THORACIC TRAUMA: THE ABCs AND BEYOND

Walter L. Biffl, M.D.
Medical Director, Acute Care Surgery, The Queen’s Medical Center
Professor and Associate Chair for Research, Department of Surgery, JABSOM/University of Hawaii Manoa
OUTLINE

- Immediate Threats to Life
- Other Stuff
Intubate for Coma (GCS $\leq 8$)

Consider Intubation if:

- Maxillofacial / Neck Trauma
- Laryngeal Fracture (Hoarse, SQ Emphysema, Fracture)
- Aspiration
PEARL

If the Patient Says He is Having Difficulty Breathing…

BELIEVE HIM!!!!
AIRWAY INJURY DIAGNOSIS

- Neck Trauma
- Dyspnea
- Dysphonia/Aphonia
- Stridor/Wheezeing
- Hemoptysis
- Subcutaneous Emphysema
- Air Leak from Wound
- Pneumomediastinum
- Air Leak from Chest Tubes
AIRWAY PITFALL

- Intubation May Obstruct Airway
- Intubate with Bronchoscope if Available
- Secure Airway = No More Emergency
Surgical Airway

- Cricothyroidotomy
- Size $\leq 6.0$
- Percutaneous Insufflation (30-45 min)
  - 12-14 ga
  - 15 L/min with side-hole (1:4 sec)
“B” - IMPAIRED VENTILATION

- Tension Pneumothorax
- Open Pneumothorax
- Pulmonary Contusion / Flail Chest
- Massive Hemothorax
1. Suspected tension PTX should be decompressed in the 2\textsuperscript{nd} intercostal space, midclavicular line

2. 36 Fr chest tube should always be used in the trauma patient with HTX or PTX

3. A retained hemothorax should be treated first with a second chest tube

4. Occult PTX must be treated with chest tube in the mechanically ventilated patient
TENSION PNEUMOTHORAX

“One-Way Valve”

↓ Venous Return, Ventilation

Dx: Distended Neck Veins, Tracheal Deviation, Hyperresonance

Rx: Needle Decompression / Tube Thoracostomy
NEEDLE DECOMPRESSION

2nd Intercostal Space, MCL

3rd Rib
NEEDLE DECOMPRESSION

2nd Intercostal Space, MCL

Breast Implant!

3rd Rib
Needle Thoracostomy: Implications of Computed Tomography Chest Wall Thickness

Melissa L. Givens, MD, Karen Ayotte, MD, Craig Manifold, DO

Conclusions: In this study, a catheter length of 5 cm would reliably penetrate the pleural space of only 75% of patients. A longer catheter should be considered, especially in women. Key words: needle thoracostomy; catheter; com-

Acad Emerg Med 2004; 11:211
Needle Thoracostomy: Implications of Computed Tomography Chest Wall Thickness

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Needle Thoracostomy: A Cautionary Note

I submit that to maximize the safety and optimize the efficacy of this procedure, the catheter should be inserted in the midaxillary line through the fifth intercostal space. If the procedure is truly done for appropriate indications (i.e., tension pneumothorax), there is minimal danger of injuring any vital structures. Because this is the thinnest part of the chest wall in most patients, the need for longer catheters is obviated as well.—Walter L. Biffl, MD (wlbiffl@usatwo.org), Division of Trauma and Surgical Critical Care, Rhode Island Hospital and Brown Medical School, Providence, RI
Is routine tube thoracostomy necessary after prehospital needle decompression for tension pneumothorax?

Kathleen M. Dominguez, M.D., A. Peter Ekeh, M.D., M.P.H., Kathryn M. Tchorz, M.D., Randy J. Woods, M.D., Mbaga S. Walusimbi, M.D., Jonathan M. Saxe, M.D., Mary C. McCarthy, M.D.*

case report of injury to the pulmonary artery and cardiac tamponade is particularly unnerving. Some authors have suggested lateral chest wall placement to reduce the risk for injury to hilar structures, but there are no data to support this theoretically appealing approach. Because air rises in the anterior chest of a supine patient, it is most accessible in this position.
Parachute use to prevent death and major trauma related to gravitational challenge: systematic review of randomised controlled trials

Gordon C S Smith, Jill P Pell

Conclusions As with many interventions intended to prevent ill health, the effectiveness of parachutes has not been subjected to rigorous evaluation by using randomised controlled trials. Advocates of evidence based medicine have criticised the adoption of interventions evaluated by using only observational data. We think that everyone might benefit if the most radical protagonists of evidence based medicine organised and participated in a double blind, randomised, placebo controlled, crossover trial of the parachute.
Evaluation of 8.0-cm needle at the fourth anterior axillary line for needle chest decompression of tension pneumothorax

Samuel J. Chang, MD, Samuel Wade Ross, MD, MPH, David J. Kiefer, MD, William E. Anderson, MS, Amelia T. Rogers, BS, Ronald F. Sing, DO, and David W. Callaway, MD, Charlotte, North Carolina

