SSRF ALGORITHM

RIB FRACTURES

1. CT CHEST
2. ASSESS RESPIRATION FUNCTION
3. MULTI-MODAL PAIN PROTOCOL
4. LOCO-REGIONAL PAIN THERAPY

SHOCK/ONGOING RESUSCITATION
SEVERE TBI
ACUTE MI
OUTSIDE RIBS 3-10
(CONSIDER RELATIVE CONTRAINDICATIONS)

NON-OP ← Y

N

Y → **CHEST WALL INSTABILITY**

N

ON VENTILATOR

N → **3+ ≥ 50% DISPLACED RIB FRACTURES + 2+ PULMONARY DERANGEMENTS**

Y → **FAILURE TO WEAN DUE TO RIB FRACTURES**

Y N → NON-OP ← N Y

OTHER HIGHER PRIORITY INJURIES

N Y

IDEALLY < 72 HOURS FROM INJURY

SSRF

DEFINITIONS OF TERMS

SEVERE TBI
- Any GCS <8
- Signs of intracranial hypertension

RELATIVE CONTRAINDICATIONS
- Age <18 years
- Significant comorbidities
- Unstable Spine injury
- Empyema
- Prior chest wall radiation
- Mild/moderate TBI

CHEST WALL INSTABILITY

Flail Segment
- 3+ ipsilateral consecutive ribs with fractures in 2 locations
- Clinical finding of paradoxical motion

Offset fractures
- 3+ ipsilateral rib fractures with displacement of 100% of rib width on axial CT

Instability or "clicking" on palpation or reported by the patient

3+ > 50% DISPLACEMENT
- Three ipsilateral consecutive or non-consecutive ribs each with a fracture displaced 50% of the rib width on axial CT

PULMONARY DERANGEMENTS
- Respiratory rate >20
- Incentive spirometry <50% of predicted
- Numerical pain score >5/10
- Poor cough

FAILURE TO WEAN

Must be clinically determined to be related to the rib fractures

Unable to progress to spontaneous breathing trial after 48 hours

Able to obtain spontaneous breathing trial for 60 minutes but develops >2 of the following
- Increased resp. rate >35
- Increased heart rate >140
- Oxygen saturation <90%
- RSBI >105
- Anxiety
- Diaphoresis
- Agitation

Of note: Ventilator weaning should be at the discretion of the treating bedside physician.

HIGHER PRIORITY INJURIES
- Pre-operative spinal injury
- Open Abdomen
- Significant vascular trauma
- Pelvic external fixation

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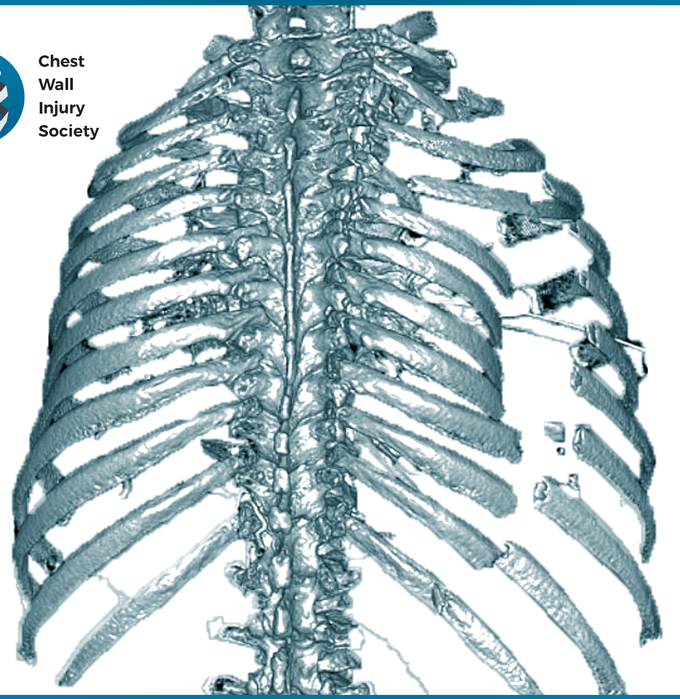

CHEST WALL INJURY SOCIETY GUIDELINE FOR SSRF INDICATIONS, CONTRAINDICATIONS AND TIMING

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SUMMARY OF RECOMMENDATIONS

INDICATIONS

Non-ventilated patients:

1. Chest wall instability
   a. Three rib flail chest
   b. Three bi-cortically displaced/offset ribs
   c. Clinical finding of paradoxical motion
   d. Instability or "clicking" on palpation or as reported by the patient
2. Three or more displaced rib fractures (≥ 50% of the rib width) with two or more pulmonary physiologic derangements
   a. Respiratory rate ≥ 20
   b. Measured volumes on incentive spirometry < 50% of predicted
   c. Numerical pain score > 5/10
   d. Poor cough

Ventilated patients:

1. Chest wall instability
   a. Three rib flail chest
   b. Three bi-cortically displaced/offset ribs
   c. Clinical finding of paradoxical motion
   d. Instability or "clicking" on palpation or as reported by the patient
2. Failure to wean

