OPEN

Chest Wall Injury Society guidelines for surgical stabilization of rib fractures: Indications, contraindications, and timing

Zachary M. Bauman, DO, MHA, FACOS, FACS, Yuqian Tian, MD, Andrew R. Doben, MD, FACS, Sebastian D. Schubl, MD, FACS, FSIS, Fredric M. Pieracci, MD, MPH, Adam J. Kaye, MD, MHA, FACS, Christopher W. Towe, MD, Bhavik Patel, MBBS, MS, FRACS, FACS, Susan Kartiko, MD, PhD, FACS, Sarah Ann Whitbeck, MBA, MEd, FACEHP, Babak Sarani, MD, FACS, FCCM, *and* **Thomas W. White, MD, FACS**, *Omaha, Nebraska*

CONTINUING MEDICAL EDUCATION CREDIT INFORMATION

Accreditation

In support of improving patient care, this activity has been planned and implemented by CineMed and the American Association for the Surgery of Trauma. CineMed is jointly accredited by the Accreditation Council for Continuing Medical Education (ACCME), the Accreditation Council for Pharmacy Education (ACPE), and the American Nurses Credentialing Center (ANCC), to provide continuing education for the healthcare team.

AMA PRA Category 1 Credits™

CineMed designates this enduing material for a maximum of 1 *AMA PRA Category 1 Credit(s)*™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

JOINTLY ACCREDITED PROVIDER™
INTERPROFESSIONAL CONTINUING EDUCATION

Objectives

After reading the featured articles published in the *Journal of Trauma and Acute Care Surgery*, participants should be able to demonstrate increased understanding of the material specific to the article. Objectives for each article are featured at the beginning of each article and online. Test questions are at the end of the article, with a critique and specific location in the article referencing the question topic.

Disclosure Information

In accordance with the ACCME Accreditation Criteria, CineMed must ensure that anyone in a position to control the content of the educational activity (planners and speakers/authors/discussants/moderators) has disclosed all financial relationships with any commercial interest (termed by the ACCME as "ineligible companies", defined below) held in the last 36 months (see below for definitions). Please note that first authors were required to collect and submit disclosure information on behalf all other authors/contributors, if applicable.

Ineligible Company: The ACCME defines an "ineligible company" as any entity producing, marketing, selling, re-selling, or distributing health care goods or services used on or consumed by patients. Providers of clinical services directly to patients are NOT included in this definition.

Financial Relationships: Relationships in which the individual benefits by receiving a salary, royalty, intellectual property rights, consulting fee, honoraria, ownership interest (e.g., stocks, stock options or other ownership interest, excluding diversified mutual funds), or other financial benefit. Financial benefits are usually associated with roles such as employment, management position, independent contractor (including contracted research), consulting, speaking and teaching, membership on advisory committees or review panels, board membership, and other activities from which remuneration is received, or expected.

Conflict of Interest: Circumstances create a conflict of interest when an individual has an opportunity to affect CME content about products or services of a commercial interest with which he/she has a financial relationship.

The ACCME also requires that CineMed manage any reported conflict and eliminate the potential for bias during the session. Any conflicts noted below have been managed to our satisfaction. The disclosure information is intended to identify any commercial relationships and allow learners to form their own judgments. However, if you perceive a bias during the educational activity, please report it on the evaluation. All relevant financial relationships have been mitigated.

AUTHORS/CONTRIBUTORS
Zachary Bauman, Zimmer Biomet/KLS Martin/Atricure/Smith & Nephew, Consulting Fee, Consulting Fee, Sharon Gautschy; Yuqian Tian, has nothing to disclose; Andrew Doben, Zimmer Biomet/KLS Martin, Royalties/Consulting Fees, Developer/Consultant, Sharon Gautschy; Sebastian Schubl, Zimmer Biomet/Younker Hyde Macfarlane, Younker Hyde Macfarlane/Younker Hyde Macfarlane, Consultant/Expert Testimony, Sharon Gautschy; Fredric M. Pieracci, has nothing to disclose; Adam Kaye, Zimmer Biomet/Zimmer Biomet, Consulting Fee/Honoraria, Consultant/Speaker, Sharon Gautschy; Christopher Towe, Intuitive Foundation/Zimmer Biomet/ZimmerBiomet/Arthrex/Atricure, Grant/Royalties/Consulting Fee, Principal Investigator/Consultant, Sharon Gautschy; Bhavik Patel and Susan Kartiko have nothing to disclose; Sara Ann Whitbeck, Chest Wall Injury Society, Salary, CEI, Babak Sarani, Haemonetics/Acumed/Up To Date/Belmont Industry/Haemonetics/Medtronic, Honoraria/Consulting Fee, Speaker/Author/ Consultant, Sharon Gautschy; and Thomas White, KLS Martin/KLS Martin, Consulting Fee/Honoraria, Honoraria/Speaker, Sharon Gautschy.
EDITOR-IN-CHIEF/DEPUTY EDITORS/ ASSOCIATE EDITORS
Conflict of Interest forms for all Journal of Trauma and Acute Care Editors have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/D55).

Claiming Credit

To claim credit, please visit the AAST website at http://www.aast.org/ and click on the "e-Learning/MOC" tab. You must read the article, successfully complete the post-test and evaluation. Your CME certificate will be available immediately upon receiving a passing score of 75% or higher on the post-test. Post-tests receiving a score of below 75% will require a retake of the test to receive credit.

Credits can only be claimed online

Cost

For AAST members and Journal of Trauma and Acute Care Surgery subscribers there is no charge to participate in this activity. For those who are not a member or subscriber, the cost for each credit is $25.

Questions

If you have any questions, please contact AAST at 800-789-4006. Paper test and evaluations will not be accepted.

Rib fractures are a common injury following blunt chest trauma, occurring in approximately 10% of all injured patients and up to 50% after blunt chest trauma.[1–5] As the number of identified rib fractures increases, there is an exponential increase in significant pulmonary-related morbidity and mortality.[4,6] Furthermore, as computed tomography (CT) technology has advanced, so too has the ability to diagnose rib fractures with greater accuracy. One third of chest wall trauma survivors will require prolonged rehabilitation, experience chronic pain, and remain disabled for more than 6 months.[4,6] Over the last two decades, however, significant advancements in the nonoperative and operative management of rib fracture patients have resulted in improved survival and complication rates.[4,6] As pain control remains the mainstay treatment, multimodal pain regimens, locoregional analgesia, and pulmonary support continue to be important in the management of patients with chest wall injuries. In addition to the aforementioned strategies, surgical stabilization of rib fractures (SSRF) has repeatedly demonstrated an effective addition to rib fracture management.[7,8] However, there still remains a lack of consensus on indications and timing for performing SSRF.

Surgical stabilization of rib fractures was introduced as a successful and safe surgical option for rib fractures in the 1950s, specifically as a treatment for patients with flail chest (three or more consecutive ribs with at least two fractures on each rib).[4,9–11] As the basic orthopedic principles of reduction and fixation of rib fractures were applied to an injured chest wall, restoring chest wall stability helped mitigate pain and pulmonary complications from respiratory failure.[4,11–13] It also demonstrated decreased medical costs and improved short- and long-term functional outcomes for chest wall-injured patients.[4,11,12] With the advancement of rib-specific fixation devices over the last two decades, SSRF has repeatedly been shown to be safe with a low complication rate and improved patient outcomes.[4,8,11,14] Additional patient outcomes demonstrated in published literature include better patient-reported pain control, decreased narcotic use, decreased pneumonia, decreased intensive care unit (ICU) length of stay (LOS) and hospital LOS, quicker return to activities of daily living (ADLs), decreased tracheostomy rates, improved quality of life, and decreased mortality rates. As such, SSRF has quickly been adopted as a popular treatment modality for patients with rib fractures.[1,2,7,11–15] The quantity and quality of research and literature supporting the benefits of this operation continue to increase exponentially.

Despite this data, there remains hesitancy among surgeons caring for these patients to perform SSRF. This is often said to be related to a paucity of guidelines and indications for SSRF. This project aims to provide evidence-based indications for SSRF in the form of a guideline to serve as a foundation for surgeons caring for their chest wall-injured patients.