<table>
<thead>
<tr>
<th></th>
<th>CWT, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-4AAL-close</td>
<td>39.6 (17.1) [14.2–94.5]</td>
</tr>
<tr>
<td>R-4AAL-close</td>
<td>39.9 (18.3) [13.6–116.6]</td>
</tr>
<tr>
<td>L-4AAL-p</td>
<td>37.6 (17.7) [11.5–108.4]</td>
</tr>
<tr>
<td>R-4AAL-p</td>
<td>37.7 (19.6) [12.3–113.9]</td>
</tr>
<tr>
<td>L-2MCL</td>
<td>46.7 (15.4) [17.8–98.9]</td>
</tr>
<tr>
<td>R-2MCL</td>
<td>43.4 (13.9) [18.7–91.9]</td>
</tr>
</tbody>
</table>
Needle Thoracentesis Decompression: Observations From Postmortem Computed Tomography and Autopsy

H. Theodore Harcke, MD; Robert L. Mabry, MD; Edward L. Mazuchowski, MD
Needle Thoracentesis Decompression: Observations From Postmortem Computed Tomography and Autopsy

L. Mabry, MD; Edward L. Mazuchowski, MD

Modified Veress needle decompression of tension pneumothorax: A randomized crossover animal study

Dafney Lubin, MD, Andrew L. Tang, MD, Randall S. Friese, MD, Matthew Martin, MD, DJ Green, MD, Trevor Jones, BS, Russell R. Means, BS, Rashna Ginwalla, MD, Terence S. O’Keeffe, MBChB, Bellal A. Joseph, MD, Julie L. Wynne, MD, Narong Kulvatunyou, MD, Gary Vermeersch, MD, Lynn Gries, MD, and Peter Rhee, MD, Tucson, Arizona
Modified Veress needle decompression of tension pneumothorax: randomized crossover animal study

Sall S. Friese, MD, Matthew Martin, MD, DJ Green, MD, Sushna Ginwalla, MD, Terence S. O’Keeffe, MBChB, Narong Kulvatunyou, MD, Gary Vercruysse, MD, Peter Rhee, MD, Tucson, Arizona
OPEN PNEUMOTHORAX

“Sucking Chest Wound”

- Pressure Equilibration; Air Passes through Hole if >2/3 Diameter of Trachea
- Temporary Occlusive Dressing Taped on 3 Sides
- Tube Thoracostomy
PULMONARY CONTUSION / FLAIL CHEST

- Pain
- Disruption of Mechanics
- Primary Problem is Underlying Contusion
- Supportive Care; Intubation if Indicated
- Rib Blocks / Epidural Analgesia
- Surgical Stabilization?

NEXT LECTURE
MASSIVE HEMOTHORAX

- >1500 mL Blood Loss
- Neck Veins Flat vs Distended
- Shock, Absent Breath Sounds, Percussion Dullness
- O.R. if: >1500 mL

200 mL/hr x 2-4 hr
Continued Transfusion

- Correct Coagulopathy, Consider Angioembolization

Pitfall: High Volume Output, Abruptly Stops
→ ?Caked Hemothorax
“C” - ETIOLOGIES OF SHOCK

- Hemorrhagic
- Cardiac Compressive
- Cardiogenic
- Neurogenic
- Septic
WHERE DOES BLOOD GO?

- Street / Wounds
- Fractures
- Chest
- Pelvis
- Abdomen
# CIRCULATION - BLOOD LOSS

## Class of Hemorrhage

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Loss (%)</td>
<td>15</td>
<td>15-30</td>
<td>30-40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>HR</td>
<td>&lt;100</td>
<td>&gt;100</td>
<td>&gt;120</td>
<td>&gt;140</td>
</tr>
<tr>
<td>SBP</td>
<td>NI</td>
<td>NI</td>
<td>Dec</td>
<td>Dec</td>
</tr>
<tr>
<td>Pulse P</td>
<td>NI / Inc</td>
<td>Dec</td>
<td>Dec</td>
<td>Dec</td>
</tr>
<tr>
<td>RR</td>
<td>14-20</td>
<td>20-30</td>
<td>30-40</td>
<td>&gt;35</td>
</tr>
<tr>
<td>UO (ml/hr)</td>
<td>&gt;30</td>
<td>20-30</td>
<td>5-15</td>
<td>Nil</td>
</tr>
</tbody>
</table>

Blood Vol = 7 ml/kg
“C” - ETIOLOGIES OF SHOCK

- Hemorrhagic
- Cardiac Compressive
- Cardiogenic
- Neurogenic
- Septic
Tension Pneumothorax

Rx: Tube Thoracostomy
“THE BOX”

Nagy KK et al. J Trauma 1995; 38:859
PHYSICAL EXAMINATION

Vital Signs, Neck Veins, Auscultation

Beck’s Triad (Hypotension, JVD, Muffled Heart Tones)

Tachycardia, Narrow Pulse Pressure

Pulsus Paradoxus (SBP Drop > 10 mm Hg with Inspiration)
ULTRASONOGRAPHY – FAST

Rozycki et al. J Trauma 1995; 39:492
PERICARDIOCENTESIS

50% False (+): Enter Chamber. Coronary Artery Puncture; Dysrhythmia.