CONTRAINDICATIONS

Absolute:

1. Shock/Ongoing resuscitation
2. Severe traumatic brain injury
3. Fractures outside of ribs 3-10
4. Acute myocardial infarction

Relative:

1. Age less than 18 years
2. Significant co-morbidities
3. Mild/moderate traumatic brain injury (TBI)
4. Spinal cord injury/Unstable spinal fracture
5. Empyema
6. History of chest wall radiation

TIMING

Non-ventilated patients

1. When feasible, less than 24 hours is optimal
2. Should be performed within 72 hours of injury
3. SSRF should be delayed in the face of higher priority injuries

Ventilated patients

1. Earliest feasible time for flail indication
2. Should be performed within 72 hours of injury for non-flail indications
3. SSRF should be delayed in the face of higher priority injuries

INDICATIONS FOR SURGICAL STABILIZATION OF RIB FRACTURES

BACKGROUND

The indications for surgical stabilization of rib fixation (SSRF) have evolved over the last decade and its use has increased with modern techniques and hardware. The most widely studied indication is chest wall instability; either "flail chest", the presence of at least 3 consecutive ribs broken in 2 locations, or three consecutive bi-cortically displaced rib fractures. This indication has been shown in multiple retrospective studies, 3 single center randomized controlled trials, a Cochrane review and several meta-analyses to potentially reduce length of stay, intensive care unit length of stay, duration of mechanical ventilation, rates of pneumonia, and the need for tracheostomy placement. Though inconsistent between studies, several authors have also shown a reduction in mortality.

Additionally, the non-flail prospective MCT and several retrospective studies and case reports suggest that select patients with non-flail pattern rib fractures may also benefit from SSRF in regards to minimizing pain and improving quality of life for less displaced fractures.

RECOMMENDATIONS

Non-ventilated patients:

1. Chest wall instability: SSRF should be performed in all patients with unstable fracture patterns
   a. Flail chest: 3 consecutive ribs broken in two places with or without displacement
   b. Bi-cortical/offset rib fractures: Patients with multiple (≥3), offset fractures (100% displacement on axial CT)
   c. Clinical finding of paradoxical motion
   d. Instability or "clicking" on palpation or as reported by the patient
2. ≥ 3 ipsilateral, severely displaced (≥ 50% of the rib width on axial CT) acute rib fractures in ribs 3-10 in combination with ≥ 2 pulmonary physiologic derangements despite loco-regional anesthesia and multi-modal pain therapy
   a. Respiratory rate ≥ 20
   b. Measured volumes on incentive spirometry < 50% of predicted
   c. Numerical pain score > 5/10
   d. Poor cough

Ventilated patients:

1. Chest wall instability: SSRF should be performed in all patients with respiratory failure due to unstable fracture patterns
   a. Flail chest: 3 consecutive ribs broken in two places with or without displacement
   b. Bi-cortical/offset rib fractures: Patients with multiple (≥3), offset fractures (100% displacement on axial CT)
   c. Clinical finding of paradoxical motion
   d. Instability or "clicking" on palpation or as reported by the patient
2. Failure to wean: Patients with displaced rib fractures who have failed to wean from the ventilator, with or without flail chest, should be considered for SSRF
   a. Failed extubation requiring reintubation
   b. Unable to progress to spontaneous breathing trial after 48 hours
   c. Able to obtain spontaneous breathing trial for 60 minutes, but develops ≥2 of the following:
      i. Increased respiratory rate > 35
      ii. Increased heart rate >140
      iii. Oxygen Saturation <90%
      iv. RSBI >105
      v. Anxiety
      vi. Diaphoresis

Other Indications: The following indications have been used successfully by some authors and should be considered on an individual basis with the understanding that data supporting these indications is limited

1. Paradoxical chest wall movement or implosion chest wall injuries, i.e. "Stoved-in Chest"
2. "On-the-way-out": in patients undergoing thoracotomy for another indication, such as evacuation of hematoma
3. Chest volume loss >30%

CONTRAINDICATIONS TO SURGICAL STABILIZATION OF RIB FRACTURES

BACKGROUND

Surgical stabilization of rib fractures remains a controversial topic amongst the trauma community. Furthermore, the ventilator dependent trauma patient can create more confusion for the provider when making decisions to provide SSRF. Despite multiple studies demonstrating significant improvement among various patient populations, the limited number of prospective, randomized trials requires an individualized approach regarding the indications or contraindications to perform SSRF.

RECOMMENDATIONS

All recommendations below are for both non-ventilator dependent and ventilator dependent patients:

Absolute Contraindications:

1. Shock/Ongoing resuscitation
Patients who are hemodynamically unstable should not undergo SSRF. A history of shock is not necessarily a contraindication to the procedure and patients who are stable on vasopressors may benefit from SSRF if this facilitates weaning pain medications and sedation, which may improve their hemodynamics.

2. Fractures outside of ribs 3-10
Fractures in these ribs have been excluded in all prospective studies of the safety and efficacy of SSRF.

