RIB FRACTURE FIXATION

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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

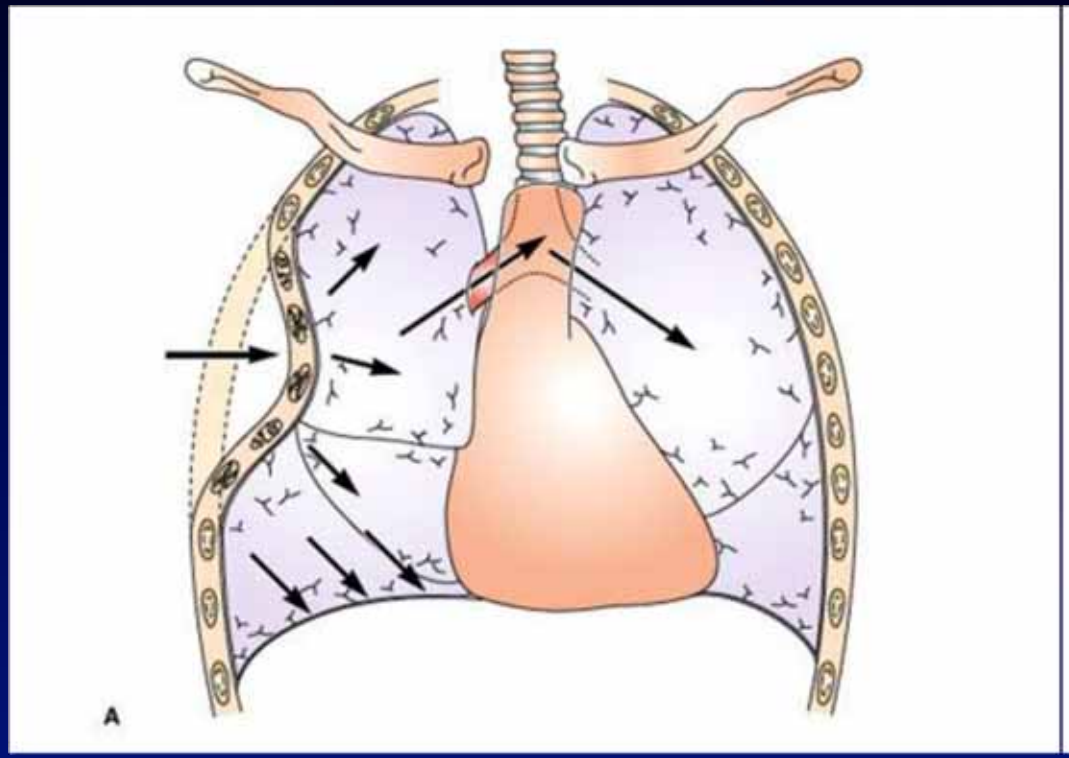
CONSEQUENCES OF PAIN

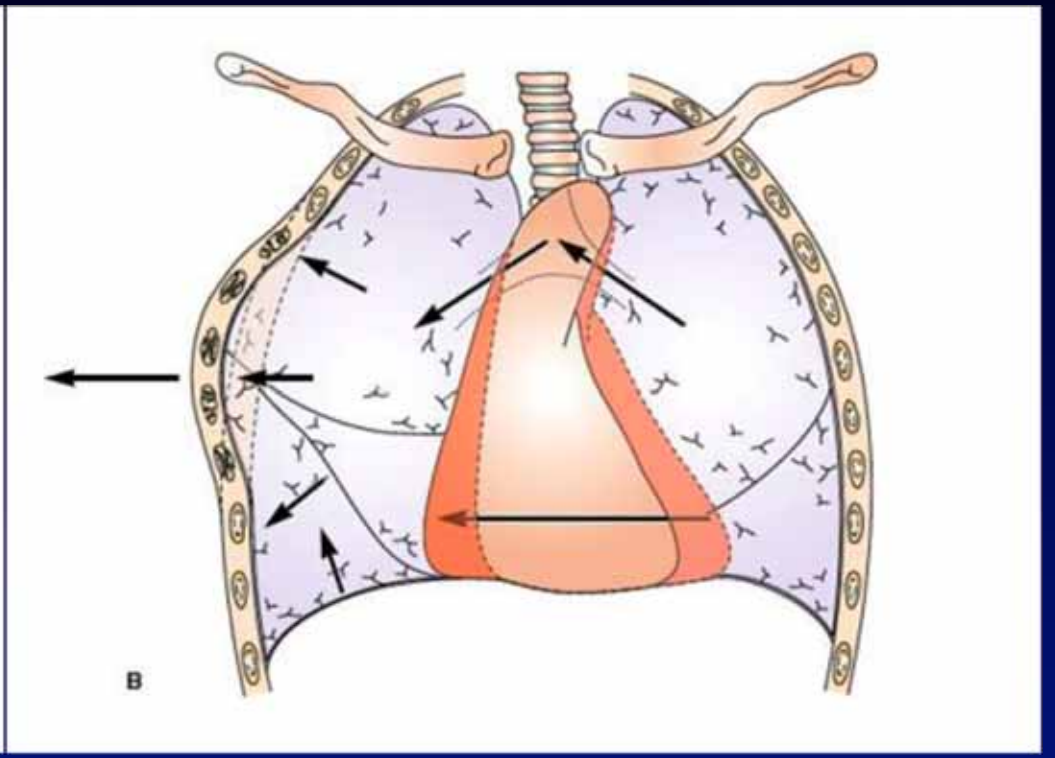
- **Splinting** – Reduced inspiration effort
- **Smaller tidal volumes** -> Reduced efficiency of Ventilation -> Hypercarbia
- **Inadequate alveolar expansion** -> Atelectasis and Hypoxia
- **Decreased forced vital capacity and cough** -> Reduced pulmonary secretion clearance -> Pneumonia

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)





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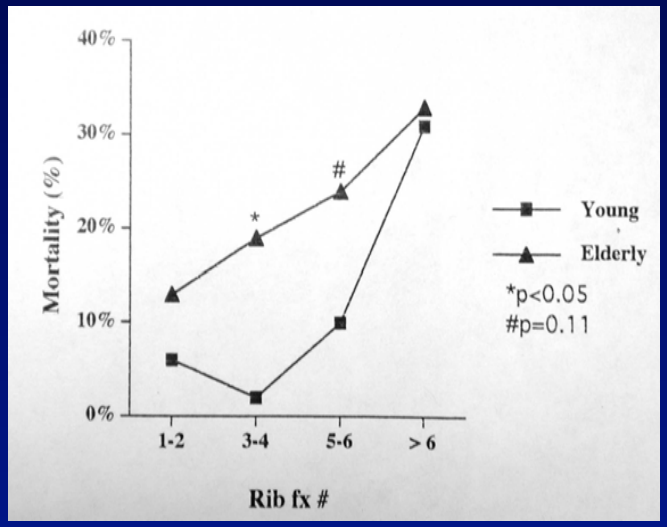
SHORT TERM OUTCOMES

- **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

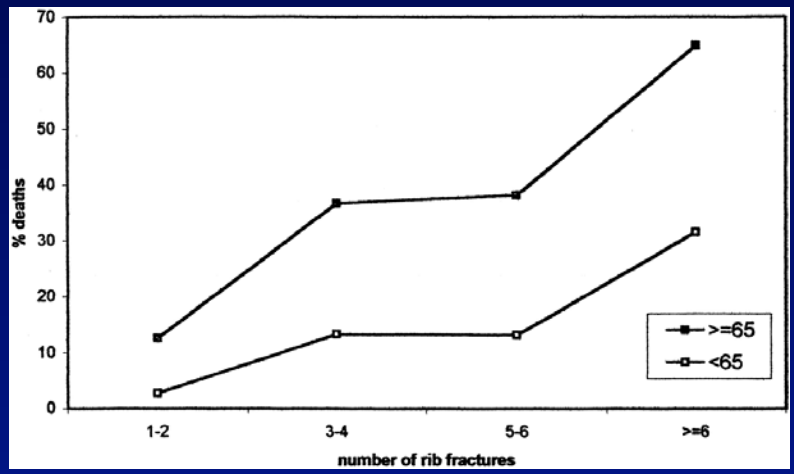
ELDERS VS YOUNG ADULTS

Mortality

Elderly	Young	
22%	10%	Bulger, J Trauma 2000; 48:1040
20%	9%	Bergeron, J Trauma 2003; 54:478
20%	11%	Stawicki, J Am Geriatr Soc 2004; 52:805