PATIENTS AND METHODS

An extensive literature search was conducted using the keywords "rib fractures," "chest wall injury," "surgical stabilization of rib fractures," "rib fixation," "rib fracture stabilization," and "rib fracture management" from 2000 to 2023. Search results were grouped based on similar characteristics for creating the guidelines, including SSRF indications and contraindications, pain management, chest wall injury imaging, and SSRF timing. The guidelines were created based on the summary of information from this literature search and expert opinion from the surgeon authors of this article. Once this was completed, the guidelines were brought before a larger group of experts, the membership of the Chest Wall Injury Society (CWIS). At this point, the guidelines were edited and adjusted per recommendations made from the membership. Once this was completed, the final guidelines were completed. The surgeon authors of this article then voted on each recommendation of the guidelines whether or not they supported that recommendation (Table 1). This was then sent to the CWIS Executive Committee and Board of Directors for vetting who unanimously agreed upon the guidelines. Lastly, the guidelines/algorithm was voted on by the CWIS membership as a whole for adoption as the official SSRF guidelines of the organization. The CWIS is a society of experts in chest wall injury management, dedicated to optimizing the operative and nonoperative care of patients with chest wall injuries. These guidelines are meant to serve as a foundation for identifying patients who may potentially benefit from SSRF and can be modified as needed for individual patient needs. Of note, the guidelines/algorithm was originally created in 2019 and revised and updated in 2023, so this is the second iteration of the guidelines. The remainder of this article will explore the entirety of the guidelines with a discussion about each portion. The full algorithm can be seen in Figure 1.

INITIAL EVALUATION AND MANAGEMENT

Imaging

As one of the adjuncts of the primary survey in trauma, chest x-rays are obtained in almost all trauma patients during the early stage of evaluation, aiming to identify life-threatening

Submitted: February 13, 2025, Revised: June 13, 2025, Accepted: June 15, 2025, Published online: August 13, 2025.

From the Division of Trauma, Emergency General Surgery and Critical Care Surgery, Department of Surgery (Z.M.B., Y.T.), University of Nebraska Medical Center, Omaha, Nebraska; Division of Acute Care Surgery (A.R.D.), St. Francis Hospital and Medical Center, University of Connecticut School of Medicine, Springfield, Massachusetts; Department of Surgery (S.D.S.), Irvine School of Medicine, University of California, Orange, California; Denver Health Medical Center (F.M.P.), Denver, Colorado; Division of Trauma and Acute Care Surgery (A.J.K.), St. Mary's Medical Center, Langhorne, Pennsylvania; University Hospitals (C.W.T.), Case Western Reserve University School of Medicine, Cleveland, Ohio; Gold Coast University Hospital (B.P.), Queensland, Australia; Department of Surgery (S.K., B.S.), The George Washington University SMHS, Washington, DC; Chest Wall Injury Society (S.A.W.), Salt Lake City, Utah; and Division of Trauma and Critical Care Surgery, Department of Surgery (T.W.W.), Intermountain Medical Center, Salt Lake City, Utah.

This study was presented at the 7th Annual Chest Wall Injury Society Summit, April 27, 2023, in Charlotte, North Carolina.

Address for correspondence: Zachary M. Bauman, DO, MHA, FACOS, FACS, Division of Trauma, Emergency General Surgery, Critical Care Surgery, Department of Surgery, University of Nebraska Medical Center, 983280 Nebraska Medical Center, Omaha, NE 68198-3280; E-mail: zachary.bauman@unmc.edu.

DOI: 10.1097/TA.0000000000004750

TABLE 1. Author Consensus on Guideline Recommendations

Recommendation	n	Agree	Disagree	%
1. All chest wall injured patients should have a CT scan of their chest prior to rib fixation to assess the extent of chest wall damage	11	11	0	100%
2. Respiratory status should be determined with incentive spirometry as early as possible to assess baseline	11	11	0	100%
3. All rib fracture patients should be placed on a multimodal pain regimen	11	11	0	100%
4. All rib fracture patients should be assessed for the use of locoregional pain therapy	11	11	0	100%
5. On-going shock is considered an absolute contraindication for SSRF	11	10	1	91%
6. Once the shock state is resolved, it is okay for SSRF to be considered	11	11	0	100%
7. Nonsurvivable TBI is an absolute contraindication for SSRF	11	10	1	91%
8. If a patient has chest wall injury instability defined by the following, it would be an indication for SSRF:				
a. Flail chest on imaging (three or more consecutive, ipsilateral rib fractures with two or more fractures per rib on imaging)	11	11	0	100%
b. Flail chest with paradoxical chest wall motion clinically	11	11	0	100%
c. Off set rib fractures: 3+ ipsilateral rib fractures with 100% rib width displacement on axial CT imaging	11	11	0	100%
d. Palpable chest wall instability or clicking/popping reported by the patient from the rib fractures	11	11	0	100%
9. If the patient is on the ventilator and the failure to wean is due to the rib fractures, this should be an indication for SSRF	11	11	0	100%
10. If the patient is not on the ventilator, has 3 or more rib fractures that are displaced 50% or more on the axial cut of the CT scan, and has the presence of 2 or more pulmonary derangements, this should be an indication for SSRF	11	11	0	100%
11. The following should be considered a pulmonary derangement:				
a. Respiratory rate consistently greater than 20 breaths per minute	11	11	0	100%
b. Incentive spirometry values less than 50% predicted or moving in the wrong direction	11	11	0	100%
c. Pain score consistently greater than 5 out of 10	11	10	1	91%
d. Poor cough	11	11	0	100%
12. Other surgical priorities should be addressed before SSRF, which should be considered on an individual patient basis and discussed with other surgical specialties	11	11	0	100%
13. All SSRF procedures should occur within 72 h of injury when possible	11	11	0	100%
14. SSRF should not be avoided if it cannot be performed within 72 h of injury if the patient meets the indications for the operation and it would provide benefit to the patient	11	11	0	100%
15. The following could be considered relative contraindications for performing SSRF:				
a. Pediatric patient	11	11	0	100%
b. Significant comorbidities following multi-disciplinary discussions	11	11	0	100%
c. Post-CPR fractures	11	10	1	91%
d. Severe TBI	11	11	0	100%
e. Spinal cord injury/unstable spinal fractures	11	11	0	100%
f. Empyema	11	11	0	100%
g. Pulmonary contusion(s)	11	10	1	91%
h. Acute cardiac event	11	11	0	100%
i. Uncorrected coagulopathy	11	11	0	100%

thoracic injuries such as pneumothorax, hemothorax, and widened mediastinum associated with aortic injury. However, it has low sensitivity in detecting rib fractures, missing up to 50% to 74.5% of them.[16,17] In current practice, computed tomography (CT) plays a significant role in identifying traumatic injuries that may not be clinically overt during the initial trauma evaluation. Chest CT has been used more in blunt thoracic trauma to identify and evaluate thoracic and pulmonary injuries, including rib fractures, with increased sensitivity.[18] Most studies agree that chest CT aids diagnosis and clinical management, but whether it improves clinical outcomes is still debatable.[17,19–22] Chest CT also provides important anatomical details that guide interventions for pain management and/or surgical planning and is more likely to identify other pulmonary complications associated with rib fractures.[17,23] It is therefore recommended to obtain a chest CT to truly assess the number and severity of rib fractures, as well as help determine if the patient is a candidate for SSRF. If the patient is determined to be a candidate for SSRF, cross-sectional imaging should help with surgical planning, including approach, incision placement, and patient positioning.

Incentive Spirometry

Tools to assess respiratory function are also recommended during the initial evaluation. Respiration rate, oxygen saturation, and ventilator settings with arterial blood gas, if intubated, should be used to assess respiratory functions. The achieved incentive spirometer (IS) volume in relation to the predicted IS volume based on age, sex, and patient height is also commonly used as a metric for evaluating respiratory function. Previous research has shown that IS is a validated surrogate for vital capacity, which can help predict pulmonary complications after rib fractures.[24] Therefore, it is recommended to obtain a baseline IS value for patients with rib fractures as early as possible to help guide clinical and operative decision making as values < 50% predicted based on device nomogram or downward trends may indicate a need for SSRF.

