Lessons Learned from 15 years of war, surgery and kids

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Pediatric Trauma Medical Director
Albany Medical Center
“He who would become a surgeon should join an army and follow it.”

Hippocrates
“Doctors will have more lives to answer for in the next world than even we generals.”

Napoleon Bonaparte
Our pediatric mission: To treat children hurt as a result of the conflict?
Types of Admissions by Age

Non-combat vs. Combat Admissions by Year

## Mechanism of Injury

<table>
<thead>
<tr>
<th>Mechanism of Injury</th>
<th>Iraq</th>
<th>Afghanistan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Combat Injuries:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blast Injuries</td>
<td>714(45)</td>
<td>717(65.5)</td>
</tr>
<tr>
<td>Gun shot wounds</td>
<td>728(45.8)</td>
<td>265(24.2)</td>
</tr>
<tr>
<td>Other/unspecified</td>
<td>145(9.1)</td>
<td>111(10.1)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1590</td>
<td>1095</td>
</tr>
<tr>
<td><strong>Non Combat Injuries:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor vehicle related</td>
<td>189(22.7)</td>
<td>297(23.4)</td>
</tr>
<tr>
<td>Burns</td>
<td>271(32.6)</td>
<td>230(18.1)</td>
</tr>
<tr>
<td>Falls</td>
<td>51(6.1)</td>
<td>210(16.5)</td>
</tr>
<tr>
<td>Bullets/projectiles/explosives</td>
<td>51(6.1)</td>
<td>71 (5.6)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>832</td>
<td>1270</td>
</tr>
</tbody>
</table>

Non-Trauma Admissions

• Half surgical, half non-surgical
• 25% infectious, 11% musculoskeletal, 9% hematologic
• Most common elective surgeries: splenectomy, cleft lip, inguinal hernia
• Most common medical disorders: infections of respiratory, GI tracts, CNS
• Mortality for surgical patients 0.9%, for medical patients 9.7%

How did we do?
Figure 2: Resource Utilization and Mortality

*Group 1 = Combat Injuries, Group 2 = Non combat trauma, Group 3 = Non trauma related admission

** No significant difference in mortality between groups 1 and 3 in Afghanistan and groups 1 and 2 in Iraq. Otherwise p<0.05 for all overall and pairwise comparisons within countries.
What did we learn about adult patients from the war?

- Blast injury: defining it, treating it
- Resuscitation strategies
- Prevention/protection
- Evacuation strategies
Blast Injury
Secondary blast-induced neurotrauma (penetrating head injury)

Primary blast-induced neurotrauma (without a direct blow to the head)

- kinetic energy transfer to the CNS
- lung injury-induced hypoxia/ischemia
- hemorrhage-induced hypoxia/ischemia
- hormones released from injured tissue

Tertiary blast mechanisms (i.e. effect of the impacts with other objects)

Site of impact "coup"

Injury to the brain opposite the site of impact "contrecoup"

Secondary blast mechanisms (i.e. effect of the missiles being propelled by blast force)

Primary blast mechanisms (i.e. effects of the blast wave itself)

Tertiary blast-induced neurotrauma (coup-contrecoup)
Terrorist incidents worldwide

- Injuries
- Deaths
- Number of incidents

from https://www.start.umd.edu/gtd University of Maryland
# Historical Data

<table>
<thead>
<tr>
<th>Location/Year(s)</th>
<th>Mechanism</th>
<th># Children</th>
<th>Mortality Rate</th>
<th>Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oklahoma City 1995</td>
<td>Bomb blast</td>
<td>66</td>
<td>28.8%</td>
<td>Head</td>
</tr>
<tr>
<td>Israel 2000-2005</td>
<td>Terror bombings</td>
<td>114</td>
<td>2.6%</td>
<td>Head</td>
</tr>
<tr>
<td>Cambodia 2003-2006</td>
<td>Land mines &amp; UXO</td>
<td>94</td>
<td>5.3%</td>
<td>Upper extremity amputation, Blindness</td>
</tr>
<tr>
<td>Turkey 2001-2008</td>
<td>Land mines &amp; UXO</td>
<td>23</td>
<td>4.3%</td>
<td>Hand amputation</td>
</tr>
<tr>
<td>Afghanistan 2002-2006</td>
<td>Land mines &amp; UXO</td>
<td>2580</td>
<td>15.1%</td>
<td>Upper body injury, Upper extremity amputation</td>
</tr>
<tr>
<td>Chechnya 1995-2005</td>
<td>Land mines &amp; UXO</td>
<td>772</td>
<td>17%</td>
<td>Upper extremity amputation</td>
</tr>
</tbody>
</table>
Demographics: Blast Injury Patients