Bulger, J Trauma 2000; 48:1040



Bergeron E et al, 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)**

Fabricant L, Mayberry J et al Am J Surg 2013, 2014

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

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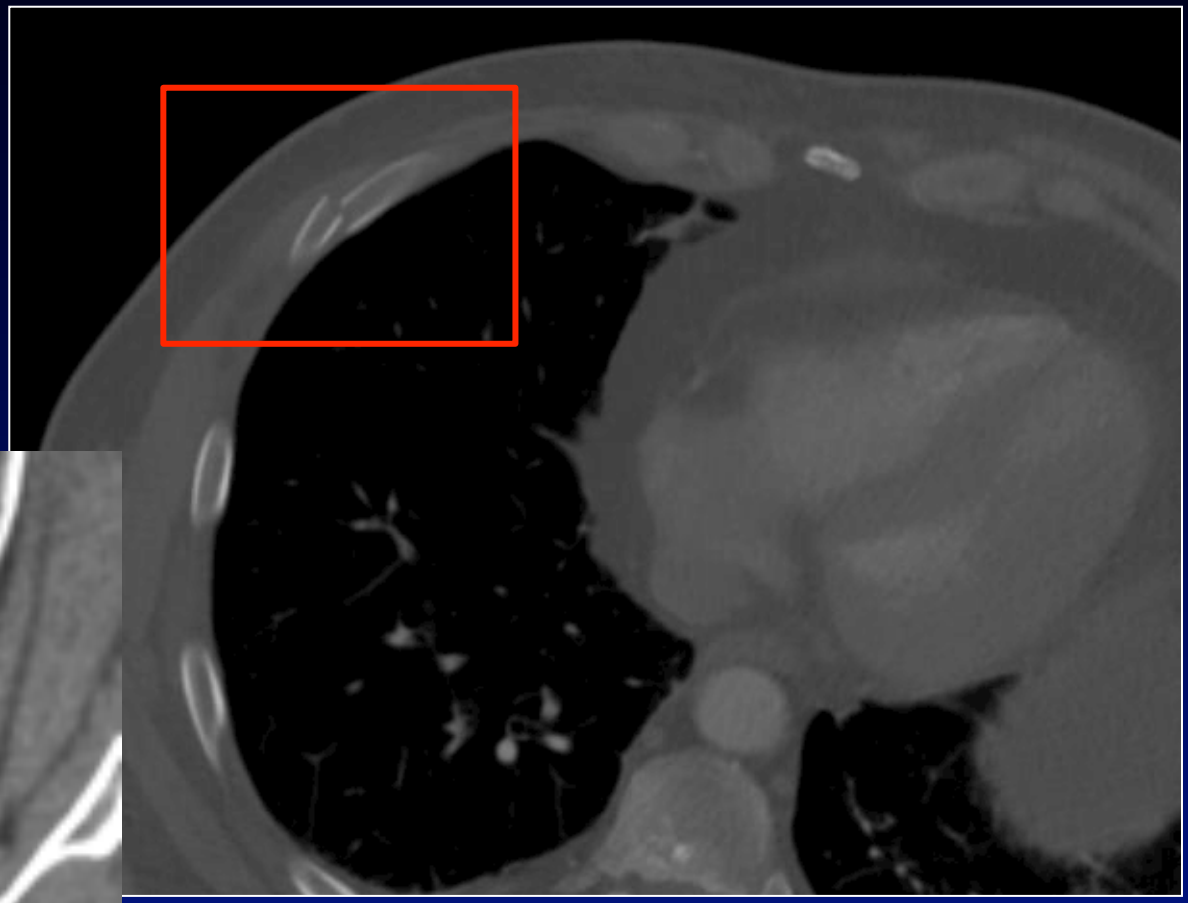
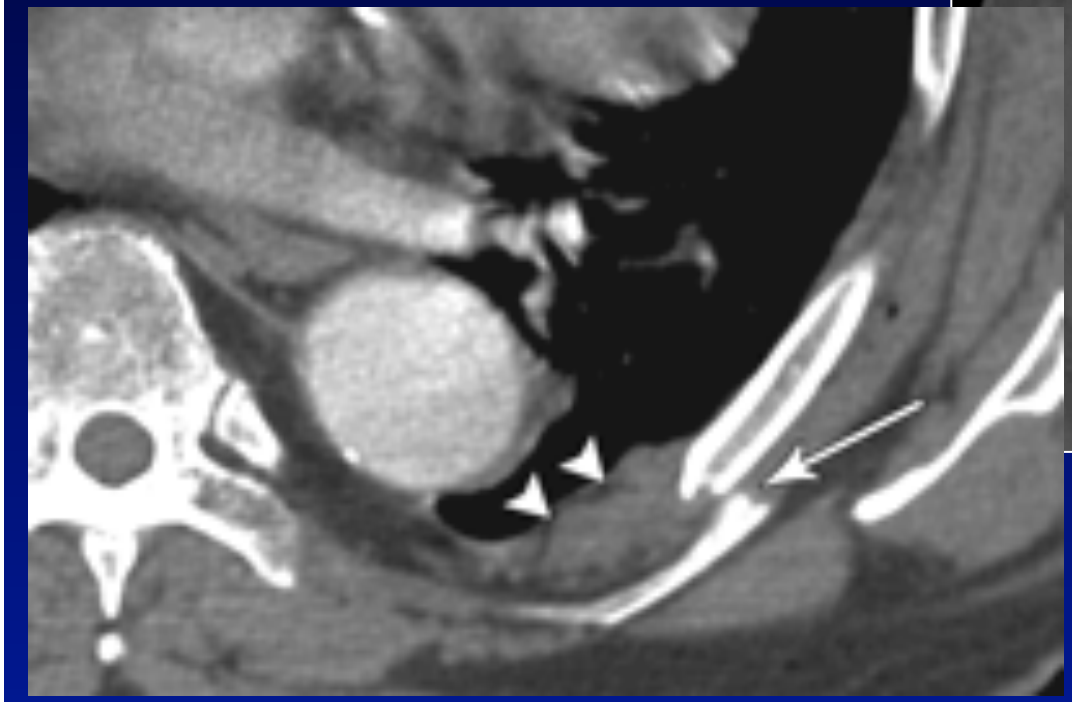
RIB FRACTURES

Anatomic considerations/terminology

- **Location**
- **Displacement**





- Locatio
- Displac
- Angula
- Overlap

[redacted]

SIDE: R

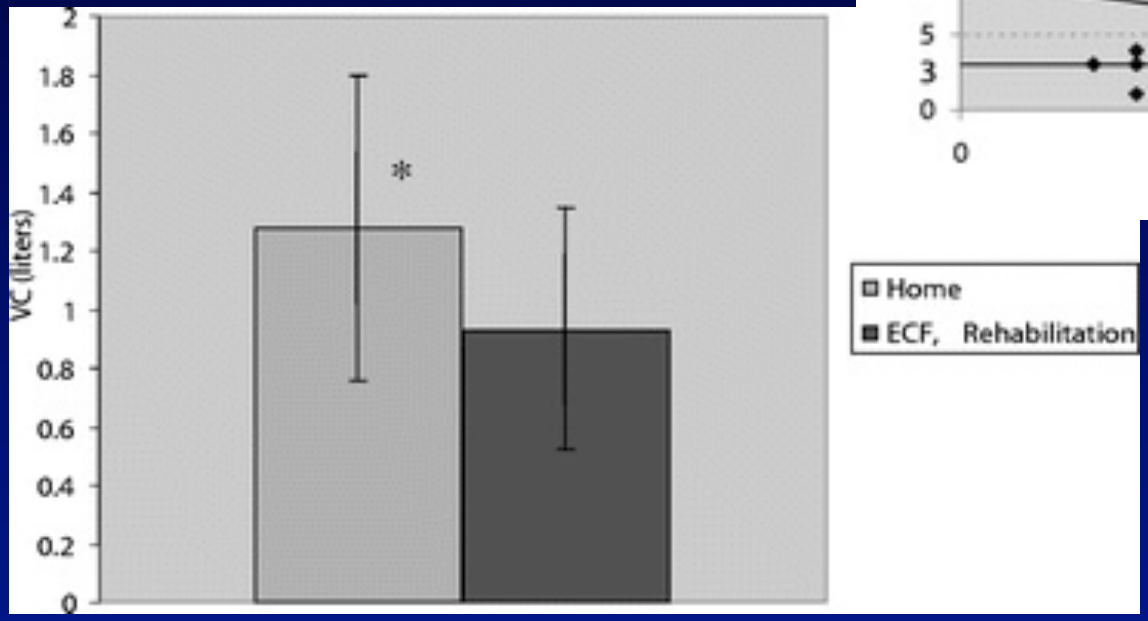
RIB	ANT	LAT	POST
3			
4		X	X
5	MIN DISPLACED	X	X
6			X
7	X		
8	X		
9	X		
10			

