RIB FRACTURE FIXATION

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Professor and Associate Chair for Research, Department of Surgery, JABSOM/University of Hawaii Manoa
RIB FRACTURES - OUTLINE

- Epidemiology and Issues
- Outcomes
- Evaluation of Injury Burden
- Medical Management
- Surgical Fixation
  - Techniques
  - Results
  - Patient Selection
  - Recommendations and Protocols
RIB FRACTURES

Common - 9-12% Trauma Admissions
Ziegler, J Trauma 1994; 37:975

- 30% of Significant Chest Trauma
- Intrathoracic Injuries Correlate with #Ribs
- Assoc Injuries Common
CONSEQUENCES OF PAIN

- **Splinting** – Reduced inspiration effort
- **Smaller tidal volumes** -> Reduced efficiency of Ventilation -> Hypercarbia
- **Inadequate alveolar expansion** -> Atelectasis and Hypoxia
- **Decreased forced vital capacity and cough** -> Reduced pulmonary secretion clearance -> Pneumonia
PULMONARY CONTUSION

- Pathophysiology – Blunt force leading to interstitial hemorrhage, alveolar collapse, and shunting
  - Decreased pulmonary compliance, Increased work of breathing
  - Hypoxemia, Hypercarbia
- Mortality as high as 30%
ALTERED MECHANICS IN FLAIL CHEST (NON-VENTILATED)
RIB FRACTURES - OUTLINE

- Epidemiology and Issues
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  - Recommendations and Protocols
**SHORT TERM OUTCOMES**

- **Battle CE et al. Injury 2012** - Mortality OR=2.02 for pt with >2 rib fractures
- **Dehghan N et al. JTACS 2014**
  - Flail chest mortality - 16%
  - Flail and pulmonary contusion mortality - 42%
- **Falgel BT et al. Surgery 2005** – NTDB study
  - 48% pulmonary complication rate
- **Ziegler DW et al. J Trauma 1994**
  - 12% Mortality
  - 34% of patient discharged to long term facility
**ELDERS VS YOUNG ADULTS**

**Mortality**

<table>
<thead>
<tr>
<th>Elderly</th>
<th>Young</th>
</tr>
</thead>
<tbody>
<tr>
<td>22%</td>
<td>10%</td>
</tr>
<tr>
<td>20%</td>
<td>9%</td>
</tr>
<tr>
<td>20%</td>
<td>11%</td>
</tr>
</tbody>
</table>

- Bulger, J Trauma 2000; 48:1040
- Bergeron, J Trauma 2003; 54:478
LONGER TERM OUTCOMES

Marasco S et al. Injury 2015-
- At 6 months only 36% of patient with isolated thoracic injury had a good recovery (GOS-E score 7-8)

- 2 mos: 76% persistent disability, 59% pain
- 6 mos: 53% chronic disability, 22% chronic pain
- Isolated rib fractures: 40% chronic disability, 28% chronic pain
RIB FRACTURES - OUTLINE

- Epidemiology and Issues
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- **Evaluation of Injury Burden**
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  - Techniques
  - Results
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  - Recommendations and Protocols
RIB FRACTURES
Anatomic considerations/terminology

- Location
- Displacement
**Anatomic considerations/terminology**

- **Location**
- **Displacement**
- **Angulation**
- **Overlap**

<table>
<thead>
<tr>
<th>RIB</th>
<th>ANT</th>
<th>LAT</th>
<th>POST</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>5</td>
<td></td>
<td>X</td>
<td></td>
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<td>6</td>
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<td>7</td>
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<td>8</td>
<td></td>
<td>X</td>
<td></td>
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<td>9</td>
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<td></td>
<td></td>
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<tr>
<td>10</td>
<td></td>
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</tbody>
</table>

*Figure 1. Fractures are enumerated using a standardized preoperative planning form. Each marking is then crossed off after the fracture has been repaired.*
## PIC Score