37% False (-): Clot
Pericardiocentesis in trauma: A systematic review

Tim H. Lee, MD, Jean-Francois Ouellet, MD, Mackenzie Cook, MD, Martin A. Schreiber, MD, and John B. Kortbeek, MD

Studies on the use of PCC for trauma are limited and biased toward survivors. The reported survival rate is high. There remains a limited role for PCC in nontrauma centers where definitive surgical management is not immediately available and transport time to a higher level of care facility supports the use of temporary decompression by PCC. (J Trauma Acute Care Surg 2013; 75:543)
SUBXIPHOID PERICARDIAL WINDOW
Screening for Occult Penetrating Cardiac Injuries

Andrew J. Nicol, PhD, FCS,* Pradeep H. Navsaria, MMed, FCS,* Steve Beningfield, FCRad(D)SA,† Martijn Hommes, MD,* and Delawir Kahn, ChM, FCS*

Methods: Patients presenting with a penetrating chest wound and a possible cardiac injury to the Groote Schuur Hospital Trauma Centre between October 2001 and February 2009 were prospectively evaluated. All patients were hemodynamically stable, had no indication for emergency surgery, and had an US scan followed by subxiphoid pericardial window exploration.

<table>
<thead>
<tr>
<th></th>
<th>US Positive</th>
<th>US Negative</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPW +ve</td>
<td>117</td>
<td>18</td>
<td>135</td>
</tr>
<tr>
<td>SPW -ve</td>
<td>35</td>
<td>2</td>
<td>37</td>
</tr>
<tr>
<td>Total</td>
<td>152</td>
<td>20</td>
<td>172</td>
</tr>
</tbody>
</table>

TABLE 2. US as a Screen for Potential Cardiac Injuries
FIGURE 2. A and B, The "cardiac zone"—the high-risk area for a PCI.

Injury in the Cardiac Zone

- Ultrasound (US) pericardial sac
  - Positive US or Pneumopericardium
    - SPW
  - Equivocal US
    - HT present or Clinical suspicion
      - CT scan or Repeat US at 24-h
  - Negative US
    - No HT
      - D/C
Results: Fifty-five patients were randomized to sternotomy and 56 to pericardial drainage and wash-out only. Fifty-one of the 55 patients (93%) randomized to sternotomy had either no cardiac injury or a tangential injury. There were only 4 patients with penetrating wounds to the endocardium and all had healed. There was 1 death postoperatively among the 111 patients (0.9%) and this was in the sternotomy group. The mean intensive care unit (ICU) stay for a sternotomy was 2.04 days (range, 0–25 days) compared with 0.25 days (range, 0–2) for the drainage group \( (P < 0.001) \). The estimated mean difference highlighted a stay of 1.8 days shorter in the ICU for the drainage group (95% CI: 0.8–2.7). Total hospital stay was significantly shorter in the SPW group \( (P < 0.001; 95\% \text{ CI}: 1.4–3.3) \).
MANAGEMENT OF CARDIAC WOUNDS

Wall MJ et al. J Trauma 1997; 42:905
RESUSCITATIVE THORACOTOMY

Objectives

- Release Pericardial Tamponade
- Repair Cardiac Wounds
- Perform Open Cardiac Massage
- Cross-Clamp Aorta to Limit Subdiaphragmatic Hemorrhage and Redistribute Blood Flow to Myocardium and Brain
- Control Intrathoracic Hemorrhage
- Control Bronchovenous Air Embolism
CARDIOGENIC SHOCK

Myocardial Infarction
Dx: ECG, Enzymes

Bronchovenous Air Embolism
Dx: Shock with Positive Pressure Vent
Rx: Hilar Cross-Clamp, Ventricular / Aortic Root Venting, Vigorous Cardiac Massage
BLUNT CARDIAC INJURY
(Formerly “Cardiac Contusion”)

Direct Impact Injury to the Heart
Right Heart (RV) Most Commonly Affected

Clinical Significance: Occult and
Inconsequential to Life-Threatening
Dysrhythmias or Pump Failure (“Sig BCI”)

- No Characteristic Presentation
- No Diagnostic Gold Standard
Cardiac Enzymes Are Irrelevant in the Patient With Suspected Myocardial Contusion

Walter L. Biffl, MD, Frederick A. Moore, MD, Ernest E. Moore, MD, Angela Saueria, MD, Robert A. Read, MD, Jon M. Burch, MD, Denver, Colorado

No Patient with SIG-BCI Had Elevated CK-MB Without Abnormal ECG
CK-MB Levels Were Not Predictive of SIG-BCI