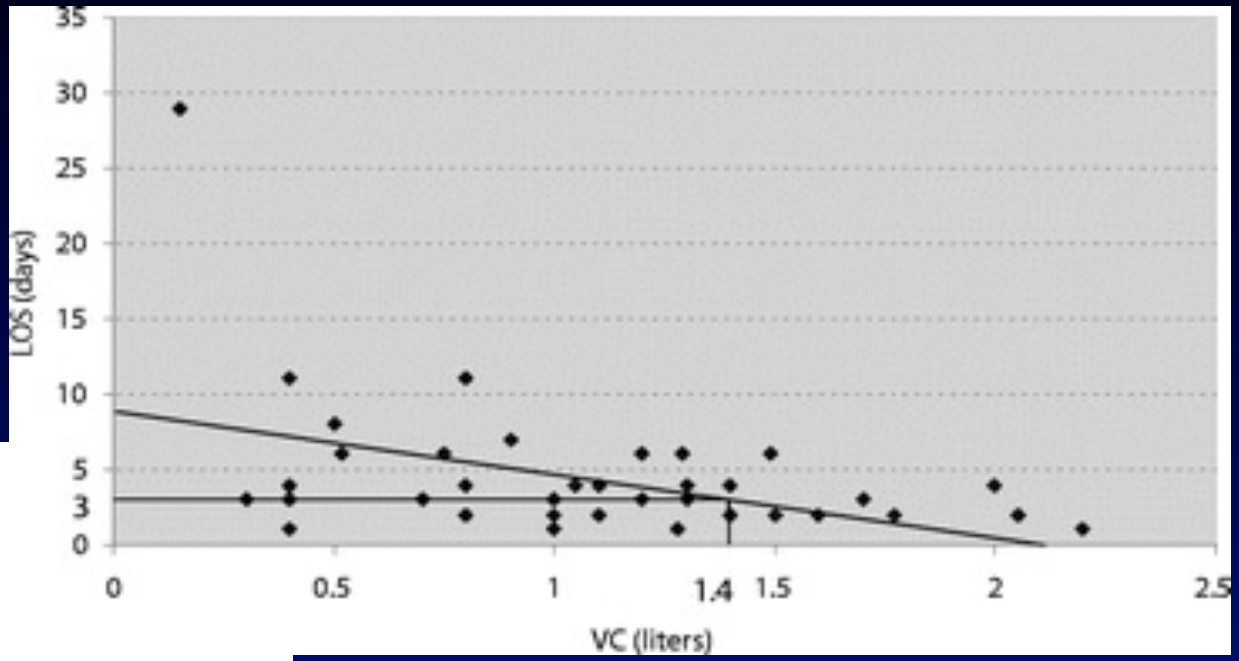
CURVE TO TP

MIN DISPLACED

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

VITAL CAPACITY





Bakhos et al, J Trauma 2006; 61:131

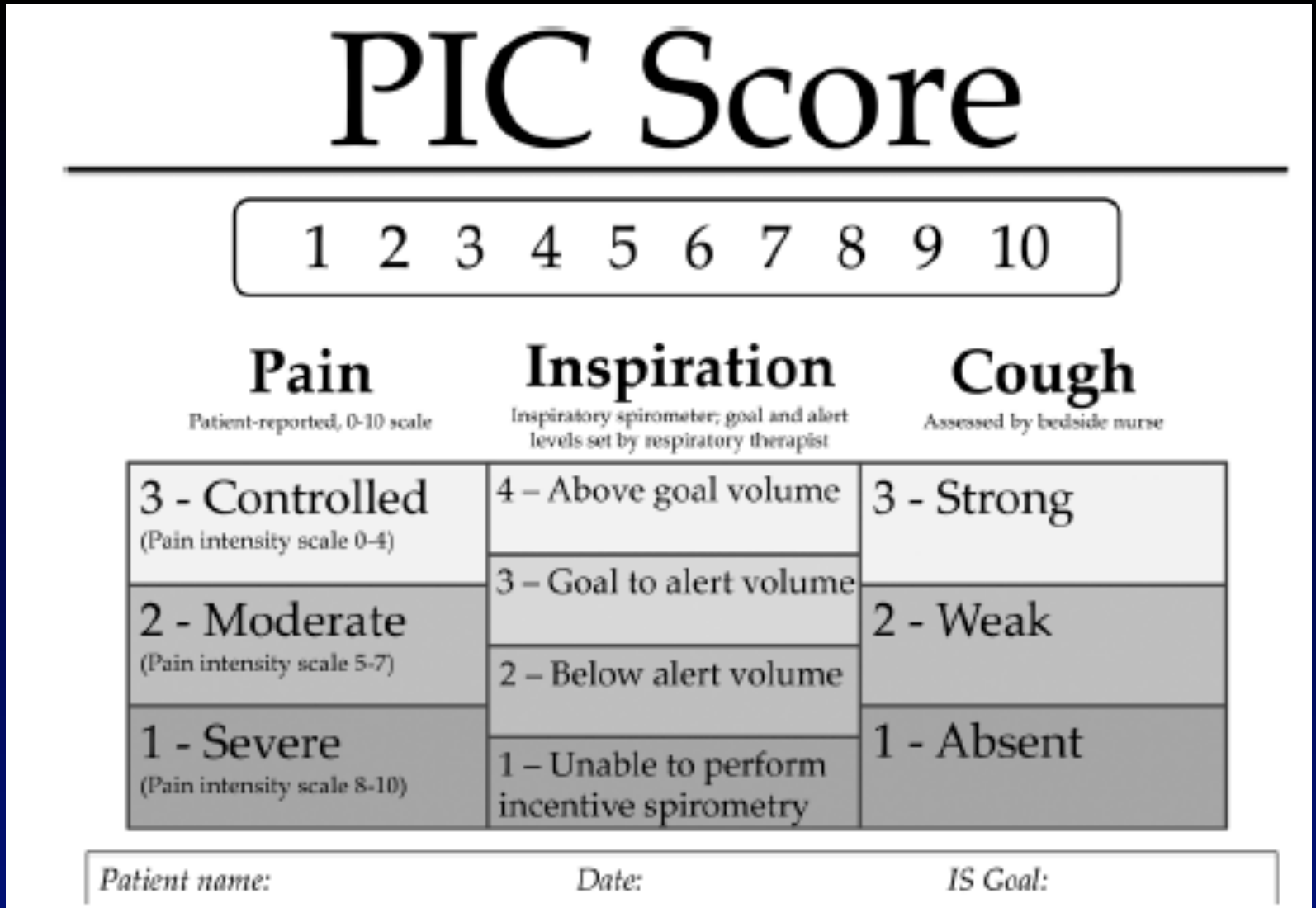


Figure 2 Harborview Medical Center PIC scoreboard. IS, incentive spirometry; PIC, Pain, Inspiratory capacity, and Cough.

Witt CE, Bulger EM. *Trauma Surg Acute Care Open* 2017;**2**:1–7.

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*

J Trauma Acute Care Surg 2016; 80:95

TABLE 2. Association of Individual RibScore Variables With Outcome Measures

Variable	Pneumonia, n (%)	Respiratory Failure, n (%)	Tracheostomy, n (%)
≥6 ribs fractured			
Present (n = 155)	33 (21.3)	68 (43.9)	39 (25.2)
Absent (n = 230)	19 (8.3)	56 (24.3)	21 (9.1)
Flail chest			
Present (n = 46)	11 (23.9)	29 (63.0)	17 (37.0)
Absent (n = 339)	41 (12.1)	95 (28.0)	43 (12.7)
Bilateral fractures			
Present (n = 120)	23 (19.2)	51 (42.5)	28 (23.3)
Absent (n = 265)	29 (10.9)	73 (27.5)	32 (12.1)
First rib fracture			
Present (n = 91)	21 (23.1)	44 (48.3)	26 (28.6)
Absent (n = 294)	31 (10.5)	80 (27.2)	34 (11.6)
≥3 displaced fractures			
Present (n = 32)	11 (34.4)	22 (68.8)	15 (46.8)
Absent (n = 353)	41 (11.6)	102 (28.9)	45 (12.7)
Fracture in each anatomic area			
Present (n = 58)	14 (24.1)	37 (63.8)	19 (32.8)
Absent (n = 327)	38 (11.6)	87 (26.6)	41 (12.5)

$p < 0.05$ for all associations tested.

sed on fracture pattern
ure, and tracheostomy

Rodil, Jennifer Salotto, MD,
MD, Clay Cothren Burlew, MD,
ID, Gregory J. Jurkovich, MD,
er, Colorado

J Trauma Acute Care Surg 2016; 80:95

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	Begin	Add	Add
ANALGESIA	• Oral narcotics • Oral muscle relaxants • Oral/IV NSAIDs • "Rib blocks"	• IV narcotics (PCA) • Continuous intercostal nerve blockade	• Continuous thoracic epidural catheter
PULMONARY TOILET	• Incentive spirometry • Upright position/ambulation • Cough and deep breathing	• Naso-tracheal suctioning	• Cricothyroidotostomy tube ("mini-trach") • +/- Intubation/ mech ventilation

Inadequate response → *Inadequate response*

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 O_2
- Positional changes
- E.T.T. suctioning
- 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.

J Trauma Acute Care Surg 2016; 80:187

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EVOLUTION OF TREATMENT

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

SKELETAL TRACTION IN THE TREATMENT OF MULTIPLE FRACTURES OF THE THORACIC CAGE*

IRWIN A. JASLOW, M.D.
Chief of Orthopedic Service, Robert Packer Hospital
SAYRE, PENNSYLVANIA

Am J Surg. 1946 Nov;72(5):753-5

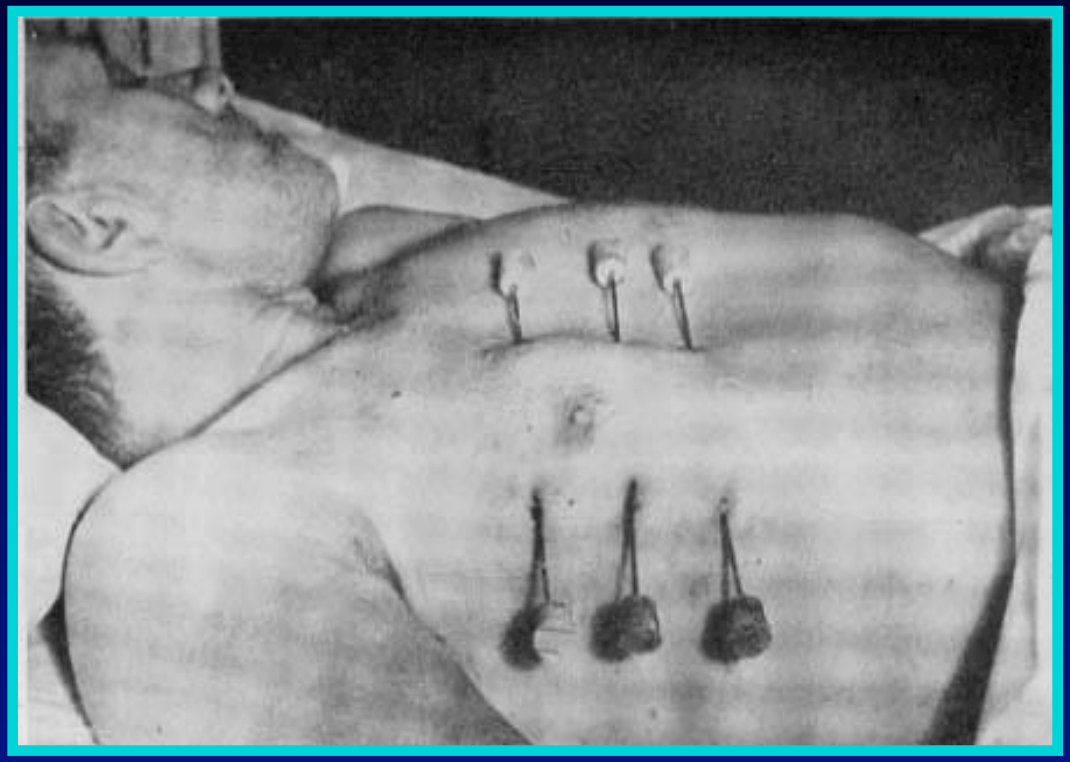
A METHOD OF SKELETAL TRACTION APPLIED THROUGH THE STERNUM IN "STEERING WHEEL" INJURY OF THE CHEST*