<table>
<thead>
<tr>
<th>Pain</th>
<th>Inspiration</th>
<th>Cough</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 - Controlled (Pain intensity scale 0-4)</td>
<td>4 – Above goal volume</td>
<td>3 - Strong</td>
</tr>
<tr>
<td>2 - Moderate (Pain intensity scale 5-7)</td>
<td>3 – Goal to alert volume</td>
<td>2 - Weak</td>
</tr>
<tr>
<td>1 - Severe (Pain intensity scale 8-10)</td>
<td>2 – Below alert volume</td>
<td>1 - Absent</td>
</tr>
<tr>
<td></td>
<td>1 – Unable to perform incentive spirometry</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 2** Harborview Medical Center PIC scoreboard. IS, incentive spirometry; PIC, Pain, Inspiratory capacity, and Cough.

RibScore: A novel radiographic score based on fracture pattern that predicts pneumonia, respiratory failure, and tracheostomy

Brandon C. Chapman, MD, Benoit Herbert, MD, Maria Rodil, Jennifer Salotto, MD, Robert T. Stovall, MD, Walter Biffl, MD, Jeffrey Johnson, MD, Clay Cothren Burlew, MD, Carlton Barnett, MD, Charles Fox, MD, Ernest E. Moore, MD, Gregory J. Jurkovich, MD, and Fredric M. Pieracci, MD, MPH, Denver, Colorado
<table>
<thead>
<tr>
<th>Variable</th>
<th>Pneumonia,  n (%)</th>
<th>Respiratory Failure, n (%)</th>
<th>Tracheostomy, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥6 ribs fractured</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present (n = 155)</td>
<td>33 (21.3)</td>
<td>68 (43.9)</td>
<td>39 (25.2)</td>
</tr>
<tr>
<td>Absent (n = 230)</td>
<td>19 (8.3)</td>
<td>56 (24.3)</td>
<td>21 (9.1)</td>
</tr>
<tr>
<td>Flail chest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present (n = 46)</td>
<td>11 (23.9)</td>
<td>29 (63.0)</td>
<td>17 (37.0)</td>
</tr>
<tr>
<td>Absent (n = 339)</td>
<td>41 (12.1)</td>
<td>95 (28.0)</td>
<td>43 (12.7)</td>
</tr>
<tr>
<td>Bilateral fractures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present (n = 120)</td>
<td>23 (19.2)</td>
<td>51 (42.5)</td>
<td>28 (23.3)</td>
</tr>
<tr>
<td>Absent (n = 265)</td>
<td>29 (10.9)</td>
<td>73 (27.5)</td>
<td>32 (12.1)</td>
</tr>
<tr>
<td>First rib fracture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present (n = 91)</td>
<td>21 (23.1)</td>
<td>44 (48.3)</td>
<td>26 (28.6)</td>
</tr>
<tr>
<td>Absent (n = 294)</td>
<td>31 (10.5)</td>
<td>80 (27.2)</td>
<td>34 (11.6)</td>
</tr>
<tr>
<td>≥3 displaced fractures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present (n = 32)</td>
<td>11 (34.4)</td>
<td>22 (68.8)</td>
<td>15 (46.8)</td>
</tr>
<tr>
<td>Absent (n = 353)</td>
<td>41 (11.6)</td>
<td>102 (28.9)</td>
<td>45 (12.7)</td>
</tr>
<tr>
<td>Fracture in each anatomic area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present (n = 58)</td>
<td>14 (24.1)</td>
<td>37 (63.8)</td>
<td>19 (32.8)</td>
</tr>
<tr>
<td>Absent (n = 327)</td>
<td>38 (11.6)</td>
<td>87 (26.6)</td>
<td>41 (12.5)</td>
</tr>
</tbody>
</table>