Pain Management

Early and effective pain control is a critical step in the management of rib fractures. The restricted chest wall motion and weak coughing effort because of poor pain control can lead

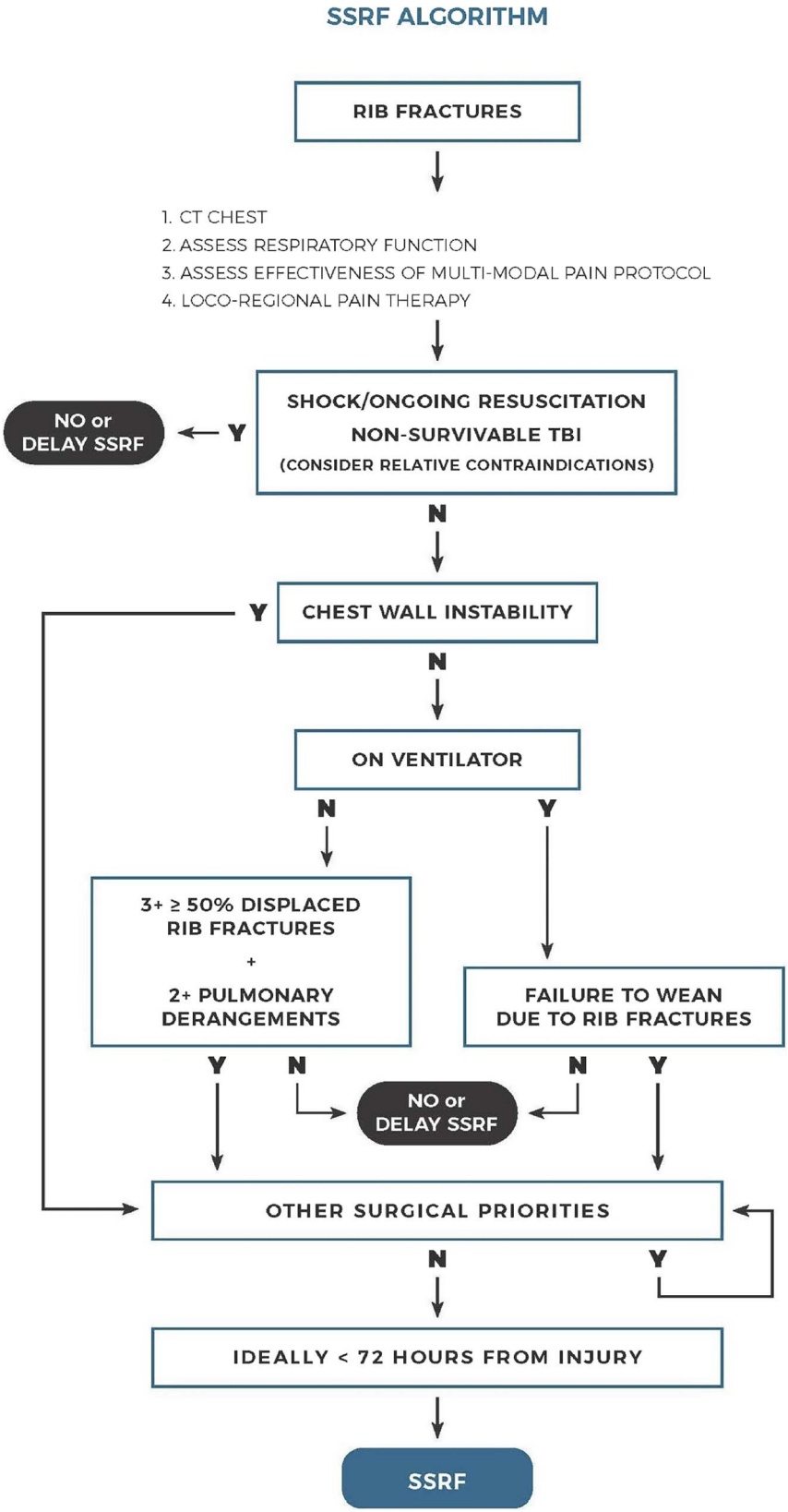

Figure 1. Surgical stabilization of rib fractures algorithm. N, no; Y, yes.

to reduced tidal volume and alveolar collapse. Decreased lung expansion predisposes patients to pulmonary complications and ultimately, poor clinical outcomes. Multimodal analgesia and locoregional anesthesia in selective cases are recommended to achieve optimal pain control while limiting narcotic use in light of their potential adverse effects.[25] Given recent practice management guidelines, locoregional analgesia should focus more on paravertebral, erector spinae, and serratus anterior blockade. Historical use of thoracic epidurals has been surpassed by more focused techniques because of their high adverse-effect profile, often difficult placement, and contraindications in polytrauma patients.[4,26] This guideline does not specify a multimodal/locoregional pain regimen. However, the authors encourage institutions to develop an institutional-specific protocol for rib fracture patients based on available pain medications and procedural capabilities for locoregional analgesia. These protocols for optimal pain management remain critical in rib fracture management whether or not the patient undergoes surgery.[4]

INDICATIONS FOR SSRF

Chest Wall Instability

Chest wall instability can be defined as the presence of a clinical flail chest with paradoxical chest wall motion, offset fractures with chest wall motion, or "clicking/popping" with palpation or as reported by the patient. Chest wall instability is considered an indication for SSRF. This patient population often sustains polytrauma with concomitant surgical priorities that may be addressed first (e.g., unstable spinal injury, open abdomen, significant vascular trauma, and pelvic external fixation); however, SSRF should be completed as soon as patient stability allows.

Definition of Flail Chest

Radiographic flail chest occurs when three or more consecutive ribs have fractures in two or more separate locations. Clinical flail chest is defined by paradoxical chest wall motion, disrupting respiratory effort and decreasing lung volume capacity.[2,27–30] An effective breath comes from orchestrated actions of the diaphragm, external and internal costal muscles, and accessory muscles. The injured segment in the flail chest moves paradoxically and independently from the remaining chest wall, leading to ineffective ventilation and chest wall instability. This is commonly associated with underlying pulmonary contusions and significant rib fracture pain, both contributing to poor pulmonary outcomes.[2–4,11,23,27]

Flail chest from rib fractures is the most researched and established indication for SSRF.[2–4,7,8,11,27] As early as the 1990s, a retrospective cohort study recognized better clinical outcomes among trauma patients with flail chest undergoing SSRF.[28] Since then, six prospective, randomized clinical trials have demonstrated that SSRF for flail chest leads to improved clinical outcomes, including shorter periods of mechanical ventilation, shorter ICU stay, decreased rates of pneumonia and other pulmonary complications, decreased need for tracheostomy, faster return to ADLs, decreased pain (especially with coughing and deep breathing), and/or decreased mortality.[29,31–35] Multiple additional studies have confirmed these conclusions via systematic reviews and meta-analyses.[27,30,36–42] Previously published practice management guidelines and consensus statements have supported SSRF for flail chest given the significant benefits demonstrated in the aforementioned literature.[2,3]

Offset Fractures

Offset fractures are defined as three or more ipsilateral fractures with displacement of 100% the rib width (also known as bicortical displacement) on CT.[43,44] Offset fractures significantly disrupt the continuity of the chest wall and negatively affect ventilation and respiratory mechanics.[43,44] Bicortical displacement of three or more rib fractures also results in an unstable chest wall but without the paradoxical motion physiology. Although fewer prospective studies have studied SSRF outcomes in this rib fracture pattern, a recent prospective trial sponsored by the CWIS demonstrated benefits from surgical management. This clinical study (CWIS NON-FLAIL) conducted by Pieracci et al.[8] revealed that patients with three or more severely displaced rib fractures in the absence of flail chest benefit from SSRF in terms of better pain control and improved respiratory disability-related quality of life. Several retrospective studies have also demonstrated benefits of SSRF (decreased pain, shorter ICU and hospital LOS, decreased pulmonary complications and need for tracheostomy, quicker return to ADLs, and better quality of life) in patients with offset rib fractures.[45–47]

Clicking/Popping

"Clicking and/or popping" is a sensation felt by the patient or on palpation by the clinician of fracture movement at the fracture site when the patient moves or breathes. Although it may not necessarily affect respiratory mechanics, the clicking/popping can result in significant chest wall instability with breathing, pain, and decreased ability to perform ADLs. Clicking/popping has a higher association with rib fracture nonunion.[1,48,49] Given these symptoms, clicking and/or popping may be considered as an unstable chest wall and as an indication of SSRF, regardless of CT findings.