CARDIAC TROPONIN
Low Sensitivity and Predictive Value for SIG-BCI

Fulda GJ et al. J Trauma 1997; 43:304

Real Value:
Normal Admission ECG + cTnI at 4-8 Hrs Has Negative Predictive Value for SIG-BCI Approaching 100%:

0/46  Salim A et al. J Trauma 2001; 50:237
0/40  Collins JN et al. Am Surg 2001; 67:821
0/131 Velmahos GC et al. J Trauma 2003; 54:45
Screening for blunt cardiac injury: An Eastern Association for the Surgery of Trauma practice management guideline

Keith Clancy, MD, Catherine Velopulos, MD, Jaroslaw W. Bilaniuk, MD, Bryan Collier, DO, William Crowley, MD,† Stanley Kurek, DO, Felix Lui, MD, Donna Nayduch, RN, Ayodele Sangosanya, MD, Brian Tucker, DO, and Elliott R. Haut, MD

In patients with a normal ECG result and normal troponin I level, BCI is ruled out. The optimal timing of these measurements, however, has yet to be determined. Conversely, patients with normal ECG results but elevated troponin I level should be admitted to a monitored setting (new).
OTHER TIDBITS
OCCULT PNEUMOTHORAX

Seen on CT but not CXR

2% Trauma Admissions

30% PTXs

If Asymptomatic, No Rx

“Prophylactic” Tube Thoracostomy for Positive-Pressure Ventilation

DeMoya et al. J Trauma 2007; 63:13
448 Pts Observed

27 (6%) Chest Tube for PTX Progression, Resp Distress, or Hemothorax

10/73 (14%) Failed on PPV- No Tension
Occult pneumothoraces in critical care: A prospective multicenter randomized controlled trial of pleural drainage for mechanically ventilated trauma patients with occult pneumothoraces

### TABLE 4. OPTX Sizes of Observed Patients Who Subsequently Required Pleural Drainage (obs-TT) or Not Required Drainage (obs-OK) on the Site Randomized to Observation

<table>
<thead>
<tr>
<th></th>
<th>Obs-OK</th>
<th>Obs-Fail</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population (n = 50)</td>
<td>40</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Ball index, median (IQR)</td>
<td>16.8 (2.5–48.0)</td>
<td>20.1 (9.8–33.0)</td>
<td>0.784</td>
</tr>
<tr>
<td>de Moya score, median (IQR)</td>
<td>18.7 (15.0–26.5)</td>
<td>17.6 (15.8–23.5)</td>
<td>0.912</td>
</tr>
<tr>
<td>AAST (mm), median (IQR)</td>
<td>8.2 (5.0–15.1)</td>
<td>7.6 (5.8–13.5)</td>
<td>0.808</td>
</tr>
<tr>
<td>Wolfman (“miniscule”)</td>
<td>15</td>
<td>1</td>
<td>NA</td>
</tr>
<tr>
<td>Wolfman (“anterior”)</td>
<td>22</td>
<td>9</td>
<td>NA</td>
</tr>
<tr>
<td>Wolfman (“anterolateral”)</td>
<td>3</td>
<td>0</td>
<td>NA</td>
</tr>
</tbody>
</table>

NA, not applicable.
HEMOTHORAX

Indications for Surgery:

• >1500 mL Output
• 200 mL/hr Output x 2-4 hr*
• Continued Transfusion*

*Correct Coagulopathy, Consider Angioembolization
Occult traumatic hemothorax: when can sleeping dogs lie?


Department of Surgery, Trauma/Critical Care, University Medical Center, University of California, San Francisco–Fresno Campus, 445 S. Cedar Ave., Fresno, CA 93702, USA

HTX < 1.5 cm (260 mL) Can Be Watched
92% Success

EAST Guideline: ALL HTXs Should be Drained
Mowery NT et al. J Trauma 2011; 70:510
<table>
<thead>
<tr>
<th></th>
<th>Kulvatunyou et al.</th>
<th>Inaba et al.³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14F PC (n = 36)</td>
<td>28F–32F CT (n = 144)</td>
</tr>
<tr>
<td>IO, mean ± SD, mL</td>
<td>560 ± 81</td>
<td>312 ± 314</td>
</tr>
<tr>
<td>Tube days, mean ± SD</td>
<td>5 ± 0.8</td>
<td>6.3 ± 3.9</td>
</tr>
<tr>
<td>Failure (retained HTX), %</td>
<td>8</td>
<td>12</td>
</tr>
</tbody>
</table>

CT, chest tube.
Two-Year Experience of Using Pigtail Catheters to Treat Traumatic Pneumothorax: A Changing Trend

Narong Kulvatunyou, MD, Aparna Vijayasekaran, MD, Adam Hansen, MD, Julie L. Wynne, MD, Terrance O’Keeffe, MD, Randall S. Friese, MD, Bellal Joseph, MD, Andy Tang, MD, and Peter Rhee, MD