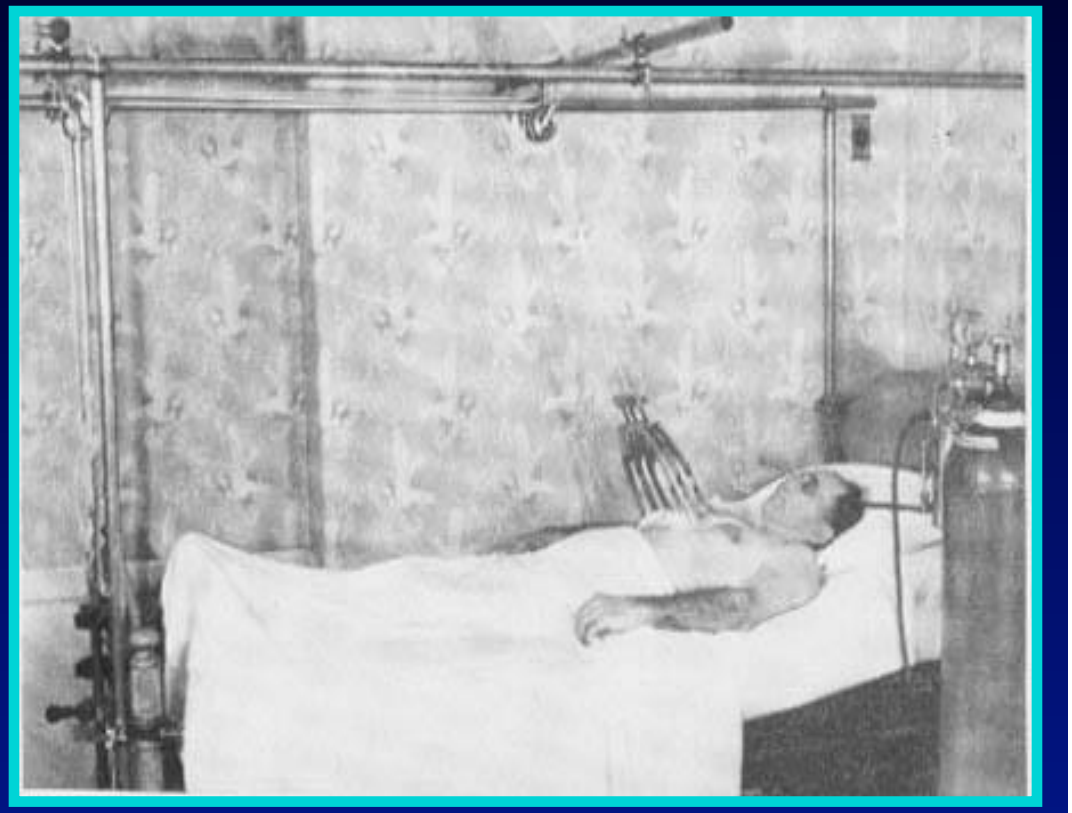
WILLIAM W. HEROY, M.D., AND FORREST C. EGGLESTON, M.D.
HEMPSTEAD, NEW YORK
FROM THE SURGICAL SERVICE, MEADOWBROOK HOSPITAL, HEMPSTEAD