Patients Requiring Mechanical Ventilation

Patients who are intubated because of significant respiratory distress from rib fractures, without parenchymal injury, and fail to progress to a spontaneous breathing within 48 hours of injury, by definition, are considered "failure to wean."[50] Patients who tolerate a spontaneous breathing trial for 60 minutes or more but exhibit two or more of the following signs of respiratory stress clearly associated with the initiation of the spontaneous breathing trial are also included in the definition of failure to wean[50]:

- Increased respiratory rate >35 breaths per minute
- Increased heart rate >140 beats per minute
- Oxygen saturation below 90%
- Rapid shallow breathing index (respiratory rate/tidal volume in liters) >105
- Signs of anxiety
- Diaphoresis
- Signs of agitation.

Patients may be considered for SSRF if they have three or more rib fractures and fail to wean from the ventilator, and it is determined that the failure is due to the rib fractures. In the flail chest population receiving SSRF, a consistent finding is a

decreased length of mechanical ventilation (MV) need, which ultimately contributes to a lower rate of complications from MV.[2–4,6,7,11,27,29,31–34,51] Additional prospective and retrospective studies have also evaluated the effect of SSRF on rib fracture patients without flail chest with MV needs and suggest that SSRF can facilitate weaning from MV in patients with severe blunt chest wall injuries.[2,4,7,11–14,34,52,53] Based on expert opinions and observed outcomes in current literature, many centers performing SSRF use failure to wean from MV as an indications for SSRF.[2,54,55]

Patients Not on Mechanical Ventilation

If a patient has rib fractures but is not on MV, a different approach to assessing the patient for SSRF must be undertaken. If the patient has chest wall instability, significant deformity, and/or substantial lung volume loss, SSRF should be considered. If these factors are not present, a thorough evaluation of the patient's chest CT should occur. Patients with three or more ipsilateral rib fractures that are 50% or more displaced on the axial CT scan should then be clinically evaluated. The patient with these radiographic findings combined with two or more of the following pulmonary derangements should be considered for SSRF:

- Respiratory rate > 20 breaths per minute
- Incentive spirometry value < 50% of predicted (or a value that is moving in a negative direction)
- Consistent numerical pain score > 5 out of 10
- Poor cough.

These pulmonary physiologic derangements are commonly included in rib fracture scoring systems that identify chest wall injury patients at high risk for pulmonary complications. The Pain, Inspiratory Effort, Cough score developed by Bass et al.[56] provides a composite score based on the numeric pain scale, IS volume, and cough strength that can predict potential respiratory failure and critical care needs with moderate confidence in patients with rib fractures. Furthermore, it has been shown in rib fracture patients that every 10% increase in vital capacity is associated with a significantly lower discharge to an extended care facility (odds ratio, 0.74; $p < 0.0001$) and a significantly lower risk of a pulmonary complication (odds ratio, 0.64; $p < 0.0001$).[24] This study also demonstrated that a vital capacity great than 50% was statistically significant for a lower risk of pulmonary complications ($p = 0.018$).[24] Since IS can be used to determine vital capacity, and given these previous findings, an IS value of less than 50% predicted (or a trend in a negative direction) was identified as pulmonary derangement for these guidelines since SSRF can improve upon this value.[24] Lastly, a previous prospective study by Pieracci et al.[8] used these four pulmonary parameters in addition to three or more severely displaced rib fractures (> 50% of the rib width on axial CT imaging) as inclusion criteria. The improved outcomes, including improved pain scores with decreased narcotic consumption, reduced pleural space complications, and improved respiratory disability-related quality of life, suggest that patients with two or more of these pulmonary derangements in the presence of three or more severely displaced rib fractures can be given consideration for SSRF.[8]

Several recent retrospective studies demonstrate that rib fractures become more displaced over time.[1,57] Therefore, it is important to remember the incipient chest CT scan may underrepresent the severity of a patient's rib fracture displacement, which may not be apparent for several days after the initial trauma.[1,57] Surgeons are strongly encouraged to personally review chest CT scans, as radiologists are often not as well versed in the terminology or classification of rib fracture displacement.[58] The authors of this guideline are not advocating for routine repeat chest CT. If the patient's pulmonary status declines or there is a progression of chest wall instability, consideration may be given for SSRF, regardless of the displacement shown on the initial CT.

Another pulmonary derangement, which may provide guidance for SSRF, is inadequate pain control. Pain is a subjective measure based on the patient's experiences and tolerance and can pose a challenge as a surgical indication. Several prospective and retrospective cohort studies have demonstrated that patients who underwent SSRF achieve greater pain relief following surgery compared with a nonoperative medical treatment group.[8,46,59–61] Additional studies are currently underway, examining the implementation of SSRF for pain control for rib fractures. Expert opinion recommends that optimal multimodal analgesia should be the first-line treatment for rib fracture pain. Surgical stabilization of rib fractures may be considered for refractory pain despite maximal optimization of multimodal analgesia and locoregional techniques. Surgical stabilization of rib fractures may also be indicated for nonventilated trauma patients with progressive respiratory failure or a worsening respiratory function stratification score. The most overt sign would be worsening hypoxia requiring invasive or noninvasive mechanical ventilation. Several scoring systems for trauma patients with rib fractures can be used to augment clinical judgment. The Sequential Clinical Assessment of Respiratory Function (SCARF) score is a prognostic tool using dynamic pulmonary parameters, specifically, IS volume, respiratory rate, numeric pain score, and cough effort.[62] A worsening SCARF score is associated with a higher risk of pneumonia and longer ICU stay.[62] The STUdy of the Management of BLunt chest wall trauma (STUMBL) score identifies patients at increased risk of developing pulmonary complications (i.e., pulmonary infection, pleural effusion, pneumothorax, hemothorax, or empyema) or who require ICU admission, have a prolonged hospital stay >7 days, or suffer a mortality because of their rib fractures.[63] Surgical stabilization of rib fractures has been shown to improve many of these outcomes; therefore, using SCARF or STUMBL may help identify patients who may benefit from SSRF to mitigate complications.[63] Several other respiratory stratification scores currently exist to help guide chest wall injury management. Although discussion of all these scores is outside the scope of this article, the authors strongly encourage their use. When these prognostic scoring tools are applied and predict worse outcomes, utilization of SSRF may be considered to help improve outcomes.

Decision to Perform SSRF

Once the decision to perform SSRF has been made, the timing of the surgery should be optimized in relation to other injuries that may take surgical priority. If the patient has “life or limb” threatening injuries that require operation, those procedures should take precedence over SSRF. For example, when positioning for SSRF, it is preferable that the abdomen is closed;

however, an open abdomen does not constitute an absolute contraindication for SSRF. Recent data suggest that it is safe to perform SSRF before definitive repair of nonurgent pelvic injuries.[64] If an external pelvic fixator is present, appropriate padding and careful positioning are mandatory.[64] Finally, consideration should be given to performing combined procedures. It is always preferable to avoid multiple operations and exposure to anesthetics when possible. Therefore, if feasible, SSRF should be performed in conjunction with other operations. It is important to examine the risks and benefits when timing SSRF compared with other surgical needs and discussed with all involved providers.

Timing of SSRF

Ideally, SSRF should be performed within 72 hours of the initial injury, as several retrospective studies have demonstrated improved patient outcomes, including improved pain control, shorter ICU and hospital LOS, decreased ventilator days, decreased rates of pneumonia, decreased need for tracheostomy, decreased operative times, and earlier mobilization and return to ADLs.[65–69] Furthermore, a recent prospective, randomized controlled trial demonstrated even greater benefits of performing SSRF within 48 hours, including decreased hospital costs and decreased inflammatory cytokine levels and infection biomarker levels, preventing hyperinflammation and further reducing infection rates.[70] All attempts should be made to perform SSRF as early as possible after the initial injury. It is important to note that when SSRF cannot be performed within 72 hours, the potential for the procedure should not be abandoned altogether. Clinical gains are still possible outside of this initial time window.

ABSOLUTE CONTRAINDICATIONS TO SSRF

Patients who are actively receiving resuscitation for their injuries should not undergo SSRF. The word "resuscitation" has no uniform definition. Therefore, it is recommended that patients be evaluated on an individual case basis. It is important to recognize that, although a patient may be actively receiving resuscitation, patients may remain candidates for SSRF once the process is completed. Careful reevaluation of patients meeting criteria will allow for timely SSRF once resuscitation efforts have been completed.