*p < 0.05 for all associations tested.
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<table>
<thead>
<tr>
<th><strong>ANALGESIA</strong></th>
<th><strong>Begin</strong></th>
<th><strong>Add</strong></th>
<th><strong>Add</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Oral narcotics</td>
<td>• IV narcotics (PCA)</td>
<td>• Continuous thoracic epidural catheter</td>
<td></td>
</tr>
<tr>
<td>• Oral muscle relaxants</td>
<td>• Continuous intercostal nerve blockade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Oral/IV NSAIDs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• “Rib blocks”</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>PULMONARY TOILET</strong></th>
<th><strong>Begin</strong></th>
<th><strong>Add</strong></th>
<th><strong>Add</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Incentive spirometry</td>
<td>• Naso-tracheal succioning</td>
<td>• Cricothyroidotostomy tube (“mini-trach”)</td>
<td></td>
</tr>
<tr>
<td>• Upright position/ambulation</td>
<td></td>
<td>• +/- Intubation/ mech ventilation</td>
<td></td>
</tr>
<tr>
<td>• Cough and deep breathing</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Inadequate response defined as ≥ 1 of the following:**
- Numeric pain score > 4
- Spirometry < 75% predicted
- RR > 20
- Poor cough/splinting/inability to clear secretions

**Routine therapies following intubation:**
- Humidified O₂
- Positional changes
- E.T.T. succioning
- CPAP

Algorithm for medical management of rib fractures. NSAIDS, non-steroidal anti-inflammatory drugs; PCA, patient-controlled analgesia; RR, respiratory rate; ETT, endotracheal tube; CPAP, continuous positive airway pressure.
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EVOLUTION OF TREATMENT

Early treatment consisted of external traction using weights and towel clips/wires to reduce flail.
EVOLUTION OF TREATMENT

Dismal results due to prolonged bedrest and immobility and local wound problems
NEGATIVE PRESSURE VENTILATION
POSITIVE PRESSURE VENTILATION

- Internal Pneumatic Stabilization
  - Internally stabilize chest wall
  - Ensure adequate ventilation
  - Allow improved pulmonary hygiene
Management of pulmonary contusion and flail chest:
An Eastern Association for the Surgery of Trauma
practice management guideline

Bruce Simon, MD, James Ebert, MD, Faran Bokhari, MD, Jeannette Capella, MD,
Timothy Emhoff, MD, Thomas Hayward, III, MD, Aurelio Rodriguez, MD, and Lou Smith, MD

Focus on Pulmonary Contusion Management

Although improvement has not been definitively shown in any outcome parameter after surgical fixation of FC, this modality may be considered in cases of severe FC failing to wean from the ventilator or when thoracotomy is required for other reasons. The patient subgroup that would benefit from early “prophylactic” fracture fixation has not been identified.

J Trauma Acute Care Surg 2012; 73:S351
FIXATION TECHNIQUES
Figure 4 An example of an intramedullary strut, or splint, with single point fixation (41). Courtesy of DuPuy Synthes (© DePuy Synthes 2017).
Figure 3 Modification of external rib plating hardware with a “U”-shaped extension over the cephalad aspect of the rib (40). This modification aligns the bicortical screws in the midportion of the rib, away from the neurovascular bundle. Additional dissection is required to use this system. Courtesy of ACUTE Innovations®.
Figure 5: An absorbable plate adaptable for rib fixation (43).

J. Rafe Sales, MD1, Thomas J. Ellis, MD1, Joel Gillard, BS, Qi Liu, MS, Joyce Chen, MD, Bruce Ham, MD, FACS, & John C. Mayberry, MD, FACS. Biomechanical Testing of a Novel, Minimally Invasive Rib Fracture Plating System. Journal of Trauma 2008: 64(5) 1270-1274.
DEPUY SYNTHES MATRIXRIB FIXATION SYSTEM
DEPUY SYNTHES MATRIXRIB FIXATION SYSTEM

- Pre-contoured titanium alloy locking low profile 1.5 mm thick plates with 2.9 mm diameter locking screws
- Plates pre-contoured to fit average rib shape, minimizing Intraoperative bending
- Plate stiffness similar to cadaveric osteoporotic rib, allowing for flexibility of the rib cage
- Plates long enough to fixate multiple and comminuted/oblique fractures
- Anterior plating technique designed to avoid surgical disruption of intercostal soft tissues; intramedullary splints allow minimally invasive procedures
- Instruments enable stabilization of sub-scapular fractures
KLS MARTIN L1 RIB FIXATION SYSTEM

