. For all age groups, it offers similar outcomes to epidural analgesia, including comparable hospital and ICU LOS, as well as similar mechanical ventilation durations.<sup>22,23</sup>

PVB has many benefits for patients with rib fractures. Unlike epidural anesthesia, PVB has minimal impact on blood pressure. The PVB technique reduces the risks associated with puncturing the thecal sac and lowers the risk of complications. Patients can be discharged with the catheter still in place, offering convenience in long-term

pain management. PVB also carries a lower risk of bleeding, making it more suitable for patients on anticoagulants, as compared with epidural catheters.

### Fascial Plane Block Techniques

Fascial plane blocks offer an alternative approach for managing rib fracture pain, especially in patients where neuraxial block may not be suitable. A significant benefit is that pharmacologic DVT prophylaxis does not need to be withheld when placing or removing this block.

### Serratus Anterior Block

SAB is particularly effective for patients with anterolateral rib fractures because it targets the area around the serratus anterior muscle. No significant difference in pain relief, inspiratory volume, or rapid shallow breathing index exists when compared with paravertebral or epidural analgesia.<sup>24</sup> Clinicians may have different tolerances to the timing for DVT prophylaxis.

An important advantage of SAB is that it may be safer and easier to perform in patients with spinal fractures or positioning restrictions. SAB also demonstrated similar mortality outcomes to epidural analgesia, as well as significant reduction in pain scores and opioid consumption.<sup>25-27</sup>

### Pectoral Nerve (PECS) Type 2 Block

A PECS type 2 block is an injection between the pectoralis minor and serratus anterior muscles, providing analgesia for the anterolateral chest wall. It targets the lateral and medial pectoral nerves and the lateral cutaneous branches of the T2-T6 intercostal nerves. Clinicians may have different tolerances to the timing for initiating DVT prophylaxis. An advantage of PECS type 2 blocks is that they may be safer and easier to perform in patients with spinal fractures or positioning restrictions. PECS type 2 blocks were also found to provide lower pain scores and opioid requirements.<sup>25,27</sup>

## Local Anesthesia

**Intercostal Nerve Blocks.** An intercostal nerve block has a short duration of action and inferior efficacy to reduce postoperative MME requirements. Intercostal liposomal bupivacaine was not shown to reduce pain scores,

opioid requirements, hospital LOS, or development of pneumonia.<sup>27-29</sup> Additionally, patients who receive liposomal bupivacaine cannot receive other regional blocks for at least 3 days.

**Cryoneurolysis.** Long-term pain management is challenging in patients with multiple or severe rib fractures. Some low-quality evidence supports intercostal cryoneurolysis as an analgesic adjunct for chest wall pain, with some studies suggesting a decrease in hospital LOS and low complication rates.<sup>30</sup> However, further prospective trials are required prior to routine use.

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## EARLY REHABILITATION SERVICES

### KEY POINTS

- Physical and occupational therapists identify muscular weakness, connective tissue contraction, and maladaptive musculoskeletal compensation and then develop a patient therapy plan that promotes the ability to regain maximal range of motion, dexterity, strength, and function.
- Circumferential binding of an injured chest wall is now highly discouraged because of the potential complications associated with restricting the chest wall.

### Physical and Occupational Therapy

Physical and occupational therapy are the cornerstone of recovery from both trauma and operative procedures. The greater the physiologic impact the injury or operation has on the patient, the greater the role of therapy in maximizing recovery. The goal of physical and occupational therapy is to promote full functional recovery or approximation and compensation for permanent disability.

The tenets of physical and occupational therapy are improving strength, mobility, and functioning through active and passive range-of-motion exercises, stretching, and participation in daily activities. Therapists may also directly contribute to the healing process using a variety of techniques that include laser therapy, dry-needling, transcutaneous electrical nerve stimulation (TENS), pulsed ultrasound, and fascial release. Their expertise is in identifying muscular weakness, connective tissue contraction, and maladaptive musculoskeletal compensation following an injury or other physiologic event. This identification is key to the patient's rehabilitation program and ability to regain maximal range of motion, dexterity, and strength for activities of daily living.

A well-equipped and capable physical and occupational therapy department is the key to successful facility management of patients with chest wall injuries. The mainstays of treatment from a physiotherapy standpoint include the following:<sup>1</sup>

- Aggressive clearance of airway secretions
- Early mobilization and range-of-motion exercises, including in ICU patients

- Other injuries (e.g., brain, spine, and orthopaedic) supersede rib fractures, and mobilization may be contraindicated in the early phases of care
- Daily reassessment focused on functional respiratory capacity, with treatment adjusted accordingly

### Rib Binding

Historically, binding the thorax with either elastic or inelastic bandages was a mainstay of rib fracture management. Circumferential binding of an injured chest wall is now highly discouraged because of the potential complications associated with restricting the chest wall.

### Transcutaneous Electrical Nerve Stimulation

TENS has been used to treat a variety of musculoskeletal disorders with varying degrees of success. The use of TENS for the management of rib fractures has been little studied. Two underpowered prospective trials suggest a favorable outcome for the alleviation of pain in patients with noncritical chest wall injuries.<sup>2,3</sup> It appears to be safe, low-cost, and reasonably effective for alleviating some pain from rib fractures in an outpatient setting. The long-term effects of TENS have not been examined with regard to rib fractures.

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BEST PRACTICES GUIDELINES  
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# INDICATIONS FOR OPERATIVE MANAGEMENT



## INDICATIONS FOR SURGICAL STABILIZATION OF RIB FRACTURES

### KEY POINTS

- Assessment of a patient with chest wall injury for SSRF requires review of the radiographic fracture pattern, pulmonary physiology, the patient's goals for return to function, and desire for surgery.
- Minimizing the time from injury to SSRF is of critical importance to optimize outcomes. Performing SSRF <72 hours after injury is ideal.
- SSRF is most beneficial in patients with flail chest and resultant respiratory failure.

The assessment for SSRF of a patient with chest wall injury is centered upon three parameters: pain control refractory to medical management, pulmonary physiology, and a radiographic fracture pattern amenable to repair. Consider these three factors in the overall clinical picture to determine the need for SSRF and its likely clinical efficacy. During clinical assessment, use validated tools to assess the patient's clinical status early and repeatedly, particularly in response to nonoperative interventions. In conjunction with radiographic findings, the clinical scenarios in which SSRF is most likely to be beneficial include:

- A flail segment (defined as  $\geq 3$  consecutive, ipsilateral ribs 2-10 fractured in  $\geq 2$  places), with respiratory failure
- Persistent pain or compromised function despite maximal medical therapy:
  - Persistently painful rib clicking/movement
  - Impaired cough secondary to pain
  - Poor incentive spirometry despite optimal pain control measures
- Significant chest wall deformity ( $\geq 3$  ipsilateral ribs 3-10 fractured with at least 50% displacement that is commonly defined on the axial formatting of a chest CT) with impaired cough or respiratory function<sup>1</sup>

Within these categories, both the number of fractures and degree of displacement ranges widely (e.g., "stoved-in chest"), making clinical judgment an imperative. However, radiographic findings are necessary but not sufficient to warrant SSRF.

A consistent, objective approach to quantifying pulmonary physiology is recommended. Using a physiologic scoring system to quantify a patient's response to their chest wall injury is useful. See Table 3 on page 21 for information about physiologic scoring systems.

Although these considerations provide an overarching framework, the only indication for SSRF for which level 1 evidence exists is flail chest with resultant respiratory failure. Other scenarios require that clinicians evaluate each patient on a case-by-case basis. Additionally, a patient's goals regarding return to function and desire to undergo surgery are key aspects of shared decision-making. With these caveats in mind, strongly consider SSRF in the following scenarios:

- Patients with intercostal (pulmonary) herniation, as both the rib fractures and the intercostal hernia require repair
- Patients in whom a rib fracture fragment/segment is impaling or compressing another organ (e.g., lung, liver, heart, aorta)

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## RELATIVE INDICATIONS FOR SURGICAL STABILIZATION OF RIB FRACTURES

### KEY POINT

- Avoid prolonged periods of inadequate analgesia and associated respiratory compromise by identifying an early and predetermined endpoint for a trial of nonoperative management (NOM).

Relative indications for SSRF are influenced by the patient's pain and physiologic responses to chest wall injury, specifically their response to medical management such as locoregional analgesia.

**Caution:** Trials of NOM need early and predetermined endpoints to avoid prolonged periods of inadequate analgesia and the associated respiratory consequences.

When a patient has a radiographic flail segment in the absence of clinical flail chest, the decision to perform SSRF will depend upon the following:

- The degree of individual fracture displacement
- The location of the individual fractures (e.g., posterior fractures will be more stable and harder to fix)
- The patient's clinical condition with respect to pulmonary function, ability to maintain pulmonary hygiene, pain control, and ability to carry out basic activities of daily living such as getting dressed and ambulating

The second relative indication for SSRF is three or more 50%-displaced ipsilateral fractures of ribs 3-10 without a flail segment (the so-called "nonflail" patient) and resultant impaired respiratory function or severe pain. However, SSRF for displaced fractures in the absence of a flail segment remains controversial, as prospective research studies have findings that are inconsistent. The CWIS NONFLAIL study provided evidence to support SSRF in patients with multiple displaced fractures when the surgery was performed soon after injury, at expert centers with experienced chest wall surgeons, and using routine adjuncts such as pleural

irrigation.<sup>1</sup> This study found short-term improvement in pain and respiratory quality of life.<sup>1</sup> Additional studies involving longer intervals from injury to repair and "standalone" SSRF did not report similar benefits.<sup>2</sup> Multiple ongoing trials continue to study this question.

The third relative indication for SSRF is chest wall instability that is encountered during another operation or procedure, such as mobile, unstable rib fractures that are encountered during thoracic surgery for another reason. In this scenario, SSRF may be needed for stable chest wall closure at the completion of surgery and potentially for longer-term benefit. Thus, a preoperative discussion of potential SSRF surgery needs to occur with any patient with rib fractures undergoing additional thoracic surgery, such as a video-assisted thoracoscopic surgery (VATS).

Even in the absence of acute symptoms, consider the need to perform surgery for certain complex chest wall injury patterns that need fixation, such as lateral implosion injuries and costal margin rupture. These injury patterns require specialized, complex repairs. Consider transfer to a trauma center with appropriate expertise when necessary.