Nonsurvivable traumatic brain injury (TBI) is an absolute contraindication for SSRF. It is well-known that TBI can be a difficult injury to prognosticate; however, in cases where TBI is deemed nonsurvivable (likely determined by a neurosurgeon), SSRF should not be undertaken. Further discussion about the survivable TBI patients and their appropriateness for SSRF is described in more detail in the Relative Contraindications section.

RELATIVE CONTRAINDICATIONS TO SSRF

Pediatric Patients

There is a paucity of data regarding SSRF in the pediatric population. One theoretical concern is the disruption of normal rib growth following surgical intervention. However, several case reports have described successful SSRF in pediatric patients.[71] The previously discussed inclusion criteria for SSRF should be applied on an individual basis for pediatric patients. Additionally, the pediatric patient's bone development should be assessed. If needed, the pediatric patient may be returned to the OR for plate removal after the initial SSRF and the fractures are healed to allow for continued bone growth.

Significant Comorbidities and Frailty

Elderly patients (older than 65 years) with multiple comorbidities and/or increased frailty may not be considered ideal candidates to undergo the stress associated with surgery. However, multiple retrospective studies have demonstrated outcome benefits specific to this patient population when undergoing SSRF, including decreased mortality, pneumonia rates, ICU and hospital LOS, narcotic usage, faster return to ADLs, improved sleep hygiene, and higher likelihood of discharge to home.[11,15,72–75] Given the inability of those patients with multiple comorbidities or increased age/frailty to tolerate multiple rib fractures, the risks of SSRF can be less than the risks of developing a complication from the rib fractures themselves.[11,15,72–76] It is also well-known that comorbidities often occur on a spectrum of severity, making the decision to perform SSRF even more challenging. Collaboration with all care teams before surgery will best optimize patient outcomes. It is important to weigh all risks and benefits of SSRF for the elderly, frail, or those with multiple comorbidities while strongly considering the increased risk of poor outcomes associated with nonoperative management.

Post–Cardiopulmonary Resuscitation Fractures

Small case series and case reports have demonstrated benefits in performing SSRF for patients with severe rib fractures resulting from cardiopulmonary resuscitation (CPR).[77,78] These benefits include liberation from MV, improved pulmonary function, and better performance with rehabilitation.[77,78] These fractures can often be complex, involving bilateral ribs, the costochondral portion of the ribs, and the sternum. The sheer nature of cardiac arrest and the requirement of CPR suggest that these patients are often initially unstable and may have some underlying neurologic derangements. Therefore, it is important to evaluate these patients on an individual basis to ensure that they are appropriate for the operation before proceeding with SSRF.

Severe TBI/Intracranial Hypertension

Significant controversy persists regarding the role and timing of SSRF in patients with traumatic brain injuries. Recent retrospective studies have demonstrated mortality benefits, decreased time on MV, and shorter ICU and hospital LOS in patients with concomitant rib fractures and moderate to severe TBI undergoing SSRF.[79–82] Often, the progression of TBI is uncertain. Hence, careful patient selection is required to determine if a given TBI patient will truly receive the benefits associated with SSRF. It is also important to consider one of the key tenants in the management of patients with moderate to severe TBI: prevention of hypotension and hypoxia.[83] If the chest wall injury is severe, especially with the paradoxical motion that can arise from a flail chest, and the patient is hypoxic, consideration should be given to SSRF to help alleviate hypoxia and prevent secondary brain insult. As always, a thorough discussion should occur with the patient's family or medical decision maker regarding expectations and goals of care.

Spinal Cord Injury/Unstable Spinal Fracture

Spinal cord injury and vertebral body fractures occur on a spectrum of severity, and patients with concomitant rib fractures should be evaluated on an individual basis for SSRF. Available studies suggest that SSRF combined with spinal surgery is feasible and safe and can result in better outcomes.[84,85] The timing of SSRF still remains controversial regarding which procedure (SSRF vs. spinal fixation) should occur first. Recognizing spinal stabilization often requires a prolonged period of prone positioning, severe chest wall trauma (especially flail chest) can potentially result in aborting the spinal repair due to ongoing intraoperative hypoxia.[85,86] Therefore, it may be beneficial, in these instances, to perform SSRF before the spinal stabilization. Discussions with the spinal surgeon should occur to determine which procedure should be performed first to minimize operative risk while the patient is positioned for the spinal surgery. Care should always be taken when moving these patients to minimize spine movement. Furthermore, the patient's level of spinal injury should influence the decision to perform SSRF for symptom relief and/or tracheostomy prevention.

Empyema

Empyema increases the risk of hardware infections. However, SSRF may still be appropriate in select cases, especially if respiratory mechanics are compromised because of the rib fractures. Isolated case reports indicate successful SSRF in patients with empyema.[86,87] A few prospective and retrospective studies have demonstrated a reduction in empyema formation because of the evacuation of any retained hemothorax with hemithorax irrigation.[8,88] Prolonged antibiotics will likely be necessary, and hardware may need to be removed once the rib fractures are healed.[89] For these reasons, empyema should not be considered an absolute contraindication to performing SSRF.[86]

Pulmonary Contusions

Historically, the presence of severe pulmonary contusions served as a contraindication for SSRF. Recent literature has shown that SSRF can be done safely and may be considered in patients sustaining any severity level of pulmonary contusions.[65,90–92] In some instances, it may be of greater benefit for patients with rib fractures and pulmonary contusions to undergo rib fixation without delay based on some retrospective data.[65]

Acute Cardiac Event

Patients experiencing an acute cardiac event should avoid undergoing early urgent/semi-elective operations, given their need for anticoagulation/antiplatelet medications.[93] The more time allotted between an acute cardiac event and noncardiac surgery demonstrates a substantial decrease in postoperative myocardial infarction.[94] If SSRF is necessary because of factors such as ongoing hypoxia from a severe flail chest, discussions with cardiology and anesthesia, and a preoperative cardiac workup are strongly recommended.[93] Perioperative cardiac surveillance for cardiac events and the continuation of ongoing cardiovascular medical therapy are key.[93] Patients falling into this category with rib fractures should be evaluated on an individual basis, weighing all risks and benefits.

Uncorrected Coagulopathy

Coagulopathy should be corrected before performing SSRF when possible. Surgical intervention may be considered for patients with deranged coagulopathy if clinically indicated. Still, all risks and benefits must be weighed and discussed with the patient and family during the consenting process.[95] It is not unreasonable to proceed with SSRF if the degree of coagulopathy is minimal, but all attempts should be made to correct it before surgical intervention.[95] When possible, antiplatelet medication should be continued, especially if the patient has had a previous coronary artery intervention.[95]

Limitations

There are some limitations to this set of guidelines. First, these guidelines were created through the CWIS based on current literature and expert opinion from members of the organization itself. Although all attempts were made to make the methodology as robust as possible, other guideline methodologies such as GRADE or PRISMA were not used. The authors do think, however, that the method used for this guideline is a good starting point to a provide a strong foundation for surgeons considering SSRF for their rib fracture patients. Future revisions of this guideline should use one of these more structured methods. Second, these guidelines were created using literature through 2023. Although these guidelines still hold true today, future revisions will include more timely articles as reference. Lastly, these guidelines provide a framework for providers, and some of the recommendations may not have literature to support them, but rather the experience of expert surgeons performing this operation. Therefore, it is important to not exclude patients who do not necessarily fall into these guidelines, especially if there is the thought they may obtain the benefits from SSRF.

CONCLUSION

The SSRF continues to demonstrate viability as a treatment option for patients with rib fractures. These guidelines represent the current opinions of chest wall injury expert surgeons, their practice patterns, and the best available research evidence. These guidelines must be adjusted based on the surgeon's judgment and available clinical resources but can serve as a solid foundation for driving decision making around surgical intervention.