Ann Surg. 1951 Jan;133(1):135-8

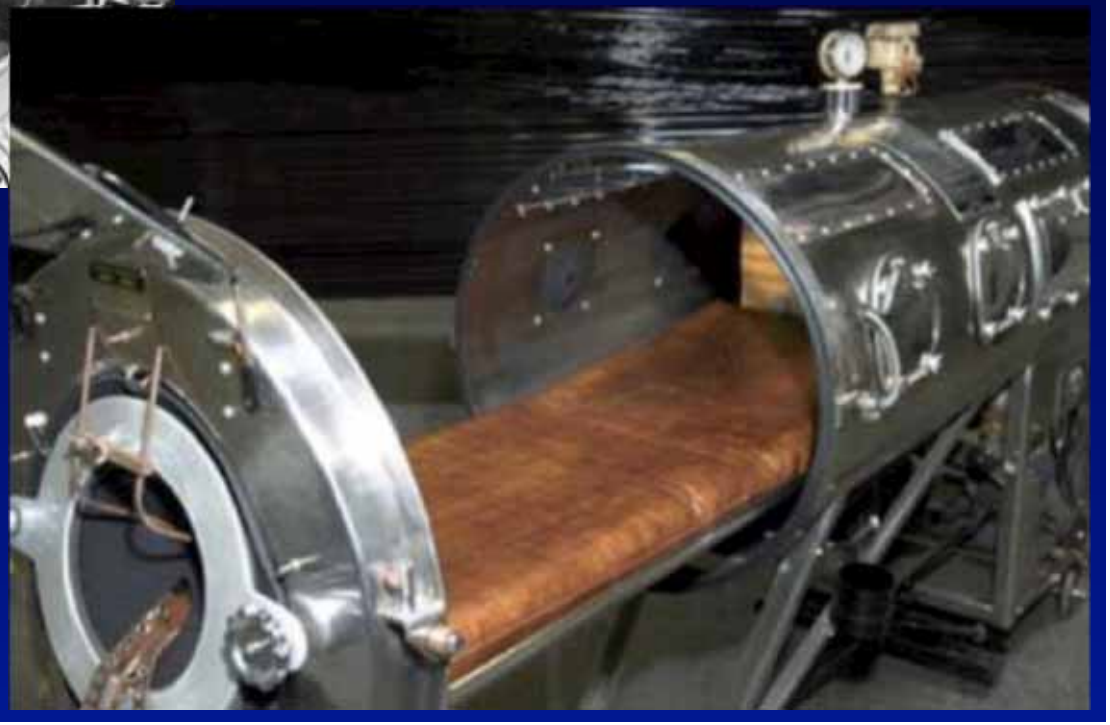
EVOLUTION OF TREATMENT

Dismal results due to prolonged bedrest and immobility and local wound problems



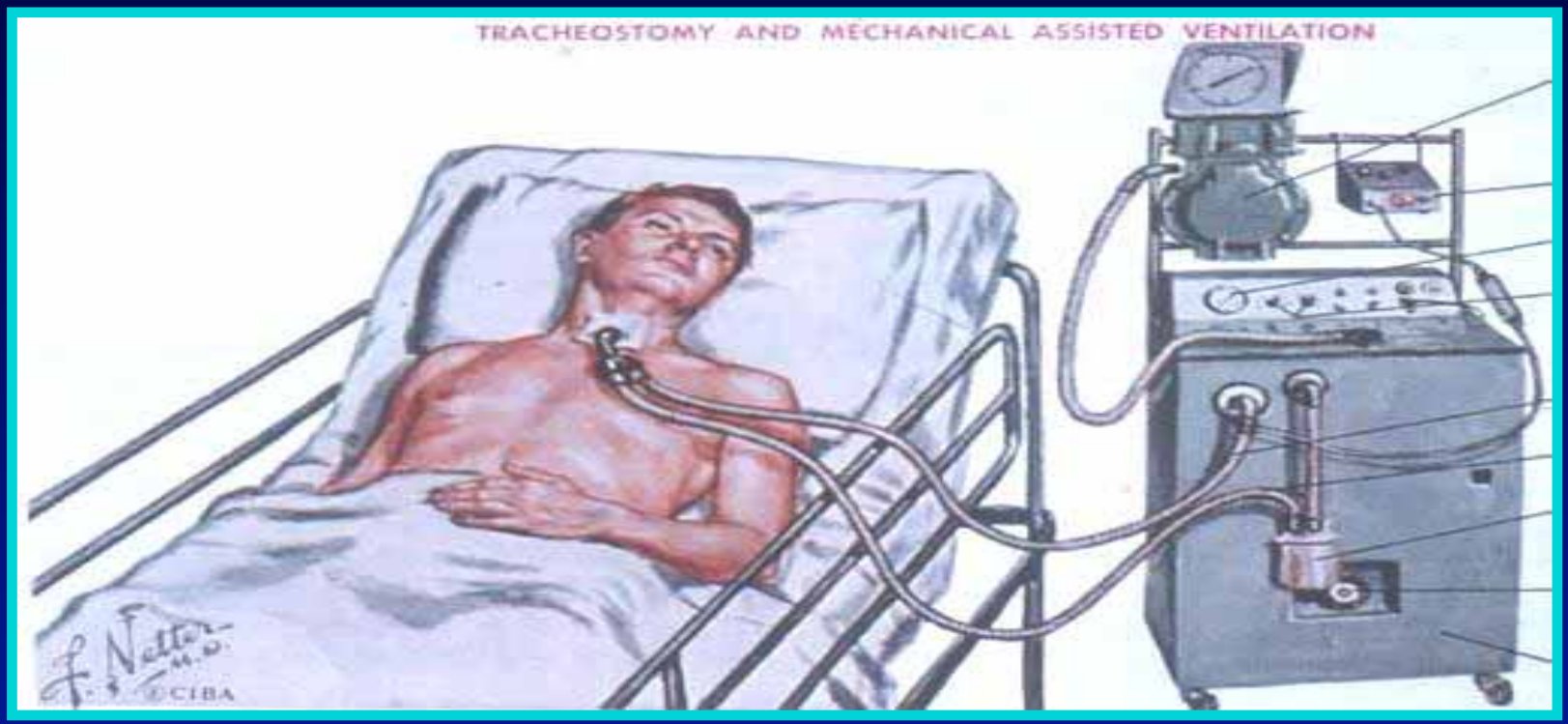


NEGATIVE PRESSURE VENTILATION



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

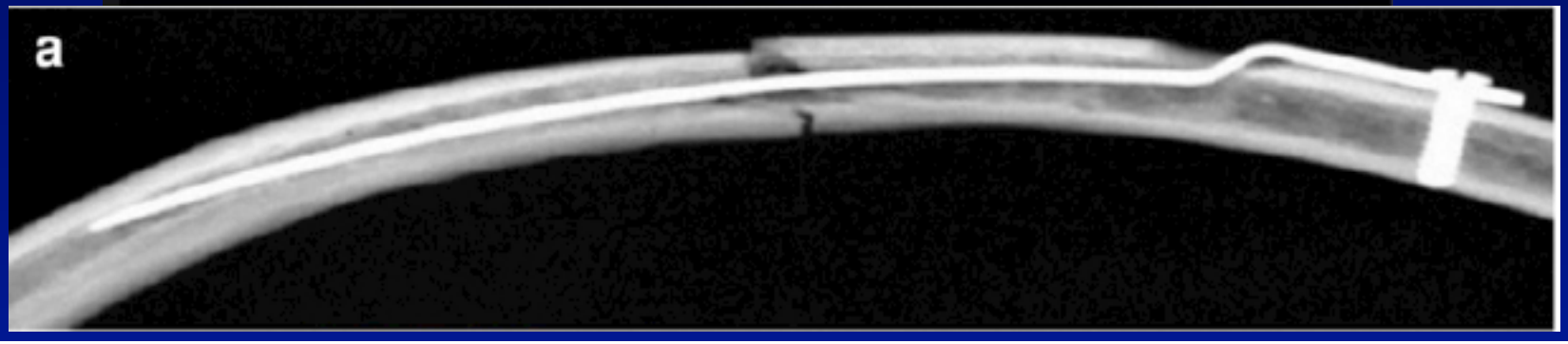
Kirsch

Rehbe

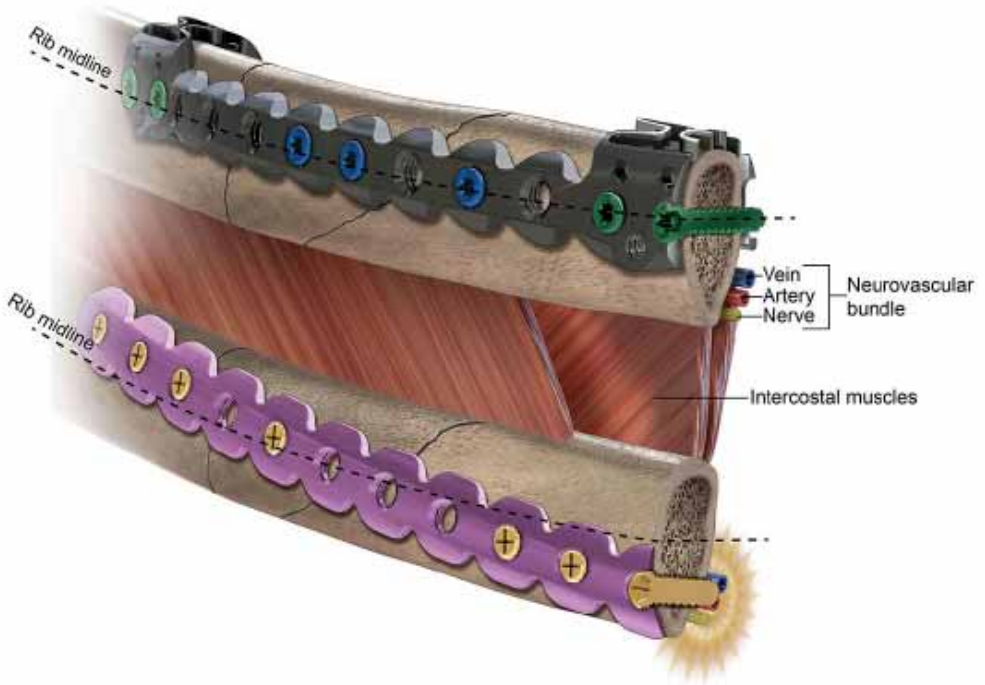
dullary
t for
cation

Figure 4 An example of an intramedullary strut, or splint, with single point fixation (41). *Courtesy of DuPuy Synthes* (© *DePuy Synthes 2017*).

Rib Splint



RIB LOC SYSTEM



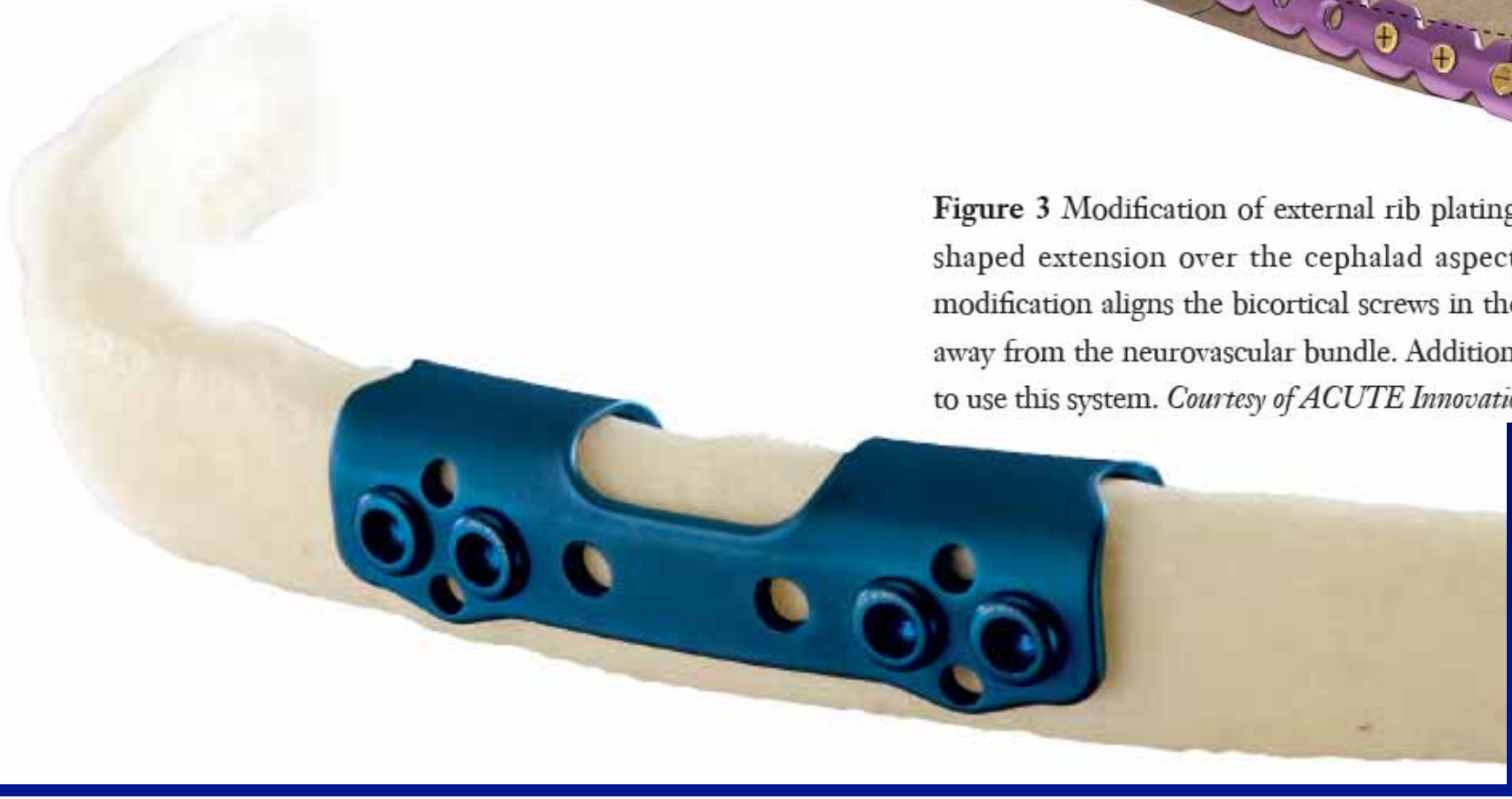
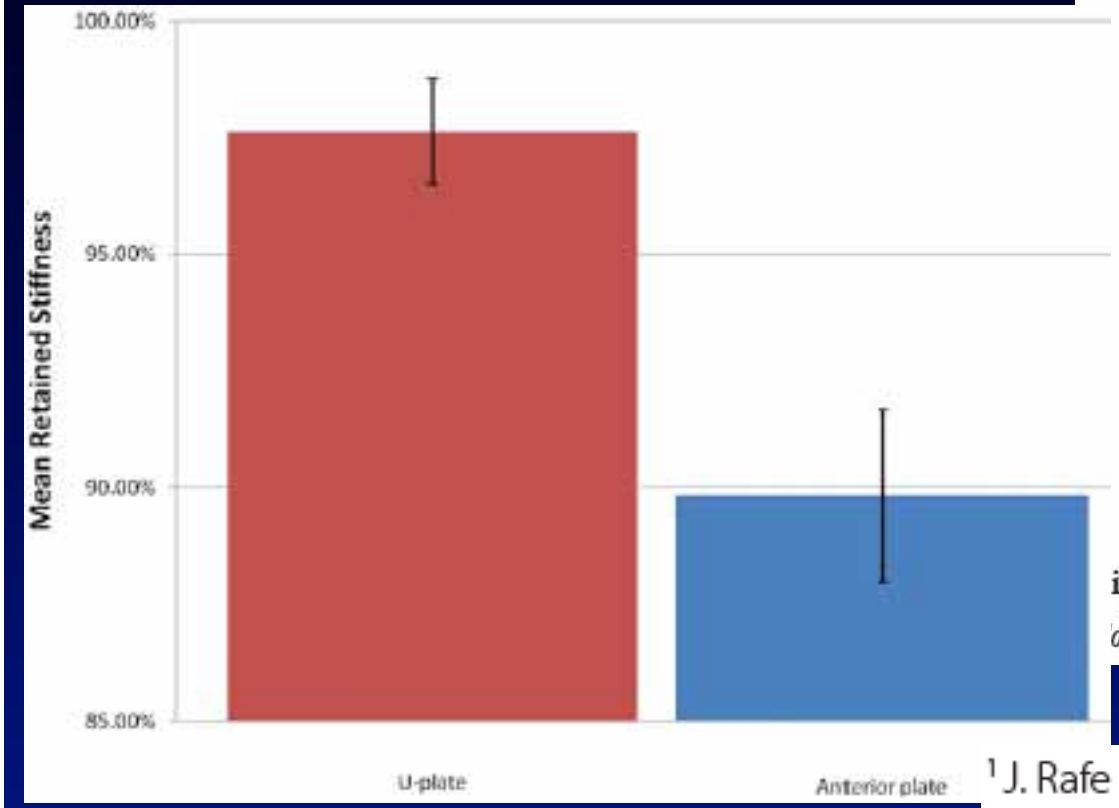
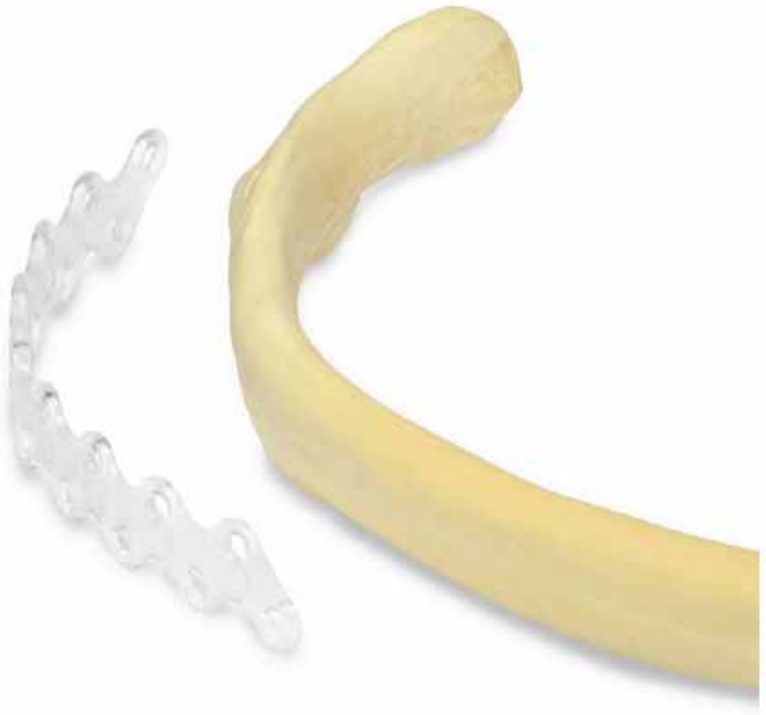