Consider the need for surgery in a patient with persistent, uncontrolled pain due to rib fractures despite optimal medical therapy. Rib fracture displacement/chest wall instability is a dynamic process, and the admission CT scan represents a "snapshot" of the patient's injury at a single, early timepoint. In these cases, consider an interval noncontrast chest CT 48-72 hours later. This may reveal interval displacement of fractures not visible on a chest radiograph or on the initial chest CT. Occult instability may be identified by asking the patient about any rib motion or clicking with either movement or respiration and by performing a repeat physical examination of the chest wall.

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## SPECIAL CONSIDERATIONS

### KEY POINTS

- When considering SSRF for older adults, use a holistic approach that incorporates an assessment of comorbidities, preexisting functional status, and goals of care. Do not consider advanced chronological age an absolute contraindication for SSRF.
- SSRF is likely beneficial in patients with TBI.

### Older Adults

Because of the concern that the operative risk outweighed any potential benefit of chest wall stabilization, it was previously thought that older adults would not benefit from SSRF. Recent data suggest that SSRF is associated with decreased mortality and increased likelihood of discharge home in geriatric patients, including octogenarians and nonagenarians.<sup>1</sup> This finding is believed to be due to older adults' poor tolerance of chest wall injuries compared with younger patients, as well as the relatively low morbidity of the operation. Early surgical intervention may be particularly important in geriatric patients to minimize the period of pain, atelectasis, and immobility. Therefore, do not consider patient age as an absolute contraindication to SSRF. However, a holistic approach that incorporates an assessment of comorbidities, preexisting functional status, and goals of care is optimal.

### Patients with Multiple Injuries

Patients with severe chest wall injuries usually incur additional injuries that require operative management, most commonly long bone and pelvic fractures, solid organ injuries, and TBI.<sup>2</sup> SSRF is beneficial specifically in polytrauma patients.<sup>3</sup> Competing operative priorities raise the importance of close collaboration with other specialists to optimize both the order and timing of SSRF relative to additional surgeries. For example, both spine and pelvic fixation (or at least clearance) may be required prior to positioning for SSRF. In addition, certain injury patterns lend themselves to concurrent fixation, most commonly thoracic spine and posterior rib fracture fixation via a single anesthetic, position (i.e., prone), and incision.

### Traumatic Brain Injury

Patients with TBI represent a challenging subgroup because an assessment of the relative influence of chest wall versus brain injury on overall prognosis can be difficult. Both single-center and multicenter studies reported the benefit of SSRF across TBI severity levels (mild to severe).<sup>4,5</sup> These findings were subsequently observed in a subgroup analysis of patients with nonflail fracture patterns.<sup>5</sup> Finally, a propensity-matched study using data from the ACS Trauma Quality Improvement Program (TQIP) reported decreased mortality among TBI patients of all severity levels who underwent SSRF compared with NOM.<sup>6</sup> Importantly, each of these studies reported increased resource utilization (ventilator days and ICU LOS) for SSRF in patients with TBI. However, decreased mortality was also reported consistently across studies. Thus, SSRF may be considered a safe and reasonable option to offer select TBI patients with severe chest wall injuries. Although these studies all suggest a benefit of SSRF, the studies are retrospective, likely have selection bias, and have no long-term follow-up. The findings need to be validated in prospective studies with appropriate follow-up. The studies also do not address how intracranial pressure abnormalities impact timing for SSRF or how SSRF affects intracranial pressure.

### Pulmonary Contusion

A pulmonary contusion is present in approximately 20% of thoracic trauma patients with at least two rib fractures, compounding the risks for pulmonary complications.<sup>7</sup> Although pulmonary contusions were considered a contraindication to SSRF, more recent data suggest that this assertion may not be valid. A recent study reported that SSRF is associated with a decreased incidence of respiratory failure and tracheostomy, improved respiratory function, and decreased pain in patients with mild to moderate pulmonary contusions.<sup>8</sup> The same study found no increased complications but also no significant benefit from SSRF in the severe pulmonary contusion subgroup. Taken together, the data on this topic suggest that SSRF in the setting of mild to moderate pulmonary contusion is safe and potentially beneficial.

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BEST PRACTICES GUIDELINES  
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**SURGICAL  
MANAGEMENT OF  
RIB FRACTURES**



## PRINCIPLES OF PLATE FIXATION AND BONE HEALING

### KEY POINTS

- Primary and secondary bone healing are important concepts to understand in order to properly plan internal fixation of fractures.
- A key axiom for plate fixation is that length, alignment, and rotation (i.e., “reduction”) of a bone must be restored for proper function.
- A gap larger than 1 cm at the fracture site can lead to nonunion and plate fracture.

### Stages of Bone Healing

**Primary bone healing** occurs when bone ends are in contact, compressed, stably fixed, and experience no fracture motion. This allows bone to deposit directly into the gap through the action of osteoblasts, which line blood vessels inside osteons called *cutting cones*. These cones lead with osteoclasts, which physiologically debride devitalized bone at the fracture site. No callus or immature bone formation occurs during primary bone healing.

**Secondary bone healing** occurs by the deposition of cartilage into the space between bone fragments that have micromotion. At the time of the fracture, a hematoma forms and stimulates the first *inflammatory phase* of fracture healing, initiated by neutrophils and macrophages. Undifferentiated cell lines are stimulated physiologically to become chondrocytic cell lines that deposit cartilage. These actions represent the *soft callus phase* of fracture healing. Within several weeks, the chondrocytes undergo apoptosis, and stimulated osteoblasts replace the soft callus with bone. Osteoblasts are stimulated by local factors including bone morphogenic proteins. This is called the *hard callus phase* of healing, and it is characterized by woven bone. Over many months, the woven bone *remodels* to form the original histological features of cortical and trabecular morphology.

## Principles of Plate Fixation

### Mechanical Principles of Plate Fixation

The motion of bone fragments across fracture gaps produces *strain*. An optimal amount of strain is required for bone healing, but if the fracture gap is too large, the amount of strain increases, which can hinder union.<sup>1</sup> A gap larger than 1 cm at the fracture site can lead to nonunion. Ultimately, there is a race between bone gap healing and breakage of the implanted plate or device.

A low-strain environment can help improve bone healing. An important principle is that bone tissue cannot be produced in high-strain conditions.<sup>1</sup> Variables the surgeon can use to modify the strain include plate thickness, material stiffness, screw spacing, and bicortical versus unicortical fixation, in addition to the size of the fracture gap. The *working length* is the distance between the screws on either side of the fracture, and a longer working length may lower the strain. Likewise, longer *plate span* reduces strain borne by the plate within the working length.

### Biologic Principles of Plate Fixation

Adequate blood supply is essential for bone healing. Ribs have both an *endosteal blood supply* from nutrient vessels penetrating the cortex at certain junctions and a *periosteal blood supply* enveloping the bone, a lining called *periosteum*. To the extent possible, the surgeon needs to preserve vascular viability near the fracture site, including soft tissue attachments from the intercostal muscles.

A key axiom of open reduction and internal fixation (ORIF) includes the concept that form and function are closely related, thus the length, alignment, and rotation of a bone must be restored for proper function. Likewise, respect for bone vascularity is paramount and may employ muscle-sparing approaches. Minimize soft tissue stripping around the fracture site. The goal of the operation is to promote a good mechanical and biological environment, distinguished by preservation of blood supply and a low-strain environment that balances motion and stability.

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## OPTIMAL TIMING OF SURGICAL REPAIR

### KEY POINT

- Current guidelines recommend SSRF within 48–72 hours of injury.

Current guidelines suggest that SSRF is best performed within 48–72 hours of the injury.<sup>1</sup> When SSRF occurs within 48–72 hours of injury, it is considered *early SSRF*. When the patient has a concomitant injury or a condition contraindicating early intervention, perform SSRF as soon as possible, ideally within 7 days after injury.<sup>2</sup>

The rationale for early SSRF is to reduce ventilator time and associated complications (e.g., pneumonia) and to reduce technical difficulties associated with chest wall hematoma, retained hemothorax, and early callus formation.

Additionally, earlier SSRF surgery often results in shorter operating times, because fewer technical difficulties (such as increased fracture displacement and tissue swelling at the operative site) are encountered.<sup>3</sup> However, as with most recommendations in trauma surgery, the supporting studies are retrospective and subject to inherent limitations.

Evidence from both prospective and retrospective multicenter trials support the benefits of early SSRF. A large multicenter prospective clinical trial comparing lengths of time before SSRF demonstrated reduced hospital and ICU LOS, as well as reduced mechanical ventilation time in patients undergoing early SSRF (<24 hours after injury) versus late SSRF (>48–72 hours after injury). Late SSRF was also associated with increased rates of pneumonia and tracheostomy.<sup>3</sup>

Another large retrospective study confirmed the above results, demonstrating that SSRF within 72 hours reduced the need for prolonged mechanical ventilation.<sup>4</sup> A recent meta-analysis subgroup analysis also confirmed benefits of early SSRF (e.g., reduced duration of mechanical ventilation, fewer cases of pneumonia, and reduced need for tracheostomy).<sup>5</sup>

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## AIRWAY MANAGEMENT: INITIAL AND OPERATIVE INTERVENTIONS

### KEY POINTS

- Initial resuscitation and airway management are based upon principles from ATLS®.
- Therapeutic bronchoscopy may be beneficial to clear secretions and bloody fluid from the tracheobronchial tree.
- The surgeon and anesthesiologist should discuss the choice of a double-lumen endotracheal tube or a “bronchial blocker” through a single-lumen endotracheal tube before surgery.

### Initial Airway Management

Immediately life-threatening injuries from blunt chest trauma include airway obstruction, tension pneumothorax, massive hemothorax, cardiac tamponade, aortic injury, and tracheobronchial injury. Initial resuscitation and airway management for the trauma patient are based upon principles from ATLS®.<sup>1</sup> Refer as well to Initial Assessment on page 19. Patients with rib fractures will present with variable symptoms, ranging from relatively minor tachypnea or dyspnea to hypoxic respiratory failure that requires immediate intubation and mechanical ventilation. Pulmonary symptoms may be due to underlying lung injury (e.g., pulmonary contusion), chest wall injury, or both. Also consider the rare possibility of tracheobronchial injury.