TABLE 3. Insertion-Related Complications for the Pneumothorax Group

<table>
<thead>
<tr>
<th>Complication</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pigtail catheter</td>
<td></td>
</tr>
<tr>
<td>1—Left subclavian vein insertion</td>
<td>Blood transfusion and withdrawal of the catheter</td>
</tr>
<tr>
<td>1—Intercostal artery injury</td>
<td>Chest tube placement, bleeding stopped</td>
</tr>
<tr>
<td>1—Subcutaneous placement</td>
<td>Tube replacement</td>
</tr>
<tr>
<td>Chest tube</td>
<td></td>
</tr>
<tr>
<td>3—Subcutaneous placement</td>
<td>Tube replacement</td>
</tr>
<tr>
<td>1—Tube dislodgement</td>
<td>Tube replacement</td>
</tr>
</tbody>
</table>

Failure rate, n (%) 8 (11%) 6 (4%) 0.06

J Trauma 2011; 71:1104
ABX FOR TUBE THORACOSTOMY

Prophylactic Abx do not Reduce Empyema/Pneumonia; Associated with Resistant HAIs

Maxwell et al. J Trauma 2004; 57:742

Presumptive antibiotic use in tube thoracostomy for traumatic hemopneumothorax: An Eastern Association for the Surgery of Trauma practice management guideline

Forrest O. Moore, MD, Therese M. Duane, MD, Charles K.C. Hu, MD, Adam D. Fox, DO, Nathaniel McQuay, Jr., MD, Michael L. Lieber, MS, John J. Como, MD, Elliott R. Haut, MD, Andrew J. Kerwin, MD, Oscar D. Guillamondegui, MD, and J. Bracken Burns, DO

Cannot Recommend For or Against Abx

J Trauma Acute Care Surg 2012; 73:S341
Residual HTX on CXR after CT Placement
= 33% Risk of Empyema

Development of posttraumatic empyema in patients with retained hemothorax: Results of a prospective, observational AAST study

Joseph DuBose, MD, Kenji Inaba, MD, Obi Okoye, MD, Demetrios Demetriades, MD, PhD, Thomas Scalea, MD, James O'Connor, MD, Jay Menaker, MD, Carlos Morales, MD, Tony Shiflett, MD, Carlos Brown, MD, Ben Copwood, MD, and the AAST Retained Hemothorax Study Group, Baltimore, Maryland

Among patients with trauma and posttraumatic RH, the incidence of empyema was 26.8%. Independent predictors of empyema development after posttraumatic RH included the presence of rib fractures, Injury Severity Score of 25 or higher, and the need for additional interventions to evacuate retained blood from the thorax. Our findings highlight the need to

**TABLE 2. Independent Predictors of Empyema in Patients with Posttraumatic Retained Hemothoraces**

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>Adjusted OR (95% CI)</th>
<th>p</th>
<th>Cumulative R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rib fractures</td>
<td>2.28 (1.27–4.11)</td>
<td>0.006</td>
<td>0.180</td>
</tr>
<tr>
<td>2</td>
<td>ISS ≥ 25</td>
<td>2.40 (1.30–4.43)</td>
<td>0.005</td>
<td>0.217</td>
</tr>
<tr>
<td>3</td>
<td>Additional intervention</td>
<td>28.82 (6.62–125.49)</td>
<td>&lt;0.001</td>
<td>0.251</td>
</tr>
</tbody>
</table>

J Trauma Acute Care Surg 2012; 73:752
PRCT 2nd Chest Tube vs VATS

VATS = Dec Duration of CT Drainage, LOS, Cost

10/24 with 2nd CT (42%) Required Surgery


EAST Guidelines 2011

“Persistent retained hemothorax, seen on plain films, after placement of a thoracostomy tube should be treated with early VATS, not a second chest tube (Level 1).

J Trauma 2011; 70:510
### Rib Fractures

Common - 9-12% Trauma Admissions

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

Ziegler, J Trauma 1994; 37:975

Bulger, J Trauma 2000; 48:1040

Bergeron, J Trauma 2003; 54:478


NEXT LECTURE
Epidural analgesia improves outcome after multiple rib fractures

Table II. Unadjusted outcome parameters

<table>
<thead>
<tr>
<th></th>
<th>Epidural (n = 22)</th>
<th>Opioids (n = 24)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumonia</td>
<td>4 (18%)</td>
<td>9 (38%)</td>
<td>.15</td>
</tr>
<tr>
<td>No. of vent days*</td>
<td>8 ± 16</td>
<td>9 ± 26</td>
<td>.41</td>
</tr>
<tr>
<td>ARDS</td>
<td>10 (45%)</td>
<td>6 (25%)</td>
<td>.15</td>
</tr>
<tr>
<td>Mortality</td>
<td>2 (9%)</td>
<td>1 (4.2%)</td>
<td>.50</td>
</tr>
<tr>
<td>LOS (d)*</td>
<td>18 ± 16</td>
<td>16 ± 13</td>
<td>.60</td>
</tr>
<tr>
<td>ICU (d)*</td>
<td>10 ± 15</td>
<td>12 ± 26</td>
<td>.78</td>
</tr>
</tbody>
</table>

Continuous Intercostal Nerve Blockade for Rib Fractures: Ready for Primetime?