Figure 3 Modification of external rib plating hardware with a "U"-shaped extension over the cephalad aspect of the rib (40). This modification aligns the bicortical screws in the midportion of the rib, away from the neurovascular bundle. Additional dissection is required to use this system. *Courtesy of ACUTE Innovations®*.

RIB LOC SYSTEM

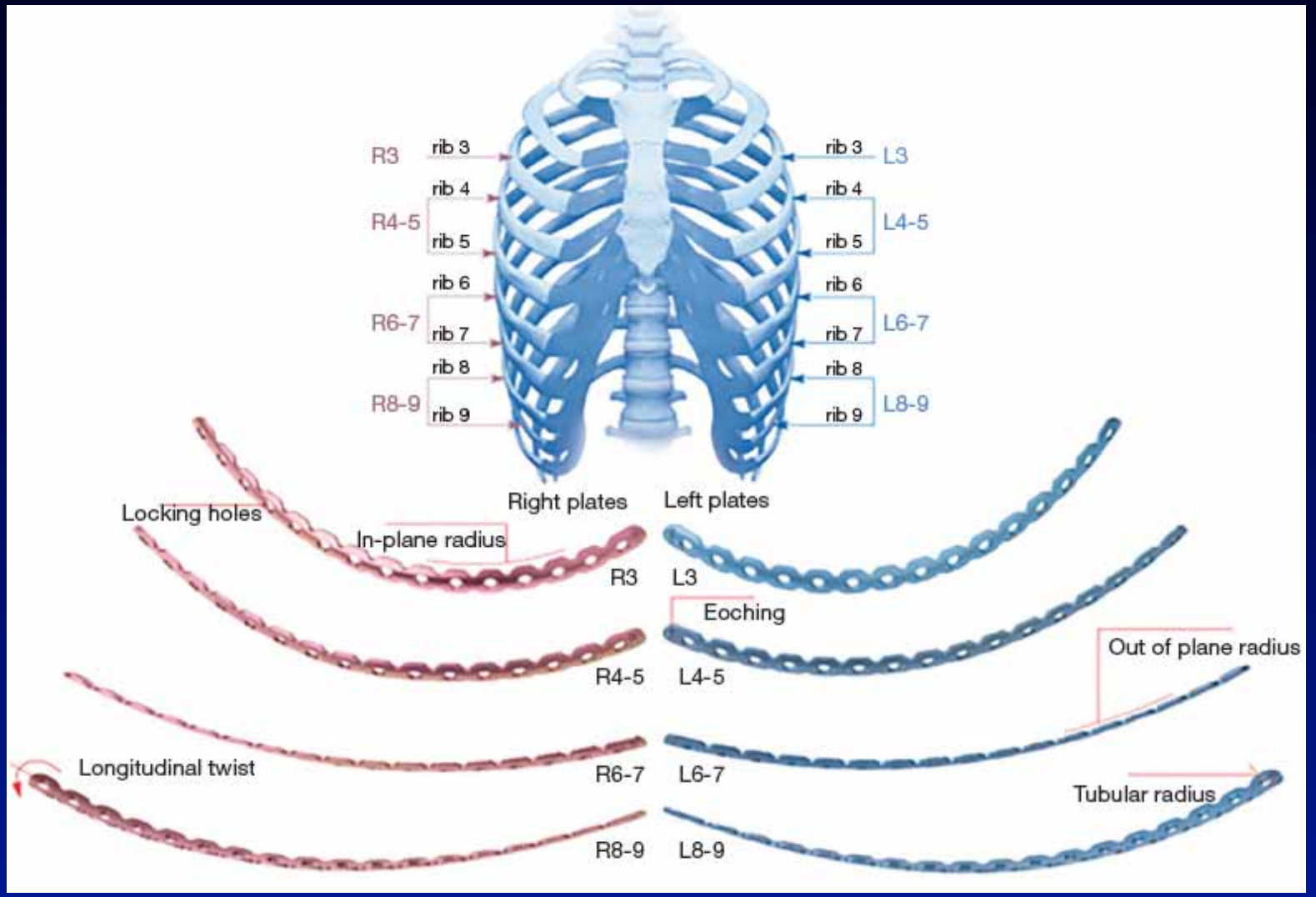




igure 5 An absorbable plate adaptable for rib fixation (43). *ourtesy of ACUTE Innovations®.*

[1] 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

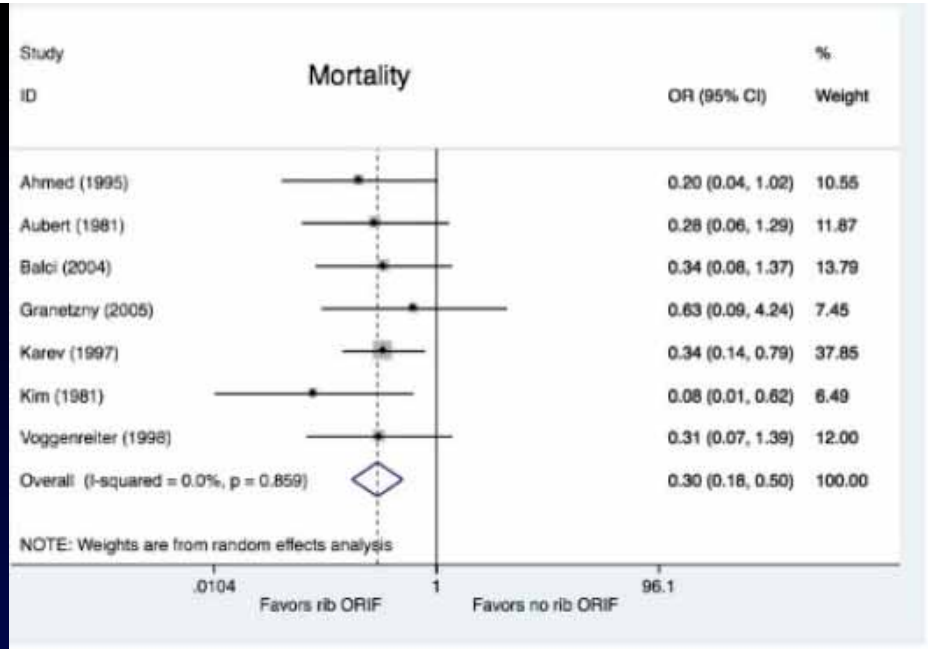
- One Size Self-Tapping/ Drill-Free Screws
- No Pre-Drilling or Measurements