Obtaining an airway and initiating supportive ventilation will be necessary in select patients. Rapid-sequence intubation is the preferred approach, with consideration given to associated injuries. A single-lumen endotracheal tube will suffice in the vast majority of patients, and whenever possible an 8 mm endotracheal tube should be used to facilitate the need for bronchoscopy, should that become necessary.

### Operative Airway Interventions

Therapeutic bronchoscopy may be beneficial to clear secretions and bloody fluid from the tracheobronchial tree, both initially and subsequently. Some trauma centers have protocols that include the routine performance of therapeutic bronchoscopy immediately prior to planned surgery.<sup>2</sup> Other trauma centers perform therapeutic bronchoscopy selectively.

The decision to use a double-lumen endotracheal tube or a “bronchial blocker” through a single-lumen endotracheal tube during surgery is made during a discussion between the surgeon and the anesthesiologist. This consideration is based mainly on whether the surgeon prefers that the lung on the affected side be partially or fully deflated during the procedure. An important consideration is whether the patient can tolerate single-lung ventilation during the procedure.

Another consideration is patient position during surgery. Placing the patient in the lateral decubitus position with the injured lung superior to the uninjured lung may result in secretions and blood from the affected lung moving into the unaffected lung during the surgery. If this occurs, the patient’s pulmonary status may worsen intraoperatively. When this phenomenon is believed likely to occur, a double-lumen endotracheal tube can block the mainstem bronchus on the affected side. This intervention permits lateral decubitus positioning without affecting the lung of the uninjured hemithorax. The decision to extubate the patient following surgery depends on the individual patient, cardiopulmonary function, and associated injuries.

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## STERNAL OR CHONDRAL REPAIR

### KEY POINT

- Fixation of sternal fractures may be indicated in cases with complete displacement or in association with flail chest segment and dorsal spine fractures, where shifting/worsening of the thoracic spine fractures will accentuate the degree of sternal displacement and could compress the heart.

### Indications for Sternal or Chondral Repair

Instability of the sternum is painful and can compromise respiratory mechanics. Some patients may benefit from surgical fixation. While indications for surgery are not well documented in the literature, surgery may be beneficial in the following situations:

- Sternum or manubrium fractures associated with a flail chest segment
- Comminuted sternal fractures
- Sternomanubrial dislocation
- Sternal fractures with 100% displacement
- Sternal fractures in association with compression fractures of the thoracic spine
- Symptomatic sternal nonunion (no evidence of healing over a 3-month interval)

The peristernal chondrium and costal margin are a confluence of cartilage attaching the bony ribs and sternum. These structures are important for chest wall stability. Surgical indications are poorly discussed in the literature, but unstable chondral injuries may benefit from surgical management in these cases:

- Dislocated costosternal joints
- Chondral fracture associated with sternum fracture or flail chest
- Costal margin disruption (acute or chronic)
- Symptomatic, chronic chondral fracture or costosternal dislocation

Fractures of the sternum have the highest frequency at the third sternal segment, but they also commonly occur adjacent to the sternal-manubrial junction.<sup>1</sup> In many of these cases, fixation of sternal fractures must cross the sternal-manubrial joint to obtain balanced fixation for adequate stability.

## Surgical Approach

The midline surgical approach to sternal fractures is centered on the fracture, down to the pectoralis fascia, which is elevated to the costosternal junction, right and left of midline. The fracture is debrided of hematoma or callus and is reduced accurately; optimally, the fracture is compressed with pointed bone tenaculums prior to fixation.

**Caution:** Most commercial postcardiac surgical sternal fixation systems are designed for sternotomy closure and not for transverse fractures associated with trauma. These systems may require augmentation with stronger constructs to withstand the deforming shear, rotational, translational, and flexion-extension forces across a transverse fracture line.

To render stability and fixation to costosternal dislocations, fix these injuries with plates that extend from the lateral rib segment to the sternum. Such fixation constructs need to accommodate the flexibility of a joint, either through the use of a low-strain working length of the plate (see Principles of Plate Fixation on page 39) or through the material properties of a more flexible device with a lower modulus of elasticity. Fixation of costal margin disruption is not well studied and only more recently recognized.<sup>2</sup> Fixation strategies need to consider both the instability of a torn associated intercostal segment, as well as the cartilaginous costal margin, which has poor purchase for screw fixation. These strategies may include longer plates with more screws, deploying screws at multiple fixed, angled vectors, and pericostal loop fixation around ribs inferior and superior to the torn intercostal segment.

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## APPROACH TO ASSOCIATED THORACIC INJURIES

### KEY POINTS

- Consider the need for VATS to treat pulmonary parenchyma and diaphragm injuries.
- Scapula and clavicle fractures and other complex shoulder injuries often occur with fractures of the chest wall.
- Thoracic spine fractures may cause instability of the body and the chest wall.
- Diaphragm injuries may be present and require repair.

### Pulmonary Parenchyma

Severe chest wall injury was historically considered a “marker” of significant intrathoracic injuries. With modern cross-sectional imaging modalities, the vast majority of intrathoracic injuries are diagnosed during initial resuscitation and evaluation of the trauma patient. However, in some instances, even clinically significant injuries can escape detection by CT.<sup>1</sup> Consider whether VATS is needed to investigate for associated thoracic cavity injuries in a patient undergoing SSRF for a chest wall injury. VATS serves to clear the chest space of any residual fibrous clot or blood and to identify any intrathoracic injuries, such as diaphragmatic lacerations, that can then be addressed.<sup>2</sup> Pulmonary parenchymal injuries can be released from the associated fracture prior to fracture repair, and if necessary, any ongoing blood loss or air leak from the lung can be surgically managed. Diaphragmatic injuries can also be directly repaired with VATS.

### Clavicle

Clavicle fractures are found frequently with flail chest and multiple rib fractures. Most clavicle fractures in isolation can be treated with NOM. However, NOM of fractures that are 100% displaced carries a 20% risk of nonunion and a 15% risk of symptomatic malunion.<sup>3</sup>

Recent literature suggests that displaced clavicle fractures in association with multiple ipsilateral rib fractures have a high rate of initial displacement and progressive displacement even after the injury. Hence, in the setting

of ipsilateral clavicle and rib fractures, a lower threshold exists to fix the clavicle fracture, in order to prevent further displacement and fracture nonunion/malunion.<sup>4,5</sup> However, no evidence reports that fixation of the clavicle will improve pulmonary function, hospital LOS, or quality of life.

### Scapula

Scapula fractures and other complex shoulder injuries often occur with fractures of the chest wall. Rib fractures are found in more than 80% of patients with operative scapula fractures.<sup>6</sup> The most common fracture location is the posterolateral angle, along the medial border of the scapula at rib levels 3–6 (a phenomenon termed the “forequarter lateral implosion injury”).<sup>6</sup> Scapula fractures are common in patients who undergo SSRF, and this subgroup has a higher ISS and incidence of pulmonary contusion.

ORIF of combined injuries around the shoulder girdle have the potential for stability, pain control, and early return to function.<sup>7</sup> See Table 5 for indications for ORIF of isolated scapula fracture.<sup>8</sup>

Another relative surgical indication is an unstable shoulder girdle with multiple disruptions of the superior shoulder suspensory complex. This complex, also termed a “floating shoulder,” may include a combination of two or more disruptions or fractures of the following: scapula neck, clavicle, coracoid, acromion, or acromioclavicular joint.<sup>9</sup>

### Thoracic Spine

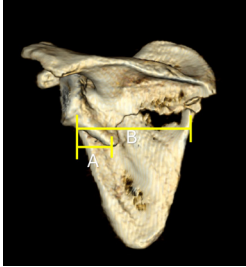
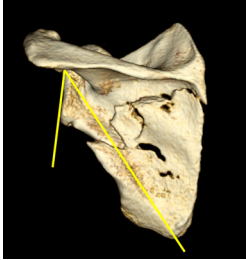


Fractures of the thoracolumbar spine are associated with an estimated 38% of traumatic rib fractures and unilateral flail chest, as well as an estimated 49% of bilateral flail chest injuries.<sup>10</sup> The spine may sustain indirect fractures due to flexion and compression injuries or hyperextension and distraction forces.<sup>11,12</sup> Thoracic spine fractures may cause relevant instability of the body and the chest wall. The anterior chest wall is considered to work as the 4th vertebral column in sagittal stability.<sup>13</sup> Refer to the ACS TQP *Best Practices Guidelines Spine Injury* for more information about management.<sup>14</sup>

### Diaphragm

Patients with multiple rib fractures and flail chest injuries are also at risk of injury to the diaphragm. These injuries can be difficult to diagnose, even with cross-sectional CT

imaging, and they can be initially missed. Have a high index of suspicion and assess the need for VATS at the time of SSRF to evaluate the diaphragm.

**Table 5. Indications for ORIF of Isolated Scapula Fracture**

Injuries	Images
<p><b>Lateral scapula border offset (“medialization”) &gt;20 mm</b>                      Measured on anteroposterior radiograph or CT view of the scapula</p>	
<p><b>Glenopolar angle &lt;22°</b>                      Measured on anteroposterior radiograph or CT view of the scapula</p>	
<p><b>Angular deformity &gt;45°</b>                      Measured on scapula Y radiograph or CT view of the scapula</p>	
<p><b>Intraarticular glenoid fracture with step-off or gap &gt;4 mm or displaced anterior/posterior rim fragment &gt;20% of glenoid</b>                      Best measured on a 2D CT scan</p>	

Courtesy of Peter A. Cole, MD, FAOA, University of Minnesota, Minneapolis-Saint Paul, MN.

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BEST PRACTICES GUIDELINES  
**MANAGEMENT OF  
CHEST WALL INJURIES**



# **COMPLICATIONS OF SURGICAL STABILIZATION OF RIB FRACTURES**



## HARDWARE FAILURE IN RIB OSTEOSYNTHESIS

### KEY POINTS

- The most common rib-related complications after SSRF are ongoing discomfort, hardware failure, and surgical site infection.
- Materials used for osteosynthesis of the ribs must withstand long-term bending and torsional loads, as the ribs are in constant motion.
- Extra-anatomical devices (e.g., wires, metal bars and plates) have a potential risk for migration to vital organs, dislocation into the thorax, and metal fatigue.

Ongoing discomfort, hardware failure, and surgical site infection are the most common rib-related complications after SSRF. Early efforts to optimize operative technique for SSRF tried to minimize the risk of hardware failure for osteosynthesis of rib and sternal fractures.