- One Size Self-Tapping/Drill-Free Screws
- No Pre-Drilling or Measurements
- Minimally Invasive Instrumentation
- Smart Shape Universal Plates
- Adaptive & Strong Geometric Design
Operative fixation of rib fractures after blunt trauma: A practice management guideline from the Eastern Association for the Surgery of Trauma

George Kasotakis, MD, MPH, Erik A. Hasenboehler, MD, Erik W. Streib, MD, Nimitt Patel, MD, Mayur B. Patel, MD, MPH, Louis Alarcon, MD, Patrick L. Bosarge, MD, Joseph Love, MD, Elliott R. Haut, MD, PhD, and John J. Como, MD, MPH, Boston, Massachusetts
A prospective, controlled clinical evaluation of surgical stabilization of severe rib fractures

Fredric M. Pieracci, MD, MPH, Yihan Lin, MD, Maria Rodil, Madelyne Synder, MPH, Benoit Herbert, MD, Dong Kha Tran, MD, Robert T. Stoval, MD, Jeffrey L. Johnson, MD, Walter L. Biffi, MD, Carlton C. Barnett, MD, Clay Cothren-Burlew, MD, Charles Fox, MD, Gregory J. Jurkovich, MD, and Ernest E. Moore, MD, Denver, Colorado

verified Level I trauma center. Eligible patients included adults (age ≥ 18 years) with one or more of the following rib fracture patterns: (1) flail chest (three or more contiguous ribs fractured in two or more places); (2) three or more severely displaced fractures, defined as bicortical displacement; (3) 30% or greater volume loss of a hemithorax and quantified using computed tomography of the chest; (4) any fracture pattern with failure of optimal medical management (see Figure, Supplemental
Figure 1. Daily incentive spirometry recordings.
Physical function and pain after surgical or conservative management of multiple rib fractures – a follow-up study

Patients undergoing surgery have a similar long-term recovery to those who are treated conservatively except for a better range of motion in the thorax and fewer limitations in physical function. Surgery seems to be beneficial for some patients, the question remains which patients benefit.
Surgical treatment of multiple rib fractures and flail chest in trauma: a one-year follow-up study

Eva-Corina Caragounis¹*, Monika Fagevik Olsén¹,², David Pazooki¹ and Hans Granhed¹

Results: Symptoms associated with pain, breathlessness and use of analgesics significantly decreased from 6 weeks to 1 year following surgery. After 1 year, 13% of patients complained of pain at rest, 47% had local discomfort and 9% used analgesics. The EQ-5D-3 L index increased from 0.78 to 0.93 and perceived overall health state increased from 60 to 90% (p < 0.0001) after 6 weeks to 1 year. Lung function improved significantly with predicted Forced vital capacity and Peak expiratory flow increasing from 86 to 106% (p = 0.0002) and 81 to 110% (p < 0.0001), respectively, from 3 months to 1 year after surgery. Breathing movements and range of motion tended to improve over time. Physical function improved significantly over time and the median Disability rating index was 0 after 1 year.

Conclusions: Patients with multiple rib fractures and flail chest show a gradual improvement in symptoms associated with pain, quality of life, mobility, disability and lung function over 1 year post surgery. Therefore, the final outcome of surgery cannot be assessed before 1 year post-operatively.
Operative fixation of rib fractures after blunt trauma: A practice management guideline from the Eastern Association for the Surgery of Trauma

George Kasotakis, MD, MPH, Erik A. Hasenboehler, MD, Erik W. Streib, MD, Nimitt Patel, MD, Mayur B. Patel, MD, MPH, Louis Alarcon, MD, Patrick L. Bosarge, MD, Joseph Love, MD, Elliott R. Haut, MD, PhD, and John J. Como, MD, MPH, Boston, Massachusetts

In adult patients with flail chest after blunt trauma, we conditionally recommend rib ORIF to decrease mortality; shorten duration of mechanical ventilation, ICU LOS and hospital LOS; incidence of pneumonia and need for tracheostomy. We cannot offer a recommendation for pain control with currently available evidence.