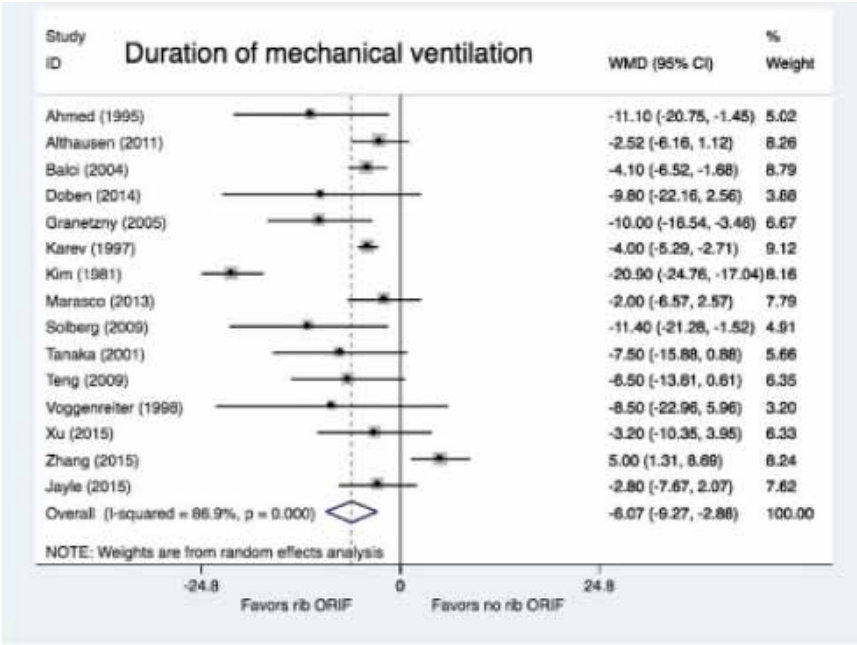
- Minimally Invasive Instrumentation
- Smart Shape Universal Plates
- Adaptive & Strong Geometric Design

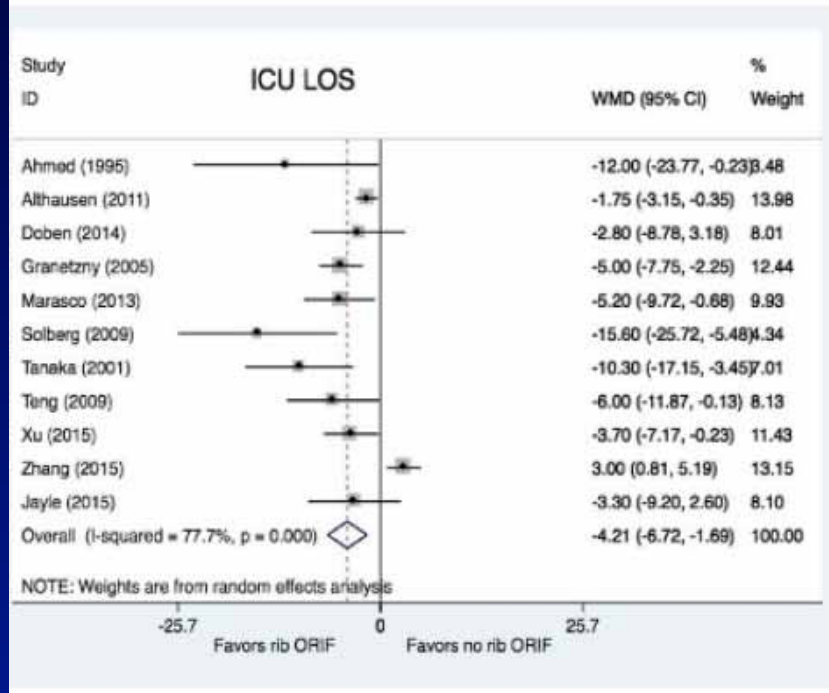
Operative fixation of rib fractures after blunt trauma: A practice management guideline from the Eastern Association for the Surgery of Trauma

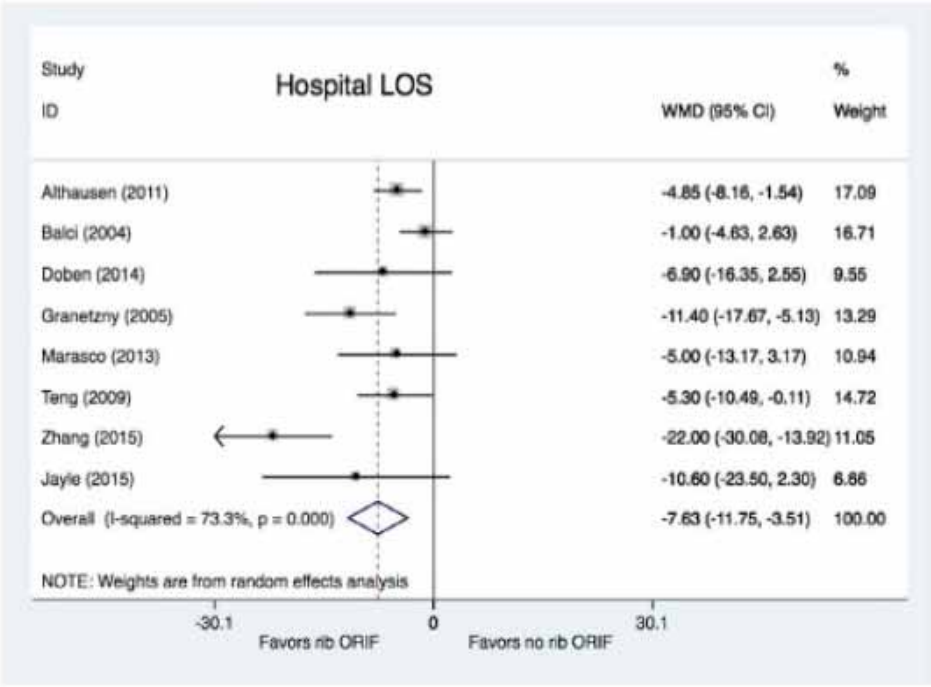
George Kasotakis, MD, MPH, Erik A. Hasenboehler, MD, Erik W. Streib, MD, Nimitt Patel, MD, Mayur B. Patel, MD, MPH, Louis Alarcon, MD, Patrick L. Bosarge, MD, Joseph Love, MD, Elliott R. Haut, MD, PhD, *and* John J. Como, MD, MPH, *Boston, Massachusetts*