### Hardware Failure

*Hardware failure* is defined as plate fracture and screw migration, occurring in 3% to 7% of patients following SSRF.<sup>1,2</sup> During sternal surgical repair, perforated plates can be fixed to this flat bone with compression screws, analogous to management of long bones; this is associated with a low risk of failure.

*Osteosynthesis* is a surgical procedure that involves stabilizing and joining the ends of fractured bones using mechanical devices like plates, screws, pins, or rods. Surgical repair of the ribs is different from other fractures. Materials used in osteosynthesis on the thorax are required to withstand bending and torsional loads over the long term. These requirements result from the continuous movement of the ribs in the dynamic network of the rib cage. The ribs have a three-dimensionally curved structure: in-plane, out-of-plane, and torsion.<sup>3,4</sup> The ribs move with each breath. This multidimensional range of motion results in widening and lowering of the rib cage, with the ribs changing both their curvature and their longitudinal extension. These motions result in both bending and torsion

forces on the ribs. In the bony areas of the ribs, the structure is relatively stable, which allows plates to be anchored across a fracture segment. In the anterior, cartilaginous part of the ribs and their connections to the sternum, however, flexibility is significantly higher than in the bony parts.<sup>5</sup> This leads to more mobility and a higher risk of implant failure.

The initial method of osteosynthesis for rib fractures consisted of the implantation of metallic bars or plates to support the ribs from their outer surface. These materials were inserted extra-anatomically, either fixed to the ribs with sutures or anchored to the sternum to achieve bilateral stabilization of the anterior chest wall.<sup>6,7</sup> These extra-anatomical materials carry the risk of possible dislocation into the thorax, which can potentially lead to intrathoracic injury. In addition, the pressure on the ribs can cause stress fractures.<sup>8</sup>

In the past, wires (such as Kirschner wires) were also used to stabilize rib and sternal fractures; they were either drilled into the bone or placed by intramedullary insertion, in many cases with additional wire cerclage.<sup>9</sup> A high rate of dislocation was observed in these procedures, because the ribs are continuously in motion. The migration of wires into the thorax can have fatal consequences, especially if they penetrate cardiac vessels or organs.<sup>10,11</sup> *Thus, smooth wire fixation of rib fractures is no longer recommended.*

Material fatigue is a problem with rigid materials such as steel, when exposed to particularly high bending loads. Steel plates were often screwed onto the ribs, but due to their rigid consistency and ongoing rib movement, loosening and material failure often occurred.<sup>12</sup>

A risk similar to conventional osteosynthesis also exists with the rib-encompassing clamp systems, originally made of steel and later of titanium. Advances in this method include the development of Sanchez-Lloret plates and Judet struts, as well as Labitzke's improvements in the elasticity of such staple plates.<sup>13-16</sup> This principle is still used today in modern titanium clamp systems, which enclose the ribs and can bridge defects and unstable areas with modular systems. Serial clamps on a plate are available for individual fractures, and a combination of clamp modules and connecting struts is available for clamping larger distances.<sup>17</sup>

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## MODERN SYSTEMS FOR RIB OSTEOSYNTHESIS

### KEY POINTS

- Failure of broken bone segments to heal in a timely manner is strongly associated with plate fracture over time, caused by repeated bending with breathing and coughing.
- Rib fractures must be carefully reduced and bridged with an optimally placed osteosynthesis system to ensure stability, support the natural healing process, and minimize the risk of complications.

### Engineering Osteosynthesis Systems

Modern systems for rib osteosynthesis are engineered to minimize the risks of hardware dislodgement at the rib and of tissue damage in the intercostal or intrathoracic space. These modern systems, made of titanium, are characterized by high durability, tensile strength, and elasticity. This allows some degree of movement, decreasing the stress on the plating system and thus the risk of fracture. The semirigid fixation of rib fractures effectively reduces deformation and supports healing of the fractures in their normal positions.

Anterior chest wall support measures, extending from the rib to the sternum to the rib on the opposite side, are exposed to permanent movement-related stress. Over time, these materials can fatigue and lead to failure. However, this issue is minimized if the materials are placed outside the thorax and migration inwards is prevented. At the same time, natural stability must be restored by rib healing, otherwise recurrent instability can occur. This phenomenon has been described both for bridging rib clamp systems and for long plate osteosyntheses.<sup>1,2</sup>

### Rib Plating Systems

A significant improvement with all modern rib plating systems is use of semirigid angular-stable titanium plates in a low-profile design. As with the rib clamps, titanium alloys are biomechanically better suited to follow the micromovements of the ribs, and they show less fatigue. In addition, the biomechanically optimized anchoring mechanisms—which are based on the principle of angle-

stable plate osteosynthesis—ensure efficient force transmission. Locked screws make the biomechanical difference, as locking provides a reliable stability between the screws and the plate. This type of fixation allows forces to be transmitted from one end of the bone to the other via the plate construct.<sup>3,4</sup>

The purpose of titanium implants is to provide fracture fixation while still allowing for repeated bending loads associated with breathing and coughing. However, the time that the plate can support this load is limited, and therefore fracture fixation is predicated on timely fracture healing. Failure of broken bone segments to heal is strongly associated with plate fracture over time.

### Absorbable Material Systems

In addition to the technologies mentioned above, absorbable material systems offer new perspectives by being relatively flexible from the outset and leaving no foreign material behind. Unfortunately, these systems have comparatively low primary stability, and they are associated with a high failure rate in fracture healing, limiting their application.<sup>5,6</sup> Another issue with prior bioabsorbable plate fixation devices was a high rate of sterile drainage from absorbable debris or fluid. The recently available angle-stable plate systems made of polyetheretherketone, a thermoplastic, appear promising.<sup>7</sup> This material is extremely elastic and durable, and it has a high breaking strength. It combines the advantages of an angle-stable anchorage with a permanent high elasticity, which is particularly relevant for the treatment of rib fractures. Initial reports suggest that these systems may be at least equal to existing solutions.<sup>8</sup>

### Optimal Osteosynthesis Design and Positioning

Fixation systems attached to the outside of the ribs act as an outer rail in the sense of the tension band principle. This means that the contour of the rib is held from the outside, and movements of the rib are transformed into compression in the fracture space, which additionally induces healing.<sup>9</sup>

It is therefore crucial that rib fractures are carefully reduced and bridged with an optimally placed osteosynthesis system. Proper placement of the implants not only ensures stability but also supports the natural healing process and minimizes the risk of complications.

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## RISKS OF MATERIAL FAILURE IN RIB OSTEOSYNTHESIS

### KEY POINT

- A core principle of plate implantation is to achieve apposition of the fracture segments and place the plate in the middle of the rib, where the cortex is thickest, giving the fixation screws the best purchase.

A general principle is that all unstable or displaced fractures need to be stabilized. In cases with two fracture segments on the same rib, it is advisable to stabilize both segments.<sup>1</sup> Failure to do so can lead to increased bending stress on the osteosynthesis material, which in turn entails the risk of premature fatigue and failure of the material.

## Factors Influencing Material Failure

### *Poorly Positioned Fixing Materials*

Improper positioning of osteosynthesis materials can lead to insufficient stability and excessive mobility, increasing the risk of plate fracture. This often happens when plates or rib clips are not fixed in an anatomically correct position, such as too close to the fracture zone or in an offset position to the rib course. This can also occur if a gap of more than 1 cm is present in the fracture segment. The core principle of plate implantation is to achieve apposition of the fracture segments and place the plate in the middle of the rib, where the cortex is thickest and therefore where the fixation screws have the best purchase.

### *High, Permanent Stress Levels*

Permanent stresses on the osteosynthesis material can endanger its integrity. In particular, if the implants are insufficiently adapted to the anatomical structure of the ribs, permanent stress arises that can lead to premature failure. The same problem exists if the plate is positioned to traverse a gap in the fracture line.

### *Absence and Delayed Fracture Consolidation*

If a fracture does not heal completely, continuous stress from movement due to breathing remains, putting permanent stress on the plate that will ultimately lead to plate fracture.

### *Insufficiency of Attached Osteosynthesis Materials*

It is possible for these systems to loosen or detach from the rib. This often happens when the contour of the rib is not imitated correctly, screws are not securely locked at an angle-stable position, or rib clamp systems are not pressed correctly. The thickness of the rib cortices changes along the height of the rib such that the cortex is thickest in the middle of the rib. It is imperative that plates are positioned in the middle of the rib to allow the best purchase for the screws.

### *Material Fatigue Due to Improper Handling*

When contouring a plate, carefully bend the titanium in only one direction. Excessive or aggressive bending can cause the material to crack and fail. This risk is greatly increased by reverse bending of implants. Reverse bending is when the original plate contour is altered in such a manner as to actually bend the plate in the opposite direction from the original contour. Modern systems require little contouring.

### *Adaptation to the Biomechanics of the Rib*

The clamp systems and plates must follow the rib in three dimensions (in-plane, out-of-plane, and torsion). Otherwise, it can cause permanent stress on the material, which can lead to discomfort, tension, or even pain during fracture healing.

### *Understanding the Whole System*

When treating rib fractures, it is important to consider the entire locomotor system of the thorax. This includes all 24 ribs, the different regions of the sternum, and each conjunction between those 25 bones. In particular, multifragmented fractures or segment fractures require careful consideration with regard to stabilization.

## Nonunion or Nonhealing

If material failure occurs due to a nonhealing fracture, thorough diagnostics are required. Nonunion or nonhealing can manifest as pain, a feeling of pressure, or a clicking phenomenon in the affected region. Clinical examination and imaging, usually a CT scan, are needed to confirm the diagnosis and possibly determine the cause of the hardware failure. Laboratory testing is needed for serum calcium;

1,25-dihydroxyvitamin D3 (calciferol); hemoglobin A1C; and parathyroid hormone levels. Modifiable risk factors, such as smoking, also need to be addressed.

Possible mechanical causes of pseudarthrosis (nonunion) include the following:

- Insufficient mechanical stability
- Interposed soft tissues that obstruct bone contact
- Loss of vitality in the fracture region due to soft tissue damage
- Infection of the fracture region

As a rule, revision surgery is required if hardware failure is confirmed and the patient complains of symptoms such as pain or clicking. The plate is removed, and a wound culture sample is obtained. If infection is confirmed, a two-stage procedure is advisable, in which the infection is treated before restabilization is done. Any existing bone defects must then be rebuilt by autogenous or allogeneic bone materials, bone substitutes such as hydroxylapatite, or ceramic bone replacement. Another alternative could be the plastic reconstruction of the rib with an osteotomy followed by excision of the rib.