3. Severe Traumatic Brain Injury (TBI)/Intracranial Hypertension
Several studies have suggested that severe TBI is a contraindication for SSRF. We agree with previous studies that performing SSRF on patients with severe TBI may not provide many of the benefits offered by SSRF, such as earlier liberation from the ventilator, decreased need for tracheostomy tube, and overall decrease in mortality. The depressed GCS should persist past the first 24 hours of admission to eliminate intoxication as a confounder.

4. Acute myocardial infarction
Patients experiencing an acute MI should not undergo any elective operation given their need for anticoagulation/antiplatelet and the stress that surgery places on cardiac function. Although there may be controversy whether or not SSRF is considered an elective surgery, it is not considered the "gold standard" for the management of rib fractures and therefore should not be considered for the acute MI.

Relative Contraindications:

1. Age < 18 years
Most literature does not support SSRF in patients < 18 as fractures should heal well as the patient grows. However, there have been several case reports describing SSRF in pediatric patients with severe injuries. These plates may need to be taken out within 3 months to allow for continued bone growth. It is also critical to consider that FDA approval for most plating systems excludes pediatric patients.

2. Significant co-morbidities/Frailty
Significant cardiopulmonary comorbidities, active malignancy or other terminal illness should promote a careful evaluation of the risk/benefit ratio of SSRF. Limited studies have suggested elderly patients are at higher risk for post-operative mortality/complications from SSRF. Most of these studies suggest individuals 80 years or older are a higher risk population. However, there have been several studies that suggest the elderly population may actually benefit more from SSRF than younger patients considering they are less likely to tolerate rib fractures than younger counterparts. Given these confounding studies, no strong recommendation can be made whether or not to exclude this patient population from SSRF. Therefore, these individuals must be assessed on a case-by-case basis.

3. Mild to Moderate TBI
Several studies have suggested that TBI is a contraindication for SSRF. TBI occurs on a spectrum of severe (GCS < 8) to mild (GCS 13 – 15). Given this spectrum, we recommend SSRF for patients with lower grade TBI be evaluated on an individual case basis. The protective effects on pneumonia development and earlier liberation from the ventilator may benefit selected patients with lower grade TBI.

4. Spinal cord injury/Unstable spine fracture
Similar to TBI, spinal cord injury can occur on a spectrum and therefore patients should be evaluated for SSRF on a case to case basis. Unstable fractures of the spine should be addressed before SSRF is attempted. Patients with high spinal injury resulting in quadriplegia may not experience symptomatic relief from SSRF, such as better pain control and decreased need for tracheostomy placement. However, lower spinal injury resulting in paraplegia may benefit from SSRF given that they still have intact sensation to the chest wall and likely did not need tracheostomy placement.

5. Empyema
Active chest space infections could increase the risk of hardware infections and potentially compromise the repair. While pneumonia appears to be safe, an empyema is potentially higher risk.

6. Prior chest radiation
Radiation is an important component in the management of various chest wall malignancies. A history of radiation or pathological rib fractures should deter SSRF. A 3D CT-scan reconstruction can be helpful to determine bone strength as it does detect post-radiation changes. The chance of hardware failure may be high in these patients if SSRF is attempted.

TIMING OF SURGICAL STABILIZATION OF RIB FRACTURES

BACKGROUND

The timing of SSRF is central to the success of the operation. The only multi-center, randomized controlled trial had a median time to SSRF of 3 days for the operative arm. Of the four single-center, prospective controlled trials, three operated on the surgical cohort within 72 hours of injury and showed statistically significant improvements in their primary outcomes. A retrospective, multicenter trial underscored the necessity of early intervention by showing that SSRF within 24 hours of injury may be superior to even 72 hours. Several retrospective studies have also largely included patients intervened upon within the first three days. Many of these studies have used avoidance of pneumonia, respiratory failure and tracheostomies as their primary outcomes and this should be understood to be the purpose of early SSRF.

Of note, polytrauma patients with "higher priority" injuries should have SSRF delayed until those can be addressed. These include, but are not restricted to, patients with open abdomens, unstable spine fractures, external fixators precluding positioning, significant vascular injuries and others.

Symptomatic nonunion of rib fractures is a rare but debilitating problem. Based on current literature, SSRF of symptomatic rib nonunion is safe and feasible with a low post-operative complication rate. Given the paucity of literature, however, patients need to be evaluated on a case-by-case basis with patient-physician discussions focused on overall goals and expectations.

RECOMMENDATIONS

Non-ventilated patients:

1. Whenever feasible, SSRF should be performed within 24 hours of injury
2. SSRF regardless of indication should ideally be performed within 72 hours of injury
3. SSRF should be delayed in the face of higher priority injuries

Ventilated patients:

1. SSRF should be performed at the earliest feasible time for patients with a flail segment
2. If SSRF cannot be performed within 72 hours for flail indications, it is still recommended for those patients whose respiratory failure/ventilator dependence is secondary to the chest wall injury
3. SSRF should ideally be performed within 72 hours for all non-flail indications
4. SSRF should be delayed in the face of higher priority injuries