Number of civilians

Edwards, Mary; Lustik, Michael; Eichelberger, Martin; Elster, Eric; Azarow, Kenneth; Coppola, Christopher
Journal of Trauma and Acute Care Surgery. 73(5):1278-1283, November 2012.
DOI: 10.1097/TA.0b013e318270d3ee
Results

Edwards, Mary; Lustik, Michael; Eichelberger, Martin; Elster, Eric; Azarow, Kenneth; Coppola, Christopher
Journal of Trauma and Acute Care Surgery. 73(5):1278-1283, November 2012.
DOI: 10.1097/TA.0b013e318270d3ee
Significant Results

• Younger patients were more likely to
  – Be female
  – Be injured in Afghanistan
  – Have severe head injuries
  – Have an ISS > 15

• Younger patients were less likely to
  – Have extremity injuries
Significant Results

• Mortality independently associated with:
  – Injury to the head
  – Burns
  – Transfusion requirement
  – Increasing ISS

• Protective
  – Age 15-20

Blast injury in children: An analysis from Afghanistan and Iraq, 2002-2010. Edwards, Mary; Lustik, Michael; Eichelberger, Martin; Elster, Eric; Azarow, Kenneth; Coppola, Christopher. Journal of Trauma and Acute Care Surgery. 73(5):1278-1283, November 2012. DOI: 10.1097/TA.0b013e318270d3ee
## Operative Procedures**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>0-3 years</th>
<th>4-8 years</th>
<th>9-14 years</th>
<th>15-19 years</th>
<th>&gt;19 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracostomy (719)</td>
<td>Exploratory Laparotomy (17)</td>
<td>Thoracostomy (77)</td>
<td>Thoracostomy (98)</td>
<td>Exploratory Laparotomy (55)</td>
<td>Thoracostomy (474)</td>
</tr>
<tr>
<td>Exploratory Laparotomy (480)</td>
<td>Thoracostomy (17)</td>
<td>54.11 Exploratory Laparotomy (58)</td>
<td>Exploratory Laparotomy (70)</td>
<td>Thoracostomy (53)</td>
<td>Exploratory Laparotomy (280)</td>
</tr>
<tr>
<td>Tracheostomy (290)</td>
<td>Tracheostomy (5)</td>
<td>Amputation closure(23)</td>
<td>Below Knee Amputation (41)</td>
<td>Below Knee Amputation (33)</td>
<td>Tracheostomy (236)</td>
</tr>
<tr>
<td>Fasciotomy (289)</td>
<td>Craniotomy (4)</td>
<td>54.99 Abdominal Washout (21)</td>
<td>Abdominal Washout (33)</td>
<td>Hemorrhage Control NOS (28)</td>
<td>Fasciotomy (223)</td>
</tr>
<tr>
<td>Below Knee Amputation (286)</td>
<td>Craniectomy (4)</td>
<td>2.02Elevate skull fx fragment (19)</td>
<td>Hemorrhage Control NOS (32)</td>
<td>Fasciotomy (25)</td>
<td>Below Knee Amputation (195)</td>
</tr>
</tbody>
</table>