J Trauma Acute Care Surgery, 2017; 82:618

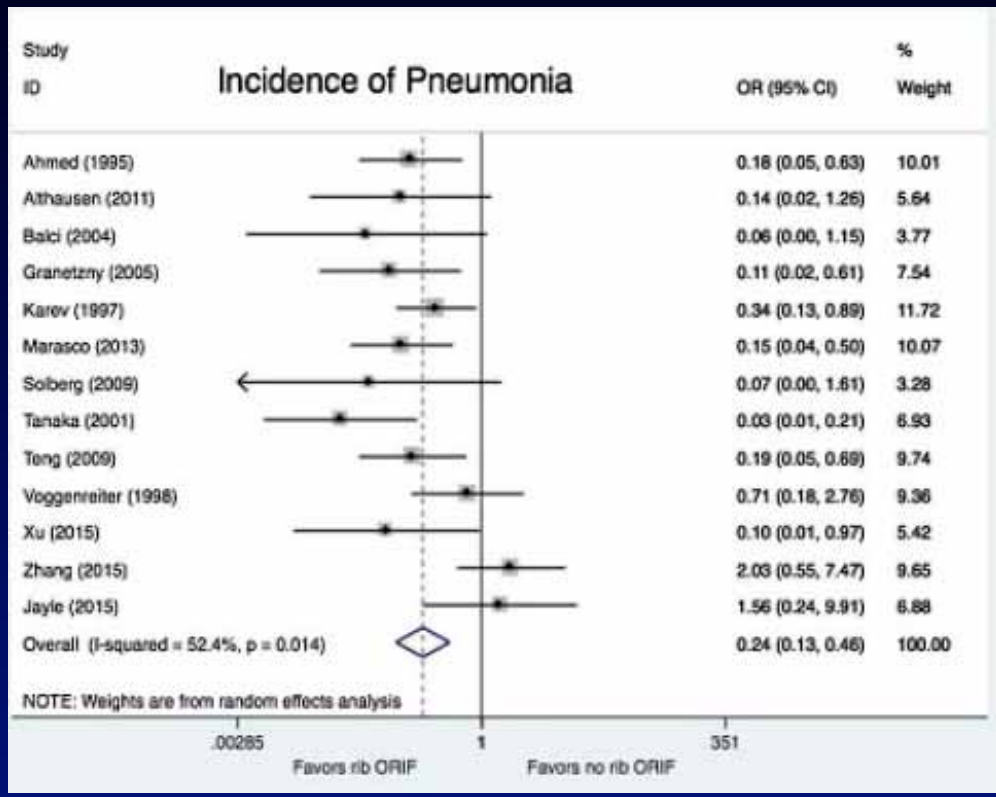


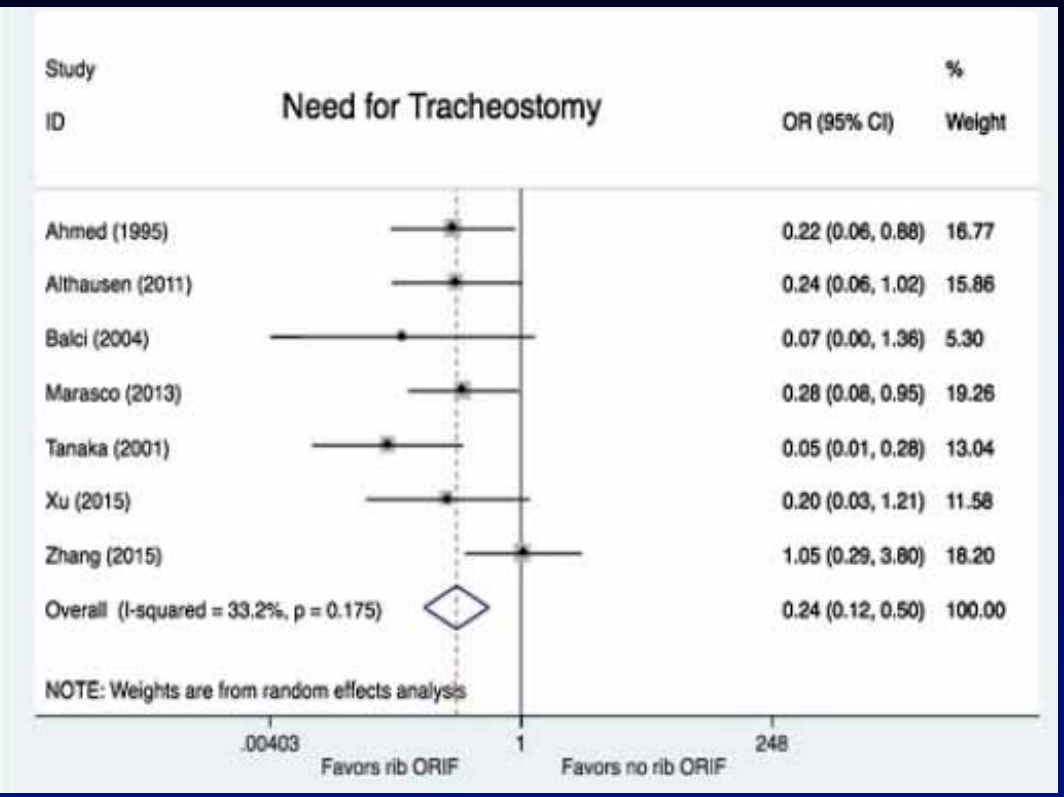






J Trauma Acute Care Surgery, 2017; 82:618





J Trauma Acute Care Surgery, 2017; 82:618

AAST 2015 PLENARY PAPER

J Trauma Acute Care Surg 2016; 80:187

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. Biffl, MD, Carlton C. Barnett, MD, Clay Cothren-Burlew, MD, Charles Fox, MD, Gregory J. Jurkovich, MD, *and* Ernest E. Moore, MD, *Denver, Colorado*

AAST Continuing Medical Education Article

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

TABLE 4 Unadjusted Outcomes

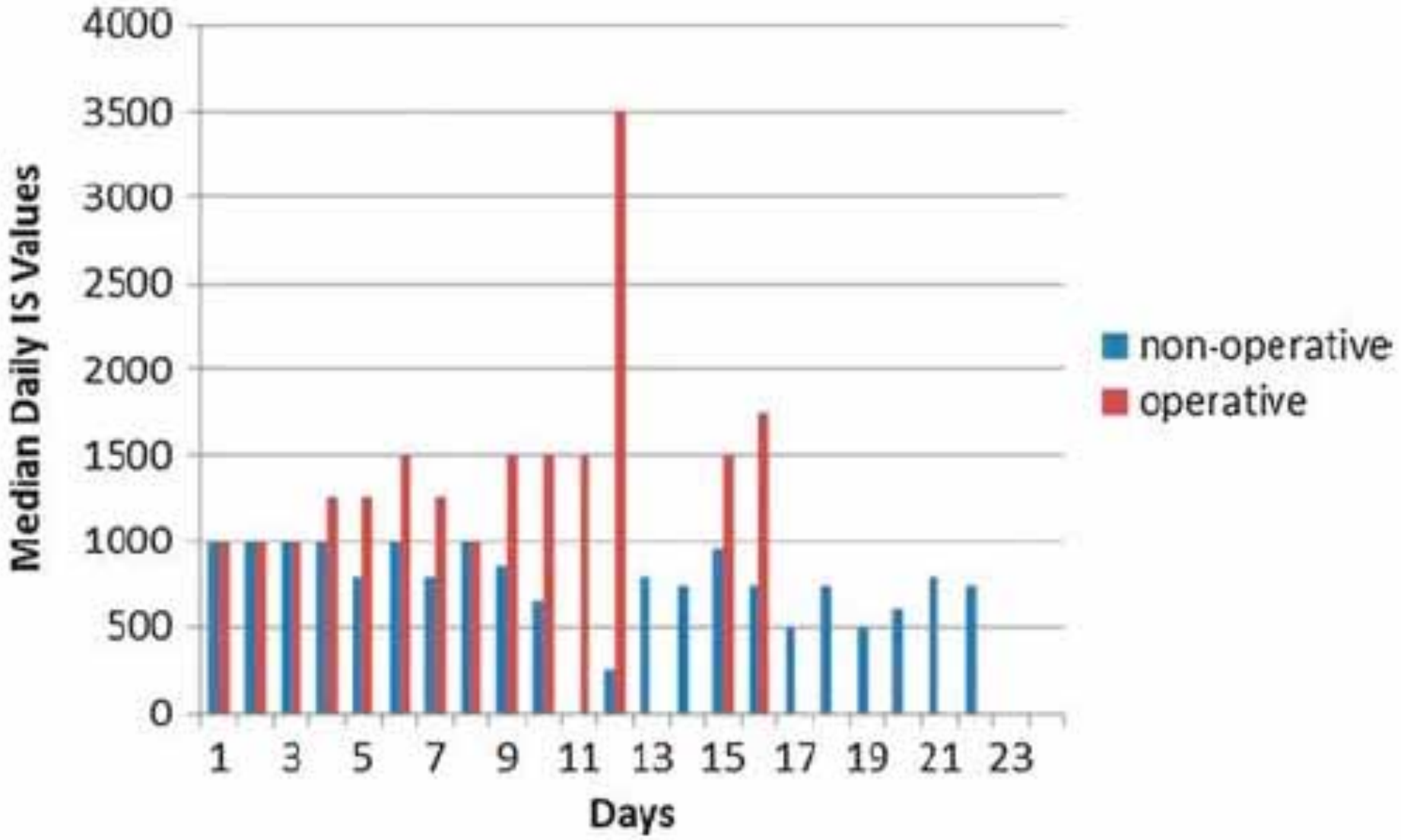


Figure 1. Daily incentive spirometry recordings.

Pneumonia	0.53	0.14–2.00	0.62

Fagevik Olsén *et al. Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine* (2016) 24:128
DOI 10.1186/s13049-016-0322-4

Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine

ORIGINAL RESEARCH Open Access

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.

Caragounis et al. World Journal of Emergency Surgery (2016) 11:27
DOI 10.1186/s13017-016-0085-2

World Journal of Emergency Surgery

RESEARCH ARTICLE Open Access

Surgical treatment of multiple rib fractures and flail chest in trauma: a one-year follow-up study

Eva-Corina Caragounis[1*], Monika Fagevik Olsén[1,2], David Pazooki[1] and Hans Granhed[1]

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.

J Trauma Acute Care Surgery, 2017; 82:618

Rib fixation: Who, What, When?

Marc de Moya,[1] Ram Nirula,[2] Walter Biffl[3,4]

Box 1 Indications

Recommended:

- ≥5 rib flail chest requiring mechanical ventilation;
- Symptomatic non-union;
- Severe displacement found during a thoracotomy for another reason.

Consider:

- ≥3 rib flail not requiring mechanical ventilation;
- ≥3 ribs with severely displaced fractures (bi-cortical displacement);
- ≥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.

de Moya M, *et al. Trauma Surg Acute Care Open* 2017;**2**:1–4.

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 ei-

admission to non-monitored setting.
[2]CT required to adequately characterize severity, although may not be clinically necessary.
[3]or other monitored setting such as a stepdown unit
[4]Pain control with narcotic, non-narcotic IV/oral meds/rib blocks

IS, cough, deep breathe
Out of bed if able

E

J Trauma Acute Care Surgery, 2017; 82:200

Rib Fracture Management Guideline for Non-Intubated Patients

THE QUEEN'S MEDICAL CENTER

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%

Traumatic injury with ≥ 3 rib fractures

↓

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

↓

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

→

2 or more risk factors present?

→ Yes

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*

→ No

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*

↓ No

Discharge home with multimodal PO analgesia medication

- Witt C and Bulger E. *Comprehensive approach to the management of the patient with multiple rib fractures: A review and introduction of a bundled rib fracture management protocol*. Trauma Surgery Acute Care Open. 2017.
- Brasel K, Moore E, Biffl W et al. *Western Trauma Association Critical Decisions in Trauma: Management of Rib Fractures.* J Trauma Acute Care Surgery, 2016.

Zhao, Praeger : Rev. 05/2017

PROCEDURES AND TECHNIQUES

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*

J Trauma Acute Care Surg 2015; 78:883

https://www.youtube.com/watch?v=3rTsvb2ef5k

<iframe width="854" height="480" src="https://www.youtube.com/embed/3rTsvb2ef5k" frameborder="0" allowfullscreen></iframe>