SUMMARY OF RECOMMENDATIONS

Indications

Ventilated Patients

1. Chest wall instability
   a. Three or more bicortical rib fractures with greater than 50% displacement on imaging
   b. Paradoxical chest wall motion (may not see with positive pressure ventilation)
   c. Significant chest wall deformity (volume loss ≥ 20%)
   d. Clicking or popping reported by the patient or palpated by the health care provider

2. Failure to wean from mechanical ventilation because of chest wall instability

Nonventilated Patients

1. Chest wall instability
   a. Three or more bicortical rib fractures with greater than 50% displacement on imaging

b. Paradoxical chest wall motion
c. Significant chest wall deformity (volume loss ≥ 20%)
d. Clicking or popping reported by the patient or palpated by the health care provider

2. Progressive respiratory failure or failure to improve despite multimodal analgesia

3. Three or more displaced rib fractures with two or more pulmonary physiologic derangements
a. Respiratory rate ≥ 20 breaths per minute
b. Incentive spirometry value < 50% of predicted (or a value that is moving in a negative direction)
c. Numeric pain score consistently greater than 5 out of 10
d. Poor cough

4. Abnormal/worsening stratification score (e.g., SCARF, STUMBL, RibScore)

Contraindications

Absolute

1. Hemodynamic instability with ongoing resuscitation
2. Nonsurvivable brain injury

Relative

1. Pediatric patients
2. Significant comorbidities, following multidisciplinary discussion
3. Post-CPR fractures
4. Severe TBI
5. Spinal cord injury/unstable spinal fractures
6. Empyema
7. Pulmonary contusion
8. Acute cardiac event
9. Uncorrected coagulopathy

Timing

1. Earliest feasible time — ideally within 72 hours of injury
2. SSRF may be delayed in the face of additional high-priority injuries
3. SSRF may be safely combined with other surgical procedures when practical (e.g., open reduction internal fixation of the spine, pelvis, scapula, others)

AUTHORSHIP

All authors participated in the literature search and creation of these guidelines. All authors participated in in writing and editing this manuscript.

DISCLOSURE

Conflicts of Interest: Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/E719).

REFERENCES

1. Bauman ZM, Grams B, Yanala U, Shostrom V, Waibel B, Evans CH, et al. Rib fracture displacement worsens over time. *Eur J Trauma Emerg Surg*. 2021;47:1965–1970.
2. Pieracci FM, Majercik S, Ali-Osman F, Ang D, Doben A, Edwards JG, French B, et al. Consensus statement: surgical stabilization of rib fractures rib fracture colloquium clinical practice guidelines. *Injury*. 2017;48:307–321.
3. Kasotakis G, Hasenboehler EA, Streib EW, Patel N, Patel MB, Alarcon L, et al. Operative fixation of rib fractures after blunt trauma: a practice management guideline from the Eastern Association for the Surgery of Trauma. *J Trauma Acute Care Surg*. 2017;82(3):618–626.
4. Stopenski S, Binkley J, Schubl SD, Bauman ZM. Rib fracture management: a review of surgical stabilization, regional analgesia, and intercostal nerve cryoablation. *Surgery in Practice and Science*. 2022;10:100089.
5. Martin TJ, Eltorai AS, Dunn R, Varone A, Joyce MF, Kheirbek T, et al. Clinical management of rib fractures and methods for prevention of pulmonary complications: a review. *Injury*. 2019;50:1159–1165.
6. Kane ED, Jeremitsky E, Pieracci FM, Majercik S, Doben AR. Quantifying and exploring the recent national increase in surgical stabilization of rib fractures. *J Trauma Acute Care Surg*. 2017;83(6):1047–1052.
7. Eriksson EA, Wijffels MME, Kaye A, Forrester JD, Moutinho M, Majerick S, et al. Incidence of surgical rib fixation at Chest Wall Injury Society Collaborative Centers and a guide for expected number of cases (CWIS-CC1). *Eur J Trauma Emerg Surg*. 2024;50(2):417–423.
8. Pieracci FM, Leasia K, Bauman Z, Eriksson EA, Lottenberg L, Majerick S, et al. A multicenter, prospective, controlled clinical trial of surgical stabilization of rib fractures in patients with severe, nonflail fracture patterns (Chest Wall Injury Society NON-FLAIL). *J Trauma Acute Care Surg*. 2020;88(2):249–257.
9. Proctor H, London PS. The stove-in chest with paradoxical respiration. *Br J Surg*. 1955;42(176):622–633.
10. Coleman FP, Coleman CL. Fracture of ribs; a logical treatment. *Surg Gynecol Obstet*. 1950;90(2):129–134.
11. Sarani B, Pieracci F. Contemporary management of patients with multiple rib fractures: what you need to know. *J Trauma Acute Care Surg*. 2024;97(3):337–342.
12. Zhang Q, Song L, Ning S, Xie H, Li N, Wang Y. Recent advances in rib fracture fixation. *J Thorac Dis*. 2019;11(Supp8):S1070–S1077.
13. Fokin AA, Hus N, Wyceeh J, Rodriguez E, Puente I. Surgical stabilization of rib fractures. *JBJS Essent Surg Tech*. 2020;10(2):e0032.
14. Su YH, Yang SM, Haung CH, Ko HJ. Early versus late surgical stabilization of severe rib fractures in patients with respiratory failure: a retrospective study. *PloS One*. 2019;14(4):e0216170.
15. Pieracci FM, Leasia K, Hernandez MC, Kim B, Cantrell E, Bauman Z, et al. Surgical stabilization of rib fractures in octogenarians and beyond-what are the outcomes? *J Trauma Acute Care Surg*. 2021;90(6):1014–1021.
16. Expert Panel on Thoracic Imaging, Henry TS, Donnelly EF, Boiselle PM, Crabtree TD, Iannettoni MD, et al. ACR Appropriateness Criteria® rib fractures. *J Am Coll Radiol*. 2019;16(5S):S227–S234.
17. Chapman BC, Overbey DM, Tesfalidey F, Schramm K, Stovall RT, French A, et al. Clinical utility of chest computed tomography in patients with rib fractures CT chest and rib fractures. *Arch Trauma Res*. 2016;5(4):e37070.
18. Murphy CE 4th, Raja AS, Baumann BM, Medak AJ, Langdorf MI, Nishijima DK, et al. Rib fracture diagnosis in the panscan era. *Ann Emerg Med*. 2017;70(6):904–909.
19. Kaiser M, Whealon M, Barrios C, Dobson S, Malinoski D, Dolich M, et al. The clinical significance of occult thoracic injury in blunt trauma patients. *Am Surg*. 2010;76(10):1063–1066.
20. Guerrero-López F, Vazquez-Mata G, Alcazar-Romero PP, Fernander-Mondejar E, Aguayo-Hoyos E, Linde-Valverde CM. Evaluation of the utility of computed tomography in the initial assessment of the critical care patient with chest trauma. *Crit Care Med*. 2000;28(5):1370–1375.
21. Exadaktylos AK, Sclabas G, Schmid SW, Schaller B, Zimmermann H. Do we really need routine computed tomographic scanning in the primary evaluation of blunt chest trauma in patients with "normal" chest radiograph? *J Trauma*. 2001;51(6):1173–1176.
22. Livingston DH, Shogan B, John P, Lavery RF. CT diagnosis of rib fractures and the prediction of acute respiratory failure. *J Trauma*. 2008;64(4):905–911.
23. Chapman BC, Herbert B, Rodil M, Salotto J, Stovall RT, Biffl W, et al. RibScore: a novel radiographic score based on fracture pattern that predicts pneumonia, respiratory failure, and tracheostomy. *J Trauma Acute Care Surg*. 2016;80(1):95–101.
24. Carver TW, Milia DJ, Somberg C, Brasel K, Paul J. Vital capacity helps predict pulmonary complications after rib fractures. *J Trauma Acute Care Surg*. 2015;79(3):413–416.
25. Galvagno SM Jr., Smith CE, Varon AJ, Hasenboehler EA, Sultan S, Shaefer G, et al. Pain management for blunt thoracic trauma: a joint practice management guideline from the Eastern Association for the Surgery of Trauma and Trauma Anesthesiology Society. *J Trauma Acute Care Surg*. 2016;81(5):936–951.