If the pseudarthrosis is not obviously infected and the patient is symptomatic, debridement back to bleeding bone and reosteosynthesis are performed. Bone defects are also filled in as described above. Culture samples need to be obtained. If the culture reveals a low-grade infection, appropriate antibiotics are prescribed for a prolonged course. Consultation with an infectious disease specialist may be useful.

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## INFECTIONS IN RIB OSTEOSYNTHESIS

### KEY POINTS

- Postoperative infection signs include pain, swelling, redness, and wound secretion leakage.
- For early-onset infections, thorough wound cleaning and antibiotic therapy are performed, and the osteosynthesis implant is left in place (if stable).
- For late-onset infections, operative intervention is required to debride the wound, and the osteosynthesis implant is removed.
- Negative-pressure therapy with or without instillation of a topical wound treatment is often used during infection treatment.

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The risk of wound healing disorders and infections exists following SSRF, as with any surgical procedure. The surgical site infection rate ranges from 0.4% to 5% in single-center series.<sup>1,2</sup> Surgery in the chest area needs to be as atraumatic as possible to minimize soft tissue damage. Keep incision lengths as short as possible, and minimize musculocutaneous flaps to prevent postoperative seroma formation.

Before the procedure, provide patients with comprehensive information about the risks of wound and soft tissue complications. It is important to consider patient-specific risk factors such as age, diabetes mellitus, nicotine use, substance use disorder, arterial occlusive disease, rheumatological diseases, and other relevant factors. Then weigh those risk factors against the benefits of osteosynthesis.

When a postoperative infection occurs, it usually manifests through pain, swelling, redness, and possibly wound secretion leakage. Assess for these general signs of infection daily as part of the established postoperative protocol at each trauma center. Other than superficial cellulitis, most significant surgical site infections require opening the wound, with possible debridement and removal of the implants for the most severe or refractory cases.

## Early-Onset Infections

It is important to distinguish between early-onset and late-onset infections. Generally, surgical site infections that occur within 30 days of the operation are considered early infections. In these cases, the focus is on soft tissue management and thorough cleaning of the wound. The stability of osteosynthesis is checked, and it is left in place if stable. It is assumed that no biofilm has yet been formed on the osteosynthesis material. The implant can usually be left in place if the plates are not directly in the infected field. Depending on the severity of the infection, wound treatment can also be carried out in one stage, followed by renewed wound closure by suture, with or without drainage.<sup>3</sup>

When a pronounced infection is present, operative debridement and planned revision of the osteosynthesis are often necessary. An effective method of treatment is negative-pressure wound therapy (NPWT) with instillation of local antiseptic solutions. After one to three cycles, the tissue often regenerates, allowing for secondary wound closure. If tissue defects remain, complex soft tissue rearrangement/coverage is necessary. Local antibiotic carriers can be used to support treatment, such as antibiotic-enriched collagen sponges containing gentamicin. Furthermore, the use of vancomycin powder in the osteosynthesis area before wound closure was reported to help resolve the infection.<sup>4</sup>

## Late-Onset Infections

Late-onset infections manifest after the 30th postoperative day and can cause similar inflammatory symptoms (e.g., redness, swelling, and pain), but secretions are less common. In these cases, comprehensive diagnostics are required to clarify the extent of the infection. Usually, a CT scan is performed to determine whether the pleural space is involved, how far the infectious reaction has extended, and whether fluid retention has formed. The bony status and osteosynthesis are also assessed.<sup>5</sup>

Late infections usually require operative intervention. All foreign materials must be removed. The soft tissues and, if necessary, the bones are debrided to clean the site of infection. In many cases, a multistage procedure is necessary. NPWT systems with and without instillation of a topical wound treatment solution can also be used to condition the soft tissues, as is commonly done for deep sternal wound infections.<sup>6-10</sup>

After the infection has resolved, evaluate the need for further osteosynthesis. If the ribs remain unstable, further osteosynthesis may be done, but this is rare. Bony defects can be rebuilt using autogenous or allogeneic grafts. Defects in the ribs can also be temporarily bridged by antibiotic-containing foreign material such as bone cement (polymethyl methacrylate [PMMA]). These materials deliver antibiotics locally and promote tissue interaction that usually leads to well-vascularized membrane formation around the antibiotic carrier.<sup>11</sup>

After a few months (usually 3–4 months), these foreign materials can be removed, and the surrounding sheath can be filled with autologous bones or bone substitutes. These measures can achieve good bone healing, though in most cases, restabilization is necessary. Consultation with orthopaedic surgery and infectious disease, with possible referral to a specialty center, is important in these complex cases.

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BEST PRACTICES GUIDELINES  
**MANAGEMENT OF  
CHEST WALL INJURIES**

# POSTOPERATIVE CARE AND FOLLOW-UP



## PLEURAL SPACE MANAGEMENT

### KEY POINTS

- Clinical findings of improved lung aeration and the amount of fluid draining from the hemithorax guide management of the pleural space.
- Discontinue the catheter when imaging reveals no hemithoracic complications, such as persistent pneumothorax or undrained fluid.

Management of the pleural space is vital to patient outcomes, for both the operative and the nonoperative patient. Best practice based on historical management recommends routine pleural space drainage after SSRF, but evidence is lacking. The drainage catheter is selected based on surgeon preference (e.g., formal tube thoracostomy, pigtail catheter, fluted drains, or thoracic lavage). Research supports the use of smaller-diameter catheters.<sup>1,2</sup> Closed chest drainage systems are recommended.<sup>3</sup>

Intraoperative decisions regarding management of the pleural space dictate the postoperative management. Most surgeons use a chest tube for pleural space drainage. Initial postoperative management involves placement of the catheter to a closed, three-chamber drainage system attached to suction, with suction regulated to 20 cm H<sub>2</sub>O negative pressure.<sup>3</sup> Commercially available chest tube drainage systems allow for this connection and negative-pressure regulation when connected to hospital suction systems.

### Drainage Duration

Appropriate management of the pleural space requires both drainage and determination of the duration of drainage. Most conventional teaching is based on progression from a closed-suction drainage system to an underwater seal to ensure there is no recurrent pneumothorax. This is followed by removal of the selected tube based on output volume. Historically this decision was based on output, but recent studies challenged this dictum and suggest that neither volume nor underwater seal are required.<sup>4,5</sup> Further studies are needed before making changes to clinical practice recommendations.

Base pleural space management on clinical findings of improved lung aeration and the amount of fluid drainage from the hemithorax. Perform a chest radiograph prior to removal of the drainage catheter to ensure there are no specific hemithoracic complications or pathology that would be best treated by the catheter currently in place. Persistent pneumothorax or undrained fluid are two specific findings on the radiograph that would alter the decision to remove the chest drainage. Pneumothorax may be less of a concern if the patient did not have a pneumothorax preoperatively and the catheter was placed solely for evacuation of fluid.

Discontinue the catheter when suggested by facility protocols. Newer data suggest drainage volumes as high as 500 mL over 24 hours may be appropriate.<sup>4</sup> Performance improvement (PI) efforts to ensure that drains are used effectively need to evaluate the duration of catheter drainage, complications related to catheter removal, and reintervention rates.

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## MONITORING PULMONARY FUNCTION

### KEY POINTS

- Trauma centers are recommended to use the nomograms packaged with their facility's specific incentive spirometry model to assess patient pulmonary function by utilizing the cutoffs for the percent predicted value.
- Patients with poor secretion clearance, poor incentive spirometry values, and inability to ambulate due to dyspnea are at high risk for pulmonary complications.

Postoperative management of pulmonary function is based on facility resources and equipment availability. Many of the scoring systems used in the initial injury assessment of respiratory function can be utilized at any time during the patient's injury course, and changes can indicate trajectories of respiratory function.<sup>1</sup> See Table 3 on page 21 for information about pulmonary scoring systems. While these complex scoring systems are readily available, they tend to be resource-demanding and less applicable to most bedside clinicians.

Studies have demonstrated that pulmonary function testing, specifically FVC and %FEV, can be predictive of adverse pulmonary outcomes.<sup>2,3</sup> While portable units for FVC and %FEV are becoming more readily available, they are unlikely to be bedside tools at most facilities. Incentive spirometry is cost-efficient, and it is a more easily obtained resource that is commonly substituted for more formal PFTs.<sup>4,5</sup> It is recommended that trauma centers use the nomograms packaged with their facility's specific incentive spirometry model to assess pulmonary function by utilizing the cutoffs for the percent predicted value.

Pulmonary function is also measured by several other clinically subjective parameters, such as cough, secretion clearance, and ability to ambulate.<sup>6</sup> While each of these measures are subjective, patients with poor secretion clearance, poor incentive spirometry values, and inability to ambulate due to dyspnea are at high risk for pulmonary complications.

Finally, monitoring SpO<sub>2</sub> is valuable for determining oxygenation. The ratio of partial pressure of oxygen in the arterial blood to the fraction of inspired oxygen (P/F ratio), which can be extrapolated from the SpO<sub>2</sub> and oxygen requirements, can be helpful in determining risk of respiratory failure. Historically this is a late indicator of either hypoxic or hypercapnic respiratory failure, but due to universally available monitoring and ease of trend tracking, it is a valuable tool to identify patients who are on a downward trajectory.

Evaluate patient pulmonary function at various time points after injury and surgery. While admitted to the hospital, assess patients no less than daily for changes in their pulmonary status. After completing their hospital course, the frequency of patient assessment is based on the severity of their injury. Assess the pulmonary function of patients during follow-up visits to determine improvement or decline over time. Examples of clinical measures that can be followed over time are SpO<sub>2</sub>, cough, incentive spirometry, and pain rating score.