Michael S. Truitt, MD, Jason Murry, MD, Joseph Amos, MD, Manuel Lorenzo, MD, MBA, Alicia Mangram, MD, Ernest Dunn, MD, and Ernest E. Moore, MD

Conclusion: Utilization of CINB significantly improved pulmonary function, pain control, and shortens LOS in patients with rib fractures.

J Trauma 2011; 71:1548
PNEUMOMEDIASTINUM

Sign of Aerodigestive Injury

5% of Chest CTs

10% Have Injuries

If Asymptomatic, Manage Expectantly

Dissanaike et al. J Trauma 2008; 65:1340
TRACHEOBRONCHIAL INJURY

Subcu Emphysema; Pneumomediastinum; PTX w Air Leak

Dx by Bronchoscopy


Western Trauma Association Critical Decisions in Trauma: Diagnosis and management of esophageal injuries

J Trauma Acute Care Surg 2015; 79:1089

Walter L. Biffl, MD, Ernest E. Moore, MD, David V. Feliciano, MD, Roxie A. Albrecht, MD, Martin Croce, MD, Riyad Karmy-Jones, MD, Nicholas Namias, MD, Susan Rowell, MD, Martin Schreiber, MD, David V. Shatz, MD, and Karen Brasel, MD, Denver, Colorado

CTA Chest
Esophagoscopy / Esophagography
Exam + CXR or E-FAST
- Hemodynamics, Location of Wound(s); Early repeat CXR

Unilateral GSW – Chest tube
- Drained vs Retained Htx vs Large Air Leak

Transmediastinal GSW – Chest tube(s), CT scan
- Add’l W/U based on trajectory

Thoracoabdominal GSW – Chest tube, Laparotomy, ?Pericardial window
DAMAGE CONTROL
RESUSCITATION
Damage Control: Keep a Badly Damaged Ship Afloat After Major Penetrating Injury to the Hull
Damage Control: Keep a Badly Damaged Ship Afloat After Major Penetrating Injury to the Hull

- Plug Gaping Holes
- Extinguish Fires
- “Dog Down” Watertight Doors

Keep Ship Afloat
- Assess Overall Damage
- Establish a Plan for Definitive Repair
DAMAGE CONTROL IN TRAUMA

1976- Lucas and Ledgerwood
1979- Calne et al
1981- Feliciano et al
1983- Stone et al
1993- Rotondo et al
“Damage control resuscitation addresses the entire lethal triad immediately upon admission to a combat hospital”

Anticipate and Attenuate; Reverse
DAMAGE CONTROL RESUSCITATION

- Permissive Hypotension
- Limit Isotonic Crystalloid
- **Aggressive Hemostatic Resuscitation**
- Bleeding Control
- Rewarming
- Correction of Acidosis, Hypocalcemia

Chang et al. Crit Care Clin 2017; 33:15
PERMISSIVE HYPOTENSION

• **Premise**: Avoid Exacerbating Hemorrhage and Dilutional Coagulopathy

• **Caveat**: Clear Evidence of Benefit and Optimal Perfusion Targets Lacking

• **Goal**: SBP 70-90; MAP >50; Radial Pulse

• **Caution**: Severe TBI; Prolonged Shock

Chang et al. Crit Care Clin 2017; 33:15
LIMIT ISOTONIC CRYSTALLOID

- **Premise:** Excess Crystalloid – Dilutional Coagulopathy, ARDS, Cardiac Dysfunction, Compartment Syndromes, Ileus, Anastomotic Leak, Wound Complications, MOF, Death

- **Mechanism:** Intracellular Edema – Disrupt Biochemical Processes (Pancreatic Insulin, Hepatocyte Glucose Metabolism, Cardiac Myocyte Excitability); Inflammation – Inflammatory Mediators; Endothelial Glycocalyx Degradation

Chang et al. Crit Care Clin 2017; 33:15
If Not Hypotensive, >500 mL Crystalloid Assoc w/ Higher Mortality and Coagulopathy

24 Hr Crystalloid Correlated w/ Vent Days, ICU & Hosp LOS, ARDS, MOF, SSI, Bloodstream Infxn, Compartment Syndromes
Optimal Fluid?

- Colloid - Discouraged due to Cost, Coagulopathy, Renal Dysfunction
- Crystalloid - NS vs LR vs Plasmalyte

Effects of Plasma-lyte A, lactated Ringer’s, and normal saline on acid-base status and intestine injury in the initial treatment of hemorrhagic shock

Ying Wang, PhD,1, Wei Guo, MD1, Dawei Gao, PhD,2 Guoxing You, MD, Bo Wang, PhD, Gan Chen, PhD, Lian Zhao, PhD, Jingxiang Zhao, PhD, Hong Zhou, PhD

Conclusions: Although the 3 crystalloid solutions play different roles, PA is better at correcting the acid-base balance and improving intestine injury during HS than NS and LR.