26. Mukherjee K, Schubl SD, Tominaga G, Cantrell S, Kim B, Haines KL, et al. Non-surgical management and analgesia strategies for older adults with multiple ribs fractures: a systematic review, meta-analysis, and practice management guideline from the Eastern Association for the Surgery of Trauma and the Chest Wall Injury Society. *J Trauma Acute Care Surg*. 2023;94:398–407.
27. Leinicke JA, Elmore L, Freeman BD, Colditz GA. Operative management of rib fractures in the setting of flail chest: a systematic review and meta-analysis. *Ann Surg*. 2013;258(6):914–921.
28. Ahmed Z, Mohyuddin Z. Management of flail chest injury: internal fixation versus endotracheal intubatation and ventilation. *J Thorac Cadriovasc Surg*. 1995;110(6):1676–1680.
29. Granetzny A, El-Aal MA, Emam E, Shalaby A, Boseila A. Surgical versus conservative treatment of flail chest. Evaluation of the pulmonary status. *Interact Cardiovasc Thorac Surg*. 2005;4(6):583–587.
30. Fitzpatrick DC, Denard PJ, Phelan D, Long WB, Madey SM, Bottlang M. Operative stabilization of flail chest injuries: review of literature and fixation options. *Eur J Trauma Emerg Surg*. 2010;36(5):427–433.
31. Tanaka H, Yukioka T, Yamaguti Y, Shimizu S, Goto H, Matsuda H, et al. Surgical stabilization of internal pneumatic stabilization? A prospective randomized study of management of severe flail chest patients. *J Trauma*. 2002; 52(2):727–723.
32. Marasco SF, Davies AR, Cooper J, Varma D, Bennett V, Nevill R, et al. Prospective randomized controlled trial of operative rib fixation in traumatic flail chest. *J Am Coll Surg*. 2013;216(5):924–932.
33. Liu T, Liu P, Chen J, Xie J, Yang F, Liao Y. A randomized controlled trial of surgical rib fixation in polytrauma patients with flail chest. *J Surg Res*. 2019; 242:223–230.
34. Pieracci FM, Lin Y, Rodil M, Synder M, Herbert B, Tran DK, et al. A prospective, controlled clinical evaluation of surgical stabilization of severe rib fractures. *J Trauma Acute Care Surg*. 2016;80(2):187–194.
35. Dehghan N, Nauth A, Schemitsch E, Vicente M, Jenkinson R, Kreder H, et al. Operative versus nonoperative treatment of acute unstable chest wall injuries: a randomized clinical trial. *JAMA Surg*. 2022;157(11):983–990.
36. Swart E, Laratta J, Slobogean G, Mehta S. Operative treatment of rib fractures in flail chest injuries: a meta-analysis and cost-effectiveness analysis. *J Orthop Trauma*. 2017;32(2):64–70.
37. Choi J, Gomez GI, Kaghazchi A, Borghi JA, Spain DA, Forrester JD. Surgical stabilization of rib fracture to mitigate pulmonary complication and mortality: a systemic review and Bayesian meta-analysis. *J Am Coll Surg*. 2021; 232(2):211–219.
38. Beks RB, Peek J, de Jong MB, Wessem KJP, Oner CF, Hietbrink F, et al. Fixation of flail chest or multiple rib fractures: current evidence and how to proceed. A systematic review and meta-analysis. *Eur J Trauma Emerg Surg*. 2019;45(4):631–644.
39. Schuurmans J, Goslings JC, Schepers T. Operative management versus nonoperative management of rib fractures in flail chest: a systematic review. *Eur J Trauma Emerg Surg*. 2017;43(2):163–168.
40. Slobogean GP, MacPherson CA, Sun T, Pelletier ME, Hameed SM. Surgical fixation vs nonoperative management of flail chest: a meta-analysis. *J Am Coll Surg*. 2013;216(2):302–311.
41. Sawyer E, Wullschleger M, Muller N, Muller M. Surgical rib fixation of multiple rib fractures and flail chest: a systematic review and meta-analysis. *J Surg Res*. 2022;276:221–234.
42. Cataneo AJ, Cataneo DC, de Oliveira FH, Arruda KA, El Dib R, de Oliveira Carvalho PE. Surgical versus nonsurgical interventions for flail chest. *Cochrane Database Syst Rev*. 2015;2015(7):CD009919.
43. Edwards JG, Clarke P, Pieracci FM, Bemelman M, Black EA, Doben A, 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.
44. Clarke PTM, Simpson RB, Dorman JR, Hunt WJ, Edwards JG. Determining the clinical significance of the Chest Wall Injury Society taxonomy for multiple rib fractures. *J Trauma Acute Care Surg*. 2019;87(6):1282–1288.
45. Qiu M, Shi Z, Xiao J, Zhang X, Ling S, Ling H. Potential benefits of rib fracture fixation in patients with flail chest and multiple non-flail rib fractures. *Indian J Surg*. 2016;78(6):458–463.
46. Zhang JP, Sun L, Li WQ, Wang YY, Li XZ, Liu Y. Surgical treatment of patients with severe non-flail chest rib fractures. *World J Clin Cases*. 2019; 7(22):3718–3727.
47. He W, Yang Y, Salonga R, Powell L, Greiffenstein P, Prins JTH, et al. Surgical stabilization of multiple rib fractures in an Asian population: a systematic review and meta-analysis. *J Thorac Dis*. 2023;15(9):4961–4975.
48. Gasparri MG, Tisol WB, Haasler GB. Rib fixation: lessons learned. *Eur J Trauma Emerg Surg*. 2010;36(5):435–440.
49. Van Wijck SFM, Van Diepen MR, Prins JTH, Verhofstad MHJ, Wijffels MME, Van Lieshout EMM, et al. Radiographic rib fracture nonunion and association with rib fracture classification in adults with multiple rib fractures without flail segment: a multicenter prospective cohort study. *Injury*. 2024;55(5):111335.
50. Vagionas D, Vasileiadis I, Rovina N, Alevrakis E, Koutsoukou A, Koulouris N. Daily sedation interruption and mechanical ventilation weaning: a literature review. *Anaesthesiol Intensive Ther*. 2019;51(5):380–389.
51. Doben AR, Eriksson EA, Denlinger CE, Leon SM, Couillard DJ, Fakhry SM, et al. Surgical rib fixation for flail chest deformity improves liberation from mechanical ventilation. *J Crit Care*. 20214;29(1):139–143.
52. Wu TH, Lin HL, Chou YP, Huang FD, Huang WY, Tarng YW. Facilitating ventilator weaning through rib fixation combined with video-assisted thoracoscopic surgery in severe blunt chest injury with acute respiratory failure. *Crit Care*. 2020;24(1):49.
53. Wada T, Yasunaga H, Inokuchi R, Matsui H, Matsubara T, Ueda Y, et al. Effectiveness of surgical rib fixation on prolonged mechanical ventilation in patients with traumatic rib fractures: a propensity score-matched analysis. *J Crit Care*. 2015;30(6):1227–1231.
54. Williams A, Bigham C, Marchbank A. Anaesthetic and surgical managemnt of rib fractures. *BJA Educ*. 2020;20(10):332–340.
55. Engel C, Krieg JC, Madey SM, Long WB, Bottlang M. Operative chest wall fixation with osteosynthesis plates. *J Trauma*. 2005;58(1):181–186.
56. Bass GA, Stephen C, Forssten MP, Bailey JA, Mohseni S, Cao Y, et al. Admission triage with pain, inspiratory effort, cough score can predict critical care utilization and length of stay in isolated chest wall injury. *J Surg Res*. 2022;277:310–318.
57. Head W, Kumar N, Thomas C, Leon S, Dieffenbaugher S, Eriksson E. Are rib fractures stable? An analysis of progressive rib fracture offset in the acute trauma setting. *J Trauma Acute Care Surg*. 2021;91:917–922.
58. Bauman ZM, Binkley J, Pieper CJ, Raposo-Hadley A, Orcutt G, Cemaj S, et al. Discrepancies in rib fracture severity between radiologist and surgeon: a retrospective review. *J Trauma Acute Care Surg*. 2021;91(6):956–960.
59. Khandelwal G, Mathur RK, Shukla S, Maheshwari A. A prospective single center study to assess the impact of surgical stabilization in patients with rib fracture. *Int J Surg*. 2011;9(6):478–481.
60. de Moya M, Bramos T, Agarwal S, Fikry K, Janjua S, King DR, et al. Pain as an indication for rib fixation: a bi-institutional pilot study. *J Trauma*. 2011; 71(6):1750–1754.
61. Li Y, Gao E, Yang Y, Gao Z, He W, Zhao Y, et al. Comparison of minimally invasive surgery for non-flail chest rib fractures: a prospective cohort study. *J Thorac Dis*. 2020;12(7):3706–3714.
62. Hardin KS, Leasia KN, Haenel J, Moore EE, Burlew CC, Pieracci FM. The sequential clinical assessment of respiratory function (SCARF) score: a dynamic pulmonary physiologic score that predicts adverse outcomes in critically ill rib fracture patients. *J Trauma Acute Care Surg*. 2019;87(6):1260–1268.
63. Giamello JD, Martini G, Prato D, Santoro M, Arese Y, Melchio R, et al. A retrospective validation study of the STUMBL score for emergency department patients with blunt thoracic trauma. *Injury*. 2023;54(1):39–43.
64. Ladhani HA, Harrell KN, Burlew CC, van Wijck SFM, Smith EF, Coleman JR, et al. Early surgical stabilization of rib fractures is feasible in patients with non-urgent operative pelvic injuries. *Am Surg*. 2023;89(12):5813–5820.
65. Lagazzi E, Rafaqat W, Argandykov D, de Roulet A, Abaid M, Proano-Zamudio JA, et al. Timing matters: early versus late rib fixation in patients with multiple rib fractures and pulmonary contusion. *Surgery*. 2024;175(2): 529–535.
66. Wang Z, Wang G, Jing B, Feng S, Zhang S, Wu D, et al. Does the timing of surgery affect outcomes in young and middle-aged patients undergoing surgical stabilization of rib fractures? Feedback was based on real data from physicians, patients, and family caregivers. *Eur J Trauma Emerg Surg*. 2023;49(6):2467–2477.
67. Su YH, Yang SM, Huang CH, Ko HJ. Early versus late surgical stabilization of rib fractures in patients with respiratory failure: a retrospective study. *PloS One*. 2019;14(4):e0216170.
68. Becker L, Schulz-Drost S, Spering C, Frankle A, Dudda M, Kamp O, et al. Impact of time of surgery on the outcome after surgical stabilization of rib fractures in severely injured patients with severe chest trauma-a matched-pairs analysis of the German trauma registry. *Front Surg*. 2022;9:852097.
69. Pieracci FM, Coleman J, Ali-Osman F, Mangram A, Majercik S, White TW, et al. A multicenter evaluation of the optimal timing of surgical stabilization of rib fractures. *J Trauma Acute Care Surg*. 2018;84(1):1–10.