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## MONITORING PAIN MEDICATION REQUIREMENTS

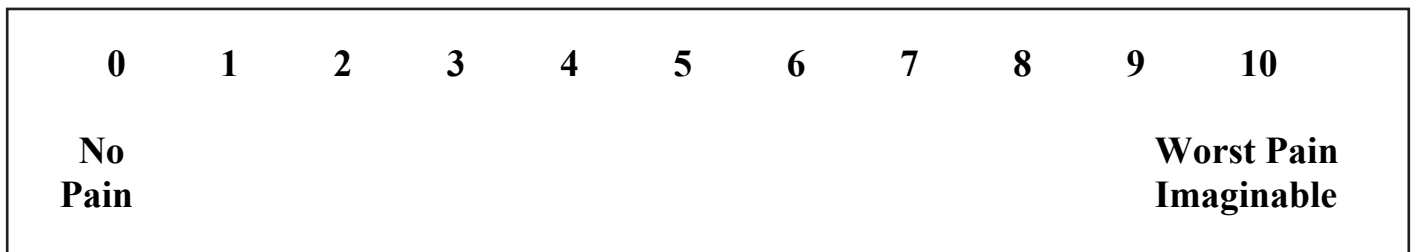
### KEY POINTS

- Use the same pain assessment tool for pain reassessment during the postinjury and postoperative periods, as well as during follow-up visits.
- Provide prescriptions for discharge that guide opioid tapering and integrate the use of nonopioid medications.

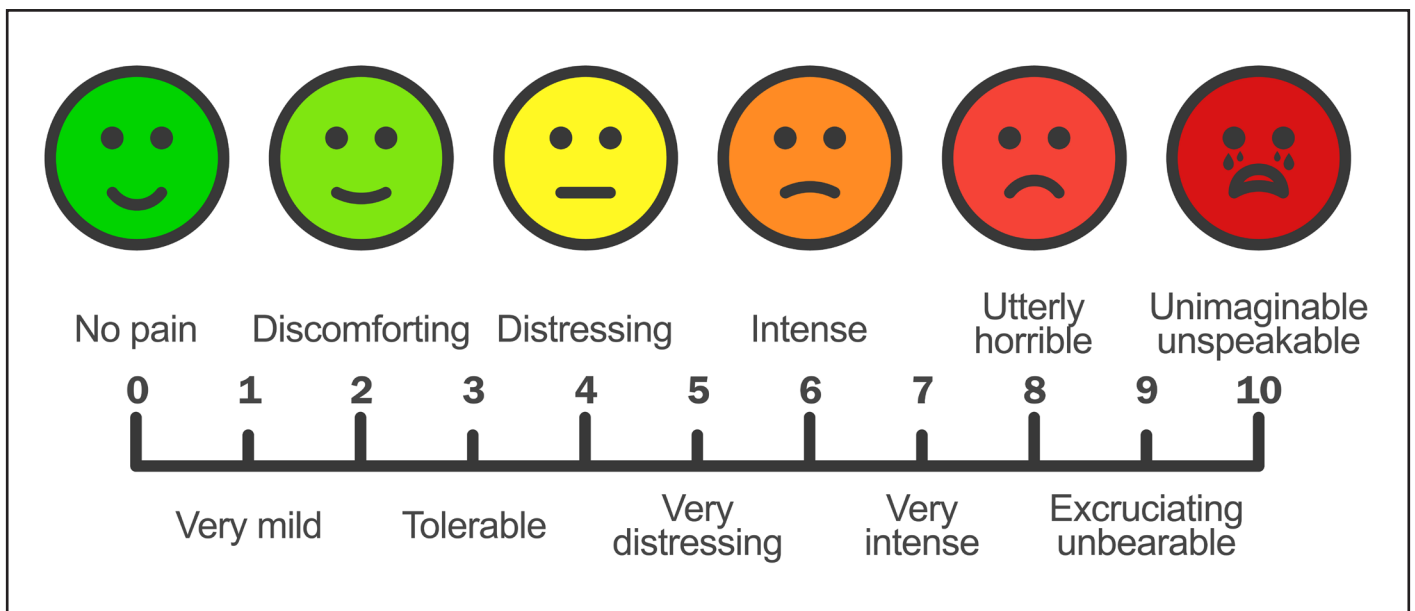
Unidimensional assessment tools, including the Numeric Rating Scale, Visual Analog Scale (VAS), and Defense and Veterans Pain Rating Scale (DVPRS), are appropriate for patients who can communicate accordingly (see Figures 7–9).<sup>2,3</sup> For cognitively impaired patients, the Behavioral Pain Scale and the Critical-Care Pain Observation Tool are suitable in the acute care setting (see Tables 6 and 7).<sup>4,5</sup> Refer to the ACS TQP *Best Practices Guidelines for Acute Pain Management in Trauma Patients* for more information about these pain assessment tools.<sup>1</sup>

Systematically reassess pain during the postinjury and postoperative periods using the same tool at regular intervals. Use the same tool during follow-up visits. The patient’s ability to communicate determines which tool to use.<sup>1</sup>

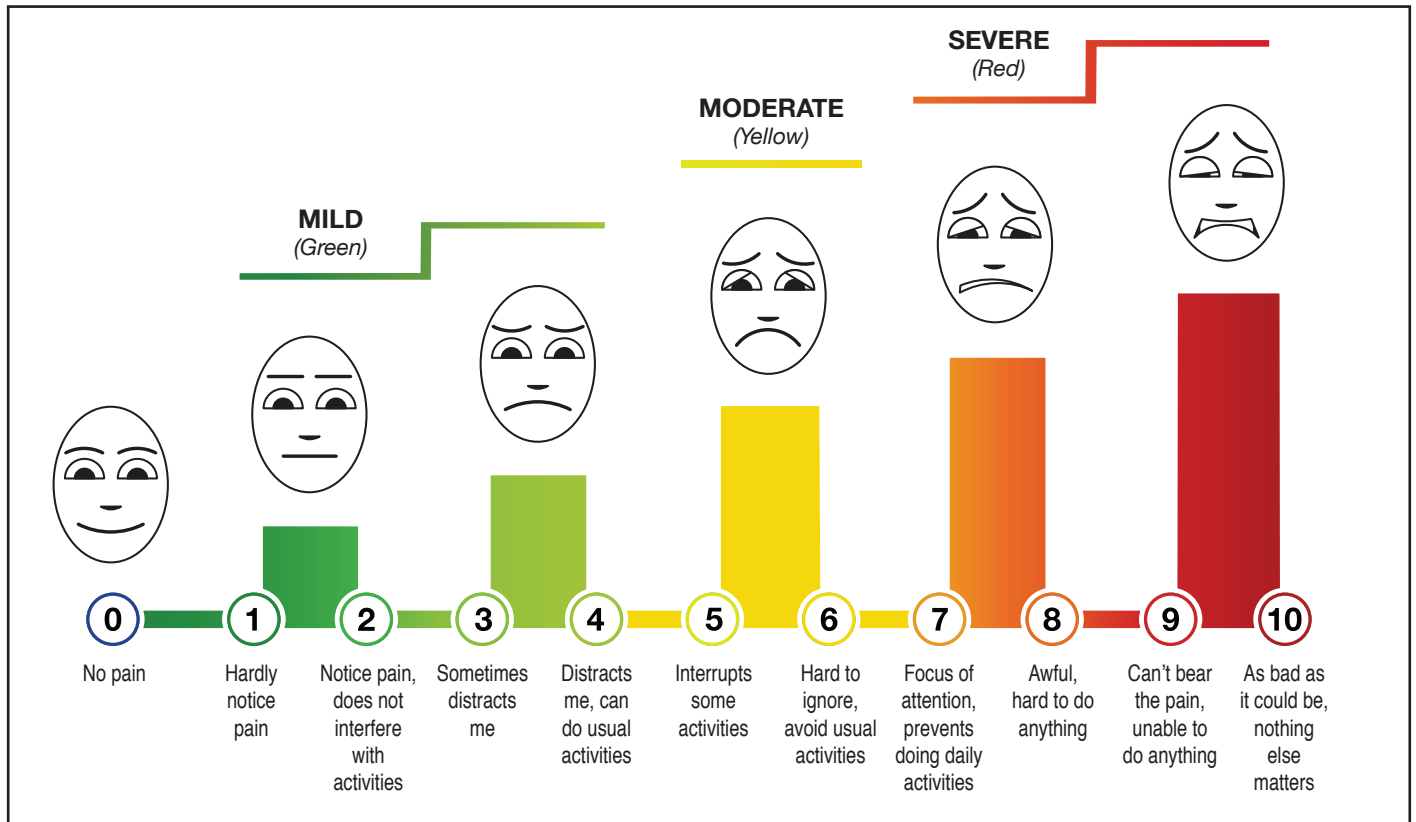
**Figure 7. Numeric Rating Scale**



**Figure 8. Visual Analog Scale (VAS)**



**Figure 9. Defense and Veterans Pain Rating Scale (DVPRS)**



Pain supplemental questions to evaluate the biopsychosocial impact of pain interference with activity, sleep, mood, and stress can be found here: <https://dvcipm.usuhs.edu/dvprs>.

From: Polomano RC, Galloway KT, Kent ML, Brandon-Edwards H, Kwon KN, Morales C, et al. Psychometric testing of the Defense and Veterans Pain Rating Scale (DVPRS): A new pain scale for military population. *Pain Med.* 2016; 17(8):1505-1519. Epub 2016 Jun 6. doi: 10.1093/pm/pnw105.

**Table 6. Behavioral Pain Scale**

Item	Description	Score
Facial expression	Relaxed	1
	Partially tightened (e.g., brow lowering)	2
	Fully tightened (e.g., eyelid closing)	3
	Grimacing	4
Upper limbs	No movement	1
	Partially bent	2
	Fully bent with finger flexion	3
	Permanently retracted	4
Compliance with ventilation	Tolerating movement	1
	Coughing, but tolerating ventilation for most of time	2
	Fighting ventilator	3
	Unable to control ventilation	4

**Scoring:** Sum the scores for each item (range from 3 to 12) for the pain score.

Borrowed with permission from Payen JF, Bru O, Bosson JL, Lagrasta A, Novel E, Deschaux I, et al. Assessing pain in critically ill sedated patients by using a behavioral pain scale. *Crit Care Med.* 2001; 29(12):2258-2263. doi: 10.1097/00003246-200112000-00004. ©Wolters Kluwer.