HEMOSTATIC RESUSCITATION

"THE BLOODY VICIOUS CYCLE"

Major Torso Trauma

Active Hemorrhage

Progressive Coagulopathy

Iatrogenic Factors

Core Hypothermia

Cellular Shock

Metabolic Acidosis

Tissue Injury

Contact Activation

Massive Transfusion

Clotting Factor Deficiencies

Pre-existing Diseases

Although coagulation studies were often poorly documented, indirect evidence of inadequate factor replacement was obtained by calculating the ratio of bank blood to unit of fresh frozen plasma (FFP) given. A consistent deviation from the commonly accepted ratio of 4–5:1 was evident, increasing to 8:1 in nonsurvivors and 9:1 in those where an overt coagulopathy was documented.

factor replacement is certainly involved. We believe fresh frozen plasma should be administered with the first four units of bank blood in the hypotensive patient, as well as
Pelvic Fracture Clinical Pathway

Hemodynamically Unstable Patient* with Biomechanically Unstable Pelvic Fracture

Immediate Notification: Attending Orthopaedic Surgeon, Blood Bank Resident, Interventional Radiology Fellow
Resuscitate with 2 Liters Crystalloid
Wrap Pelvis with Sheet, Tape Knees and Ankles, ± C-Clamp
Place CVP Line
Transfuse PRBCs and FFP 1:1; 5 U PLTs for each 5 U PRBCs
Rule Out Thoracic Source (Portable Chest X-Ray)

Ultrasound Abdomen

Positive

Laparotomy

?Stable

No

?Candidate for Pelvic Fixation

No

Angiography

Yes

Yes

Pelvic Fixation

SICU

?Candidate for Pelvic Fixation

No

Angiography

?Candidate for Pelvic Fixation

Yes

Pelvic Fixation

SICU

CT Abdomen

?Stable

No

Consider DPL#

Yes

SICU

CT Abdomen

#DPL may be warranted in the setting of refractory shock

*Trauma Team Activation = Attending Trauma Surgeon Present in Emergency Department Upon Patient Arrival

CVP, Central Venous Pressure; PRBCs, Packed Red Blood Cells; FFP, Fresh Frozen Plasma;
PLTs, Platelets; DPL, Diagnostic Peritoneal Lavage; SICU, Surgical Intensive Care Unit

Biffl et al, Ann Surg 2001; 233:843
Post-Injury Life Threatening Coagulopathy

1:1:1 FFP:PLT:RBC

Special Commentary

Damage Control Resuscitation: Directly Addressing the Early Coagulopathy of Trauma

John B. Holcomb, MD, FACS, Don Jenkins, MD, FACS, Peter Rheem, MD, FACS, Jay Johanniignan, MD, FS, FACS, Peter Mahoney, FRCA, RAMC, Suneru Mehta, MD, E. Darrin Cox, MD, FACS, Michael J. Gehrke, MD, Greg J. Beilman, MD, FACS, Martin Schreiber, MD, FACS, Stephen F. Flaherty, MD, FACS, Kurt W. Grahtzwohl, MD, Phillip C. Spinella, MD, Jeremy G. Perkins, MD, Alec C. Beckley, MD, FACS, Neil R. McMinn, MD, Myung S. Park, MD, FACS, Ernest A. Gonzalez, MD, FACS, Charles E. Wade, PhD, Michael A. Dobick, PhD, C. William Schwab, MD, FACS, Fred A. Moore, MD, FACS, Howard R. Champion, FRCS, David B. Hoyt, MD, FACS, and John R. Hess, MD, MPH, FACP

UNCLASS ALARACT
SUBJECT: OPTIMAL RESUSCITATION OF SEVERELY INJURED SOLDIERS

1. COMBAT RESUSCITATION DATA ANALYZED BY THE US ARMY INSTITUTE OF SURGICAL RESEARCH (USAISR) DEMONSTRATE THAT CASUALTIES WHO RECEIVE MORE THAN 10 UNITS OF PACKED RED BLOOD CELLS (PRBCS) IN A 24-HOUR PERIOD (MASSIVE TRANSFUSION) HAVE A PROFOUND SURVIVAL BENEFIT WHEN THE PLASMA (FFP) TO PRBC TRANSFUSION RATIO IS 1:1. CASUALTIES WHO RECEIVE LESS FFP (1 UNIT FFP TO 4 UNITS PRBCS, OR LESS) HAVE AN OVERALL MORTALITY OF 65%, WHILE THOSE WHO RECEIVE A 1:1 RATIO HAVE AN OVERALL MORTALITY OF 20% (P<0.001).