In adult patients with nonflail rib fractures after blunt trauma, we cannot offer a recommendation for any of the outcomes with currently available evidence.
Box 1  Indications

**Recommended:**
- \( \geq 5 \) rib flail chest requiring mechanical ventilation;
- Symptomatic non-union;
- Severe displacement found during a thoracotomy for another reason.

**Consider:**
- \( \geq 3 \) rib flail not requiring mechanical ventilation;
- \( \geq 3 \) ribs with severely displaced fractures (bi-cortical displacement);
- \( \geq 3 \) ribs with mild to moderate displacement and 50% reduction of expected forced vital capacity percent despite optimal pain management.

**Absolute contraindications:**
- Contaminated field.

**Relative contraindications:**
- Severe lung contusion requiring prolonged mechanical ventilation;
- High cervical spine injury requiring mechanical ventilation.

**Rib fixation: Who, What, When?**

Marc de Moya,¹ Ram Nirula,² Walter Biff³,⁴
Patient with >2 acute rib fractures

small retrospective studies. When deciding whether rib fixation is a good option, there are a few things to consider other than the severity of the rib fractures. First, the patient should be free of other injuries that would prolong intubation or immobility, such as a severe head injury or pelvic fracture. In these cases, rib fixation is not likely to alter the patient's overall clinical course, as the benefits that have been most clearly shown are related to decreasing ventilator days. Second, the fixation should occur early, ideally within 48 hours of admission, to maximize the likelihood of avoiding ventilator-associated complications that would independently increase ventilator days. Lastly, if the patient needs e-
Rib Fracture Management Guideline for Non-Intubated Patients

**Risk Factors for Morbidity & Mortality**

**Age/Frailty**
- Age ≥ 65
- Severe comorbidities (Active CAD, CHF, COPD)
- Partially or completely dependent for ADLs

**Pulmonary Physiology**
- Incentive spirometry < 15cc/kg or 1500ccs
- Weak or absent cough
- Pain level > 7

**Severity of Injury**
- ≥ 3 ribs with flail segments
- ≥ 3 ribs with severe/bicortical displacement
- ≥ 1 lobe (20%) pulmonary contusion
- ≥ 2L of oxygen to keep saturation >92%

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**Traumatic injury with ≥ 3 rib fractures**

**Trauma team evaluation of patient for risk factors within 1 hour.**
- Age/frailty
- Pulmonary physiology
- Severity of injury

**Discharge home with multimodal PO analgesia medication**

**Risk factors present?**

**Yes**

**Admit to hospital and start multimodal pain regimen if possible**
- Restart home pain medications
- Schedule Q4hr Tylenol PO or IV
- Schedule Q6hr NSAIDs (Celebrex, Motrin, or Toradol)
- Schedule Gabapentin
- Lidoderm patches
- PO or IV narcotic, PCA if necessary

**ICU management**
- Q1hr nursing/RT - Assessment for pain control, cough, and IS
- After 8 hours - If pain not controlled, lack of strong cough, or IS < 15cc/kg, escalate to invasive analgesia (Epidural or Paravertebral catheter placement)
- Consider early (<72hrs) rib fixation if clinical deterioration or continued uncontrolled pain – See Rib Fracture Fixation Guideline

**Yes**

**No**

**2 or more risk factors present?**

**Yes**

**Ward Management**
- Q4hr nursing/RT - Assessment for pain control, cough, and IS
- After 8 hours - If pain not controlled, lack of strong cough, or IS < 15cc/kg, escalate to invasive analgesia (Epidural or Paravertebral catheter placement)
- Clinical deterioration -> ICU
- Consider early (<72hrs) rib fixation for severe fractures without improvement on medical therapy – See Rib Fracture Fixation Guideline

---

**References**


Zhao, Praeger : Rev. 05/2017
Surgical stabilization of severe rib fractures

Fredric M. Pieracci, MD, MPH, Maria Rodil, BA, Robert T. Stovall, MD, Jeffrey L. Johnson, MD, Walter L. Biffl, MD, Cyril Mauffrey, MD, Ernest E. Moore, MD, and Gregory J. Jurkovich, MD, Denver, Colorado
https://www.youtube.com/watch?v=3rTsvb2ef5k