**Table 7. Critical-Care Pain Observation Tool**

Indicator	Score	Description
Facial expression	0	No muscle tension
	1	Frowning, brow lowering, orbit tightening, levator contraction, or any other change
	2	All previous facial movements plus eyelids tightly closed
Body movements	0	Does not move at all or normal position
	1	Slow, cautious movements, touching or rubbing the pain site, seeking attention through movements
	2	Pulling tube, attempting to sit up, moving limbs/thrashing, not following commands, striking at staff, trying to climb out of bed
Muscle tension Evaluation by passive flexion and extension of upper extremities	0	No resistance to passive movements
	1	Resistance to passive movements
	2	Strong resistance to passive movements or incapacity to complete them
Compliance with the ventilator (intubated patients)  <b>OR</b>	0	Alarms not activated, easy ventilation
	1	Coughing, alarms may be activated but stop spontaneously
	2	Asynchrony, alarms frequently activated
Vocalization (extubated patients)	0	Talking in normal tone or no sound
	1	Sighing, moaning
	2	Crying out, sobbing
<b>Total Score</b>	<b>__ of 8</b>	

Used with permission of the American Association of Critical-Care Nurses, from Gélinas C, Fillion L, Puntillo KA, Viens C, Fortier M. Validation of the Critical-Care Pain Observation Tool in adult patients. *Am J Crit Care*. 2006;15(4):420–427. PMID: 16823021. doi:10.4037/ajcc2006.15.4.420; permission conveyed through Copyright Clearance Center, Inc.

Postdischarge analgesia requirements are associated with in-hospital analgesia use, the severity of chest wall fractures, and premorbid conditions.<sup>6</sup> Provide discharge prescriptions that separate opioid and nonopioid analgesics to guide opioid tapering. Consider providing naloxone as a prescription for patients felt to be at high risk for opioid overdose.

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## DISCHARGE DESTINATION AND FOLLOW-UP

### KEY POINTS

- Discharge destination is determined by the patient's functional status and preferences, in addition to assessments by multidisciplinary team members.
- The follow-up visit includes patient assessment for pain management, functional recovery, and indications of complications, as well as analgesic medication de-escalation.

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### Discharge Destination

Operative or nonoperative management of rib and sternal fractures does not require discharge to a specific destination. The patient's functional status and preferences, in collaboration with multidisciplinary clinicians, determine the discharge destination after injury or surgery. Physical therapy, occupational therapy, and other care team members make the assessment to determine the optimal discharge location, just as determined for other trauma patients. Patients with comorbidities who have undergone SSRF may more likely be discharged home rather than to a rehabilitation or skilled nursing facility.<sup>1</sup>

### Patient Recovery

Counsel patients to prepare for a prolonged recovery period, and plan for weaning their multimodal pain medications. Patients with rib injuries often require a significant amount of time to return to preinjury level of function and activity. Complications after surgery can take several months to become evident. Choi et al. evaluated patient quality of life following rib fractures 3 months after hospital discharge.<sup>2</sup> Findings revealed that many patients had difficulty performing activities of daily living, experienced a slower than expected recovery, and were not returning to preinjury level of function.<sup>2</sup> Additionally, 33% of patients were not working at their preinjury level, and 7% were using opioid pain medication.<sup>2</sup> When the same group of patients was evaluated 1 year after injury, they were found to have a suboptimal quality of life.<sup>3</sup> Rib pain persisted in 40% of

patients, and 29% had not returned to preinjury work ability.<sup>3</sup> Patients with isolated rib injuries reported outcomes similar to patients with multiple injuries in addition to rib fractures.<sup>3</sup>

### Follow-Up Care

Given the significant morbidity associated with rib fractures, these patients need follow-up care at regular intervals with clinicians knowledgeable about recovery after rib fractures. Arrange for these patients to be seen in the surgical clinic by their chest wall surgeon and surgical team at least once in the early postinjury time period. Some facilities offer a clinic focused on caring for patients with chest wall injuries.<sup>4,5</sup> These clinics need to offer access to the trauma/surgical team to ensure adequate follow-up for patients with both operative and nonoperative management. This follow-up is important to optimize patient recovery and to assess for late complications of their injuries or surgical interventions.

The appropriate time to follow up after discharge is not well studied. The CWIS recently reviewed the literature about complications after operative and nonoperative management and provided recommendations on follow-up periods for these patients. The CWIS recommended that patients who received NOM be followed for at least 1 month postinjury to capture approximately 98% of complications.<sup>6</sup> However, this recommendation does not take into account the nonunion rate, which is not well known. Van Wijck et al. reviewed CT scans at 6 months postinjury in patients with nonflail rib fractures and found a nonunion rate of 12% for rib fractures.<sup>7</sup>

Patients who undergo SSRF or surgical stabilization of sternal fractures need a planned follow-up visit at least 3 months after surgery, with additional planned appointments based on symptoms.<sup>6</sup> During follow-up visits, focus on pain management and recovery timing. Focus on evaluating the patient for signs, symptoms, and radiological evidence of pleural space complications, fractures at risk of resulting in nonunion or malunion, and hardware-related wound complications.

Be alert for the following issues:

- Patients may develop delayed pleural space complications that present in the first few weeks after discharge.<sup>8</sup>
- Patients with persistent instability of their fractures are at risk of nonunion/malunion fracture healing.<sup>9</sup> This may present as paradoxical chest wall motion or as patient report of the sensation of the ribs moving, popping, clicking, or clunking.
- Hardware complications are rare, but perform assessment for acute fixation failure, either routinely or based on symptoms, to optimize patient recovery.<sup>10</sup>

Patients with persistent symptoms after 3 to 6 months may need additional radiographic imaging. A CT scan, preferably with a 3D reconstruction, provides a better image of the ribs, the healing process, and hardware than a one- or two-view chest radiograph. Consider the location of the fractures as well as radiation dose when determining the appropriate imaging to obtain.

When patients present for follow-up, assess them for pain management, functional recovery, and late complications. Counsel patients on the appropriate timing and order of medication therapy de-escalation with the ultimate goal of eliminating all analgesic medications. Assess their functional status needs for ongoing rehabilitation services. Assess for physiologic and anatomic complications during the physical exam. Chest radiograph and ultrasound may also be used as adjuncts to the physical exam in the assessment of these complications. Some centers obtain routine radiographic assessments of patients, while others only obtain radiographic imaging if the patient shows signs or symptoms of complications.

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BEST PRACTICES GUIDELINES  
**MANAGEMENT OF  
CHEST WALL INJURIES**



# **IMPLEMENTATION AND INTEGRATION OF THE BEST PRACTICES GUIDELINES**



## GAP ANALYSIS AND EDUCATION PLAN

### KEY POINTS

- These best practices recommendations, based upon evidence and expert opinion, are intended as guidance to trauma centers for the care of patients with chest wall injuries.
- The trauma medical director (TMD), trauma program manager (TPM), trauma liaisons, registrars, and staff have a leadership role in implementing the ACS TQP *Best Practices Guidelines for the Management of Chest Wall Injuries*.
- An interdisciplinary stakeholder workgroup, receiving its directives from the TMD and trauma operations committee, implements the best practices recommendations.
- The workgroup reviews the best practices recommendations and completes a gap analysis related to the trauma center's current care for patients with chest wall injuries.

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The TMD, TPM, trauma liaisons, and registrars are leaders and change agents for implementing recommended best practices in the trauma center. These individuals are responsible for the oversight, management, and continuous commitment to improving care within the trauma center and the trauma system, regardless of trauma center designation level. These leaders define the leadership structure, culture, and implementation processes for the BPG that foster stakeholder engagement. This process includes the following:

- The chest wall injury guidelines interdisciplinary workgroup, with a defined leader and reporting structure, is charged with reviewing the BPG and determining the need to complete a gap analysis that compares current trauma center practices to the recommendations in the ACS TQP *Best Practices Guidelines for the Management of Chest Wall Injuries*.
- An education plan is developed for implementation of the trauma center's revised chest wall injury management guidelines and for sustaining new practices.
- Documentation is integrated into the electronic health record (EHR) to facilitate reporting consistency and to track outcomes.

## Performing a Gap Analysis

The chest wall injury guidelines interdisciplinary workgroup is charged with comparing current trauma center practices to those recommended after review of the BPG to identify gaps between the two. This gap analysis identifies opportunities to align the trauma center's chest wall injury management practices with the ACS TQP *Best Practices Guidelines for the Management of Chest Wall Injuries*.

The workgroup, in conjunction with the trauma center's operations committee, establishes the priorities for change. Progress reports regarding the completion of these identified tasks are provided to the trauma operations committee. Refer to Table 8 for gap analysis recommendations to consider.

**Table 8. Chest Wall Injury Best Practices Guidelines Gap Analysis Recommendations**

Gap Analysis Recommendations	Met	Partially Met	Not Met	Priority	Comments
Interfacility transfer guidelines and agreements for chest wall injury patients					
Trauma activation criteria include hemodynamic instability and/or hypoxemia if a high suspicion for a serious chest wall injury is present					
Chest tube insertion equipment available in the ED, trauma bay, ICU, and other acute care settings					
Specific imaging and reimaging recommendations for chest wall injuries					
Scoring tool for chest wall injuries with rib fractures					
Protocol for chest wall injuries, including serial pulmonary function assessments and chest tube management					
Multimodal pain management to include use of regional pain techniques and frequency of pain assessments for chest wall injuries					
Concomitant injuries and their priority in coordination with chest wall injuries					
Operative indications for chest wall injury management					
Consideration of SSRF capability or transfer out to appropriate center for management					
Performance Improvement and Patient Safety (PIPS) process to identify and address SSRF failure based on clinical criteria (e.g., infection, return to the operating room for hardware failure, failure to achieve pain control or incentive spirometer goals)					
Aggressive and early pulmonary hygiene protocol to reduce risk for pneumonia					
Documentation of pleural catheter drainage duration					
Recommendations for early tracheostomy					
Management of comorbidities and prevention of hospital events associated with chest wall injuries					
Rehabilitation guidelines for chest wall injuries					
Coordination of early mobilization					
Expected long-term outcomes assessment based on type and degree of chest wall injury					
Goals of care and functional recovery expectations discussion with patient and family					
Discharge planning coordination with patient and family					

Once the gap analysis is completed, the next step is to revise or develop the trauma center's chest wall injury management guidelines for the phases of care provided by the trauma center. These guidelines are reviewed and approved by the trauma operations committee and TMD. The operations committee is responsible for the dissemination of and communication about the revised chest wall injury management guidelines to clinicians and departments who participate in trauma care.