**Except: soft tissue debridements/closures and vascular access.
Blast injury Procedure Rates by Age

All Ages: Mean 4.5/patient
mean procedures/patient

Severe Injury: Head and Cspine

% with procedure on the head and C spine

p=0.019*
Severe Injury: Face and Neck

% with procedure in face and neck

- 0-3 years
- 4-8 years
- 9-14 years
- 15-19 years
- 20 and older

p=0.809
Severe Injury: Chest

% with procedure in chest

<table>
<thead>
<tr>
<th>Age Group</th>
<th>% with Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3 years</td>
<td>45.0</td>
</tr>
<tr>
<td>4-8 years</td>
<td>50.0</td>
</tr>
<tr>
<td>9-14 years</td>
<td>70.0</td>
</tr>
<tr>
<td>15-19 years</td>
<td>65.0</td>
</tr>
<tr>
<td>20 and older</td>
<td>60.0</td>
</tr>
</tbody>
</table>

p-=0.012*
Severe Injury: Abdomen

% with procedure in abdomen

p=0.429
Severe Injury: Extremity and Bony Pelvis

% with procedures on extremities/pelvis

p = 0.158
2-wk-old female, flame burn to face
Severe Injury: External

% with SST procedures

p=0.071
Results

• Older children more likely to have procedures than others
• Very young children less likely to have procedures in spite of/because of increased mortality
• Significant differences in head and chest procedures
  – ? Survival
  – Personnel/equipment
Damage Control Resuscitation

Courtesy of Lorne Blackbourne, M.D.
Damage Control Resuscitation

• Early and abbreviated Surgery
• Permissive Hypotension
• Avoidance of Crystalloid
• Early administration of blood products in balanced component ratios 1:1:1
The Ratio of Blood Products Transfused Affects Mortality in Patients Receiving Massive Transfusions at a Combat Support Hospital

Matthew A. Borgman, MD, Philip C. Spinella, MD, Jeremy G. Perkins, MD, Kurt W. Grathwohl, MD, Thomas Repine, MD, Alec C. Beekley, MD, James Sebesta, MD, Donald Jenkins, MD, Charles E. Wade, PhD, and John B. Holcomb, MD

**Background:** Patients with severe traumatic injuries often present with coagulopathy and require massive transfusion. The risk of death from hemorrhagic shock increases in this population. To treat the coagulopathy of trauma, some have suggested early, aggressive correction using a 1:1 ratio of plasma to red blood cell (RBC) units.

**Methods:** We performed a retrospective chart review of 246 patients at a US Army combat support hospital, each of who received a massive transfusion (≥10 units of RBCs in 24 hours). Three groups of patients were constructed according to the plasma to RBC ratio transfused during massive transfusion. Mortality rates and the cause of death were compared among groups.

**Results:** For the low ratio group the plasma to RBC median ratio was 1:8 (interquartile range, 0:12–1:5), for the medium ratio group, 1:2.5 (interquartile range, 1:3.0–1:2.3), and for the high ratio group, 1:1.4 (interquartile range, 1:1.7–1:1.2) (p < 0.001). Median Injury Severity Score (ISS) was 18 for all groups (interquartile range, 14–25). For low, medium, and high plasma to RBC ratios, overall mortality rates were 65%, 34%, and 19%, (p < 0.001); and hemorrhage mortality rates were 92.5%, 78%, and 37%, respectively, (p < 0.001). Upon logistic regression, plasma to RBC ratio was independently associated with survival (odds ratio 8.6, 95% confidence interval 2.1–35.2).

**Conclusions:** In patients with combat-related trauma requiring massive transfusion, a high 1:1.4 plasma to RBC ratio is independently associated with improved survival to hospital discharge, primarily by decreasing death from hemorrhage. For practical purposes, massive transfusion protocols should utilize a 1:1 ratio of plasma to RBCs for all patients who are hypocoagulable with traumatic injuries.