2. SEVERELY INJURED CASUALTIES SHOULD HAVE THE 1:1 RATIO INITIATED AS EARLY AFTER INJURY AS POSSIBLE. TRANSFUSIONS MUST BE ACCOMPLISHED ACCORDING TO GUIDELINES ESTABLISHED BY THE CENTCOM BLOOD PROGRAM MANAGER. THE CURRENT APPROVED CENTCOM CLINICAL PRACTICE GUIDELINES FOR DAMAGE CONTROL RESUSCITATION AND TRANSFUSION IS POSTED ON THE JOINT PATIENT TRACKING APPLICATION (JPTA) WEBSITE:
HEMOSTATIC RESUSCITATION

• 2 Lg Bore IVs Upper Ext
• Early MTP
• FFP:PLTs:PRBCs 1:1:1-2
MASSIVE TRANSFUSION

- ABC Score ≥2
  - Penetrating Mechanism
  - SBP <90
  - HR >120
  - (+) FAST
- Persistent hemodynamic instability
- Active bleeding requiring operation or angioembolization
- Blood transfusion in trauma bay

TQIP Best Practices
THROMBELASTOGRAPHY

Goal-Directed Resuscitation
PRBCs, FFP, PLTs
Fibrinogen, Anti-Fibrinolysis
Goal-directed Hemostatic Resuscitation of Trauma-induced Coagulopathy

A Pragmatic Randomized Clinical Trial Comparing a Viscoelastic Assay to Conventional Coagulation Assays

Eduardo Gonzalez, MD,* Ernest E. Moore, MD,*† Hunter B. Moore, MD,* Michael P. Chapman, MD,* Theresa L. Chin, MD,* Arsen Ghasabyan, MPH,* Max V. Wohlauer, MD,* Carlton C. Barnett, MD,*† Denis D. Bensard, MD,*† Walter L. Biffi, MD,*† Clay C. Burlew, MD,*† Jeffrey L. Johnson, MD,*† Fredric M. Pieracci, MD, MPH,*† Gregory J. Jurkovich, MD,*† Anirban Banerjee, PhD,* Christopher C. Silliman, MD, PhD,*†§ and Angela Sauraia, MD, PhD*¶

<table>
<thead>
<tr>
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<th>CCA (N = 47)</th>
<th>TEG (N = 64)</th>
<th>P</th>
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<tbody>
<tr>
<td>Deaths, no. (% within group)</td>
<td>19 (40.4)</td>
<td>12 (18.7)</td>
<td>0.011</td>
</tr>
<tr>
<td>Time to death in hours, median (IQR)</td>
<td>3.5 (2.2–8.3)</td>
<td>11.5 (4.9–211.0)</td>
<td>0.073</td>
</tr>
<tr>
<td>Deaths occurring in the first 6 hours from ED arrival, no. (% within group)</td>
<td>11 (23.4)</td>
<td>4 (6.2)</td>
<td>0.010</td>
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<tr>
<td>Deaths occurring &gt;6 h from ED arrival, no. (% within group)</td>
<td>8 (17.0)</td>
<td>8 (12.5)</td>
<td>0.589</td>
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<tr>
<td>Hemorrhagic deaths, no. (% within group)</td>
<td>11 (23.4)</td>
<td>5 (7.8)</td>
<td>0.020</td>
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<td>TBI deaths, no. (% within group)</td>
<td>6 (12.8)</td>
<td>4 (6.3)</td>
<td>0.321</td>
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<tr>
<td>Organ failure, no. (% within group)</td>
<td>2 (4.3)</td>
<td>3 (4.7)</td>
<td>1.00</td>
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CONSISTENT TREND TOWARD REDUCED BLOOD PRODUCT UTILIZATION

Kashuk et al, Transfusion 2011
# PLASMA FIRST IN THE FIELD FOR POSTINJURY HEMORRHAGIC SHOCK

Ernest E. Moore, †Theresa L. Chin, †Michael C. Chapman, †Eduardo Gonzalez, †Hunter B. Moore, †Christopher C. Silliman, †Kirk C. Hansen, †Angela Sauaia, †and Anirban Banerjee

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**TABLE 1. Denver massive transfusion activation protocol**

<table>
<thead>
<tr>
<th>I. Field alert criteria (physiologic)</th>
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<tr>
<td>Resuscitation Outcome Consortium vital signs</td>
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<tr>
<td>(a) SBP &lt; 70 mmHg</td>
</tr>
<tr>
<td>(b) SBP 71–90 mmHg + heart rate &gt;108/min</td>
</tr>
</tbody>
</table>

| II. ED activation criteria (anatomic) |
| Field physiologic criteria + ED anatomic |
| (a) Penetrating torso |
| (b) Abdominal ultrasound positive in >1 region |
| (c) Unstable major pelvic fracture |

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Knowledge Gaps Where Future Research Endeavors Are Needed

- Prehospital Monitoring Shock/Coagulopathy
- Hypotensive Resuscitation; Endpoints of Resuscitation
- Whole Blood vs Components; Dried Products
- Pathogen Reduced Technology for Products
- Role of TBI