## Interdisciplinary Education Plan Development

The next priority is development of an interdisciplinary education plan for the revised chest wall injury management guidelines for each trauma center unit and phase of care. This education plan outlines the expectations for the various clinician roles involved in chest wall injury assessment and management, as well as the specific tasks

associated with assessment, documentation, interventions, and reassessment. Refer to Table 9 for education plan elements to consider for integration in chest wall injury best practices recommendations.

**Table 9. Education Plan Elements for Chest Wall Injury Best Practices Guidelines Integration**

Chest Wall Injury Education Elements	Priority for Education	Targeted Staff
Anatomical and physiological considerations associated with chest wall injury		
Epidemiology and patterns of chest wall injury		
Transport and triage of chest wall injury patients		
Basic assessment and imaging of chest wall injuries		
Airway and ventilation considerations in chest wall injury patients		
Indications for chest tube placement		
Management of chest wall injuries to include elements of chest tube management: <ul style="list-style-type: none"> <li>• Wet or dry set systems</li> <li>• When to seal</li> <li>• Repeat imaging</li> <li>• Metrics for when to remove</li> </ul>		
Imaging recommendations for chest wall injury patients		
Assessment of pain and implementation of pain management modalities in chest wall injury patients		
Indications for surgical management of chest wall injuries		
Complications associated with chest wall injuries		
Special considerations for assessment and management of chest wall injuries for older adults, as well as patients with multiple injuries, TBI, and pulmonary contusion		
Follow-up care and recuperation expectations for chest wall injury patients		
Quality indicators for PI		

## IMPLEMENTATION AND INTEGRATION INTO THE TRAUMA CENTER PERFORMANCE IMPROVEMENT PROCESS

### KEY POINTS

- The interdisciplinary workgroup defines which elements of the ACS TQP *Best Practices Guidelines for the Management of Chest Wall Injuries* to monitor through the trauma Performance Improvement and Patient Safety (PIPS) process.
- After approval by the trauma PIPS committee, the approved chest wall injury management elements are integrated into the existing PIPS plan for compliance monitoring.
- Trauma centers need to have predefined chest wall injury transfer criteria when surgical stabilization is indicated, and criteria compliance must be monitored by the PI process.
- The trauma registry will integrate data elements related to the management of chest wall injury to facilitate reporting and outcome reviews.

which may require regional data related to chest wall injury management and outcomes. Potential priorities for development of regional chest wall injury management guidelines include a focus on the following:

- Prehospital care, triage, and destination—requires the trauma center to share data related to chest wall injury outcomes
- Early access to rehabilitation—requires the region to identify the various levels of rehabilitation services available and the services they provide
- Postacute follow-up for all chest wall injury patients—requires the region to identify clinicians experienced in managing chest wall injury
- Psychological and peer-to-peer support—requires the region to identify community resources for patients with chest wall injuries

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The interdisciplinary workgroup defines and recommends key elements of the ACS TQP *Best Practices Guidelines for the Management of Chest Wall Injuries* to integrate into the trauma PI processes. These trauma PI recommendations are applicable to the trauma center admissions with chest wall injury. The trauma registry needs to integrate data elements related to chest wall injury management to facilitate reporting and outcome reviews. Interdisciplinary teams will integrate chest wall injury management standards into the EHR. See Table 10 for PI recommendations.

### Regional System Integration

A regional system may choose to develop a regional collaborative to review and coordinate chest wall injury management across the region. This regional collaborative initiative is interdisciplinary and needs to include rehabilitation and psychosocial services. The chest wall injury collaborative defines its priorities and focus,

**Table 10. Performance Improvement Recommendations for Management of Chest Wall Injury for Consideration by Trauma Centers (Each Trauma Center/System Will Define PIPS Elements for Review)**

Performance Improvement Recommendations	Outcome Measure and Threshold
Select a scoring system(s) that enables facility to predict outcomes (refer to Table 3).	100% of patients with severe or multiple rib fractures have a documented score prior to admission.
Clinical assessment includes an initial chest radiograph and baseline PFT.	<ul style="list-style-type: none"> <li>• An initial chest radiograph is obtained in all patients.</li> <li>• A baseline PFT is performed 100% of the time.</li> </ul>
Admission: ICU versus ward.	<p>Hospital admission location is correct for patients (based on clinical and physiologic factors) 100% of the time.</p> <p>Select parameters for facility tracking:</p> <ul style="list-style-type: none"> <li>• Rates of unplanned admission to the ICU</li> <li>• ICU bed utilization rates</li> <li>• Nonsurgical admission rates</li> </ul>
<p>Surgical management is monitored for appropriateness and timeliness.</p> <ul style="list-style-type: none"> <li>• Older adult age should not be considered an absolute contraindication for SSRF.</li> <li>• SSRF is likely beneficial in patients with TBI.</li> </ul>	<p>Patients who require SSRF undergo surgical stabilization within 72 hours.</p> <ul style="list-style-type: none"> <li>• Frequency with which SSRF is performed in older adults</li> <li>• Frequency with which SSRF is performed in patients with TBI</li> </ul> <p>Postoperative complication filters (includes both acute and late timing):</p> <ul style="list-style-type: none"> <li>• Surgical site infection</li> <li>• Unplanned return to operating room (hardware failure, nonunion, etc.)</li> </ul>
Chest tube management monitored whether or not surgical intervention is performed.	<p>Chest tube complications (duration of drain, removal complications, and reintervention rates) are documented.</p> <ul style="list-style-type: none"> <li>• Compliance with the chest tube management guideline includes suction placement, water seal parameters, and discontinuation parameters.</li> </ul> <p>Chest radiograph is obtained prior to chest tube removal.</p>
Pulmonary function assessment is initiated.	<ul style="list-style-type: none"> <li>• Incentive spirometry is documented on all patients who are participatory during hospitalization.</li> <li>• %FEV<sub>1</sub> is performed and documented on all patients who are participatory.</li> <li>• SaO<sub>2</sub> is not the only measure used to determine pulmonary function.</li> </ul>
Unplanned intubations due to respiratory failure are monitored.	<p>Unplanned intubation rates are minimal in the following patients:</p> <ul style="list-style-type: none"> <li>• Without underlying lung disease</li> <li>• Are participatory in pulmonary interventions</li> </ul>
Evidenced-based guidelines are used to implement multimodal pain management and to recommend pain assessment tools and intervals.	<p>Multimodal pain management:</p> <ul style="list-style-type: none"> <li>• 100% of patients have a validated pain assessment tool that takes more than self-report into account.</li> <li>• 100% of patients have multimodal pain management documented or considered.</li> <li>• Assessment intervals are documented.</li> <li>• Early consultation with the acute pain service is documented.</li> <li>• Older adult considerations with medications and dosing are documented.</li> </ul>

**Table 10. (continued).**

Performance Improvement Recommendations	Outcome Measure and Threshold
Early mobilization or simple interventions (such as passive movement and splinting) are an integral part of rehabilitation.	<p>Early mobilization and simple interventions are implemented as soon as clinically feasible.</p> <p>Mainstays of treatment are documented:</p> <ul style="list-style-type: none"> <li>• Aggressive clearance of airway secretions is documented.</li> <li>• Early mobilization and range-of-motion exercises are documented.</li> <li>• Other injuries (e.g., brain, spine, and orthopaedic) supersede rib fractures, and mobilization may be contraindicated in the early phases of care.</li> <li>• Daily reassessment is focused on functional respiratory capacity, with treatment adjusted accordingly.</li> </ul> <p>Other therapies are documented and reviewed for appropriateness:</p> <ul style="list-style-type: none"> <li>• TENS</li> <li>• Cryoneurolysis</li> </ul>
Timely transfers occur, especially if patient is a candidate for surgical fixation.	<p>Trauma center develops a protocol and/or guideline to aid in diagnosis, patient evaluation, indications for transfer, and timeline.</p> <p>Timeliness of transfer for patients meeting criteria for surgical intervention is documented.</p>
Psychological support, chest wall injury education, and resources are provided to the patient and family, starting at admission.	Psychological considerations are documented on all patients.
Facility monitors hospital readmission rates associated with chest wall injuries.	<ul style="list-style-type: none"> <li>• Less than 10% of patients with ED return and/or readmission are due to pain management.</li> <li>• Readmissions due to complications are minimal (&lt;10%).</li> </ul>

BEST PRACTICES GUIDELINES  
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**ACRONYMS**

**A**

ACS—American College of Surgeons  
 AI—artificial intelligence  
 AIS—Abbreviated Injury Scale  
 ATLS®—Advanced Trauma Life Support

**B**

BPGs—Best Practices Guidelines

**C**

COPD—chronic obstructive pulmonary disease  
 CT—computed tomography  
 CWIS—Chest Wall Injury Society

**D**

DVPRS - Defense and Veterans Pain Rating Scale  
 DVT—deep vein thrombosis

**E**

ED—emergency department  
 EHR—electronic health record

**F**

FEV—forced expiratory volume  
 FVC—forced vital capacity

**G**

GI—gastrointestinal

**I**

ICU—intensive care unit  
 IM—intramuscular  
 ISS—injury severity score  
 IV—intravenous

**L**

LMWH—low-molecular-weight heparin  
 LOS—length of stay

**M**

MME—morphine milligram equivalents  
 MVC—motor vehicle crash

**N**

NMDA—N-methyl-D-aspartate  
 NOM—nonoperative management  
 NPWT—negative pressure wound therapy  
 NSAID—nonsteroidal anti-inflammatory drug  
 NTDB—National Trauma Databank

**O**

ORIF—open reduction and internal fixation

**P**

PECS—pectoral nerve  
 PFT—pulmonary function test  
 PI—performance improvement  
 PIC— Pain, Inspiratory Effort, Cough  
 PIPS—Performance Improvement and Patient Safety  
 PMMA—polymethyl methacrylate  
 PVB—paravertebral block

**R**

RIG—Rib Injury Guidelines

**S**

SAB—serratus anterior block  
 SaO<sub>2</sub>—oxygen saturation  
 SCARF—Sequential Clinical Assessment of Respiratory Function  
 SSRF—surgical stabilization of rib fractures  
 STUMBL—STudy of the Management of BLunt chest wall trauma

**T**

TBI—traumatic brain injury  
 TENS—transcutaneous electrical nerve stimulation  
 TMD—trauma medical director  
 TPM—trauma program manager  
 TQIP—Trauma Quality Improvement Program  
 TQP—Trauma Quality Program

**V**

VAS—Visual Analog Scale  
 VATS—video-assisted thoracoscopic surgery

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