70. Wang Z, Jia Y, Li M. The effectiveness of early surgical stabilization for multiple rib fractures: a multicenter randomized controlled trial. *J Cardiothorac Surg*. 2023;18(1):118.
71. Polycarpou A, Kim BD. Pediatric surgical rib fixation: a collected case series of a rare entity. *J Trauma Acute Care Surg*. 2021;91(6):947–950.
72. Fitzgerald MT, Ashley DW, Abukhdeir H, Christie DB 3rd. Rib fracture fixation in the 65 years and older population: a paradigm shift in management strategy at a level I trauma center. *J Trauma Acute Care Surg*. 2017;82(3): 524–527.
73. Zhu RC, de Roulet A, Ogami T, Khariton K. Rib fixation in geriatric trauma: mortality benefits for the most vulnerable patients. *J Trauma Acute Care Surg*. 2020;89(1):103–110.
74. Kane ED, Jeremitsky E, Bittner KR, Kartiko S, Doben AR. Surgical stabilization of rib fractures: a single institution experience. *J Am Coll Surg*. 2018; 226(6):961–966.
75. Wasfie T, Sowa M, White H, Nesheiwat Oms-Iv SN, Hille J, Hella J, et al. Rib plating outcomes in elderly trauma patients with multiple rib fractures: A community hospital experience. Am Surg 2023;89(7):3200–3202.
76. Bulger EM, Arneson MA, Mock CN, Jurkovich GJ. Rib fractures in the elderly. *J Trauma*. 2000;48(6):1040–1046.
77. DeVoe WB, Abourezk M, Goslin BJ, Saraswat N, Kiel B, Bach JA, et al. Surgical stabilization of severe chest wall injury following cardiopulmonary resuscitation. *J Trauma Acute Care Surg*. 2022;92(1):98–102.
78. Comanici M, Farmidi A, Bhudia SK, Anikin V. Concomitant cardiac surgery and fixation of bilateral rib fractures sustained during cardiopulmonary resuscitation. *J Card Surg*. 2022;37(12):5521–5523.
79. Prins JTH, Van Lieshout EMM, Ali-Osman F, Bauman ZM, Caragounis EC, Choi J, et al. Surgical stabilization versus nonoperative treatment for flail and non-flail rib fracture patterns in patients with traumatic brain injury. *Eur J Trauma Emerg Surg*. 2022;48(4):3327–3338.
80. Lagazzi E, Argandykov D, de Roulet A, Proano-Zamudio JA, Romijn ASC, Abaid M, et al. Evaluating the impact of trimming to rib fixation in patients with traumatic brain injury: a nationwide analysis. *J Trauma Acute Care Surg*. 2023;95(6):846–854.
81. Prins JTH, Van Lieshout EMM, Ali-Osman F, Bauman ZM, Caragounis EC, Choi J, et al. Outcome after surgical stabilization of rob fractures versus nonoperative treatment in patients with multiple rib fractures and moderate to severe traumatic brain injury (CWIS-TBI). *J Trauma Acute Care Surg*. 2021; 90(3):492–500.
82. Liao CH, Kuo LW, Huang JF, Fu CY, Chen SA, Tee YS, et al. Timely surgical fixation confers beneficial outcomes in patients' concomitant flail chest with mild-to-moderate traumatic brain injury: a trauma quality improvement project analysis — a cohort study. *Int J Surg*. 2023;109(4):729–736.
83. Abdelmalik PA, Draghic N, Ling GSF. Management of moderate and severe traumatic brain injury. *Transfusion*. 2019;59(S2):1529–1538.
84. Evans WE, Briese A, Gratton A, Yon JR, Mentzer CJ. Rib fractures with concomitant spinal fractures may benefit from surgical stabilization. *Am Surg*. 2023;89(9):3928–3929.
85. Wessell JE, Pereira MP, Eriksson EA, Kalhorn SP. Rib fixation for flail chest physiology and the facilitation of safe prone spinal surgery: illustrative case. *J Neurosurg Case Lessons*. 2022;4(21):CASE22337.
86. Allen R, Estroff J, Sarani B. Surgical stabilization of rib fractures in a patient with empyema: a case report. *JBJS Case Connect*. 2019;9(4):e0202.
87. Tokumaru T, Kurata H, Mitsui J, Tomioka J. Radical surgery for intractable thoracic empyema complicating traumatic pneumothorax and rib fractures. *Surg Case Rep*. 2023;9(1):185.
88. Majercik S, Vijayakumar S, Olsen G, Wilson E, Gardner S, Granger SR, et al. Surgical stabilization of severe rib fractures decreases incidence of retained hemothorax and empyema. *Am J Surg*. 2015;210(6):1112–1116.
89. Forrester JD, Bukur M, Dvorak JE, Faliks B, Hindin D, Kartiko S, et al. Surgical Infection Society: Chest Wall Injury Society recommendations for antibiotic use during surgical stabilization of traumatic rib or sternal fractures to reduce risk of implant infection. *Surg Infect (Larchmt)*. 2022;23(4):321–331.
90. Van Wijck SFM, Pieracci FM, Smith EF, Madden K, Moore EE, Wijffels MM, et al. Rib fixation in patients with severe rib fractures and pulmonary contusions: is it safe? *JTACS*. 2022;93(6):721–726.
91. Jiang Y, Wang X, Teng L, Liu Y, Wang J, Zheng Z. Comparison of the effectiveness of surgical versus nonsurgical treatment for multiple rib fractures accompanied with pulmonary contusions. *Ann Thorac Cardiovasc Surg*. 2019; 25(4):185–191.
92. Kocher GJ, Sharafi S, Azenha LF, Schmid RA. Chest Wall stabilization in ventilator-dependent traumatic flail chest patients: who benefits? *Eur J Cadriothorac Surg*. 2017;51(4):696–701.
93. Mahmood SR, Lobo SA, Fischer S. Cardiac risk assessment. Updated July 24, 2023. In: StatPearls [Internet]. Treasure Island, FL: StatPearls Publishing; 2024 Jan. Available at: https://www.ncbi.nlm.nih.gov/books/NBK537146/. Accessed January 2, 2025.
94. Livhits M, Ko CY, Leonardi MJ. Risk of surgery following recent myocardial infarction. *J Vasc Surg*. 2011;54(3):912.
95. Peralta R, Thani H, Rizoli S. Coagulopathy in the surgical patient: trauma-induced and drug-induced coagulopathies. *Curr Opin Crit Care*. 2019; 25(6):668–674.