**Key Words:** Blood components, Fresh frozen plasma, Trauma, Coagulopathy.

*J Trauma. 2007;63:805–813.*
<table>
<thead>
<tr>
<th>Condition</th>
<th>Low n=20</th>
<th>Medium n=18</th>
<th>High n=31</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemorrhage %†</td>
<td>18.5</td>
<td>14</td>
<td>11.5</td>
</tr>
<tr>
<td>Sepsis %</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>MOF %</td>
<td>0</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Airway/Breathing %</td>
<td>0</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>CNS %</td>
<td>2.5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Time to death (hrs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 (1-4) a</td>
<td>4 (2-16) b</td>
<td>38 (4-155) c</td>
</tr>
</tbody>
</table>

*Note: The data is presented as a bar graph showing the percentage of each condition across different groups. The table provides numerical values for each category.*
Civilian Data: Adult patients

The Prospective, Observational, Multicenter, Major Trauma Transfusion (PROMMTT) Study

Comparative Effectiveness of a Time-Varying Treatment With Competing Risks

- Ratios changed over time
- Lower ratios associated with decreased 6h mortality
- Most hemorrhagic deaths in the first 3 hours
• No difference in 24 or 30 day mortality with 1:1 vs 1:2 (FFP:PRBCs or PLT:PRBCs)
  – Decreased exsanguination deaths at 24 hours
• No increased complications with BCR
• Likely underpowered
Pediatric DCR: Clinical Data with MTPs

  - No change in outcome
  - No change in transfusion ratios
  - Decreased incidence of thromboembolic events with MTP

  - Decreased time to transfusion
  - Decreased transfusion ratio for plasma only
  - No difference on outcome

<table>
<thead>
<tr>
<th>Ratio group</th>
<th>Plasma/PRBC ratio AOR (95% CI)</th>
<th>P</th>
<th>Platelet/PRBC ratio AOR (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td></td>
<td>.990</td>
<td></td>
<td>.970</td>
</tr>
<tr>
<td>Medium</td>
<td>.91 (.02–41.42)</td>
<td>.960</td>
<td>1.27 (.03–49.58)</td>
<td>.900</td>
</tr>
<tr>
<td>High</td>
<td>.81 (.02–34.60)</td>
<td>.914</td>
<td>.63 (.01–84.71)</td>
<td>.853</td>
</tr>
</tbody>
</table>

Plasma/PRBC ratio regression controlled for GCS score ≤ 8, head AIS ≥ 3, cryoprecipitate units, and platelet units, and platelets/PRBC regression controlled for GCS score ≤ 8, admission hemoglobin, admission hematocrit, and plasma units.

AIS = Abbreviated Injury Scale; AOR = adjusted odds ratio; CI = confidence interval; GCS = Glasgow Coma Scale; PRBC = packed red blood cell.
Massive transfusion in pediatric trauma: An ATOMAC perspective

Daniel K. Noland, Nadja Apelt, Cynthia Greenwell, Jefferson Tweed, David M. Notrica, Nilda M. Garcia, R. Todd Maxson, James W. Eubanks, Adam C. Alder

Journal of Pediatric Surgery
Volume 54, Issue 2, Pages 345-349 (February 2019)
DOI: 10.1016/j.jpedsurg.2018.10.040
Fig. 2

Mortality Rate by RBC:FFP Group

- **RBC:FFP Group**
  - 1:1
  - 2:1
  - 3:1+

- **Mortality Rate**
  - 0.0
  - 0.1
  - 0.2
  - 0.3
  - 0.4
  - 0.5
Military Data: Pediatric DCR

- Neff et al. JOT Dec 2015
  - Mortality increased if > 40ml/kg total blood products transfused.
  - Head injured patients excluded

  - 10% of 776 patients <=18 years given TXA
  - Independent predictor of decreased mortality
Balanced Component Resuscitation

• Iraq/Afghanistan 2002-2012
  – 935 transfused children
    • 224 > 40 ml/kg in 24 hours
    • 77 > 70 ml/kg in 24 hours
Logistic Regression for predictors of massive/high volume transfusion:

<table>
<thead>
<tr>
<th>Variables predicting transfusion of &gt; 40ml/kg</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (0-3 vs. 8-14)</td>
<td>2.14</td>
<td>(1.35, 3.40)</td>
<td>0.001</td>
</tr>
<tr>
<td>Age (4-7 vs. 8-14)</td>
<td>1.44</td>
<td>(1.00, 2.08)</td>
<td>0.049</td>
</tr>
<tr>
<td>Gender (male vs. female)</td>
<td>0.74</td>
<td>(0.52, 1.06)</td>
<td>0.099</td>
</tr>
<tr>
<td>Military operation (OIF vs. OEF)</td>
<td>0.94</td>
<td>(0.68, 1.30)</td>
<td>0.719</td>
</tr>
<tr>
<td>Dominant injury type (Penetrating vs. blunt)</td>
<td>2.25</td>
<td>(1.36, 3.70)</td>
<td>0.002</td>
</tr>
<tr>
<td>Dominant injury type (burn vs. blunt)</td>
<td>0.38</td>
<td>(0.17, 0.83)</td>
<td>0.016</td>
</tr>
<tr>
<td>ISS categorized 16-32 vs. 0-15</td>
<td>1.97</td>
<td>(1.41, 2.75)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ISS categorized 33-75 vs. 0-15</td>
<td>2.65</td>
<td>(1.50, 4.68)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variables predicting transfusion of &gt; 70 ml/kg</th>
<th>OR</th>
<th>95% CI</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (0-3 vs. 8-14)</td>
<td>1.81</td>
<td>(0.09, 3.64)</td>
<td>0.096</td>
</tr>
<tr>
<td>Age (4-7 vs. 8-14)</td>
<td>1.42</td>
<td>(0.82, 2.47)</td>
<td>0.212</td>
</tr>
<tr>
<td>Gender (male vs. female)</td>
<td>0.81</td>
<td>(0.47, 1.38)</td>
<td>0.431</td>
</tr>
<tr>
<td>Military operation (OIF vs. OEF)</td>
<td>0.96</td>
<td>(0.59, 1.56)</td>
<td>0.858</td>
</tr>
<tr>
<td>Dominant injury type (Penetrating vs. blunt)</td>
<td>3.12</td>
<td>(1.21, 8.02)</td>
<td>0.018</td>
</tr>
<tr>
<td>Dominant injury type (burn vs. blunt)</td>
<td>0.89</td>
<td>(0.24, 3.22)</td>
<td>0.853</td>
</tr>
<tr>
<td>ISS categorized 16-32 vs. 0-15</td>
<td>2.14</td>
<td>(1.25, 3.67)</td>
<td>0.006</td>
</tr>
<tr>
<td>ISS categorized 33-75 vs. 0-15</td>
<td>4.15</td>
<td>(1.96, 8.81)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
FEfect of Crystalloid administration on Mortality

Crystalloid given in the first 24 hours (ml/kg)
*p=0.038
Effect of increasing FFP:PRBC ratio on mortality for children receiving transfusion

JTS clinical practice guidelines: Damage control resuscitation

• 3. Recognition of patients requiring damage control resuscitation.
  – a. Most casualties who require immediate use of uncrossmatched Type O blood in the ED will require a massive transfusion (MT). Defined as equal to or as, or greater than, 10u pRBCs/24 hours, MT patients present a unique challenge both in the ED and OR, as well as the ICU post-operatively. These patients must be identified early and receive hemostatic resuscitation in the ED, OR, and ICU. Anticipating the need for a MT requires experience and the coordination of extensive resources.

b. A number of predictors for massive transfusion upon hospital admission have been identified. In a patient with serious injuries, these include:

- 1) Systolic blood pressure $< 110$ mm Hg
- 2) Heart rate $> 105$ bpm
- 3) Hematocrit $< 32$
- 4) pH $< 7.25$
- Note: Patients with 3 of the above 4 factors have approximately a 70% predicted risk of massive transfusion; patients with all 4 of the above have an 85% predicted risk.
- 5) Other risk factors for massive transfusion include: INR level $> 1.4$, NIR-derived StO2 $< 75\%$.  

c. Examples of clinical scenarios that are associated with the need for massive transfusion include:
Uncontrolled truncal, axillary, neck, or groin bleeding, uncontrolled bleeding secondary to large soft tissue injuries, proximal amputation or mangled extremity, clinical signs of coagulopathy, or severe hypothermia associated with blood loss.

d. Rotational thromboelastometry (ROTEM®) may also facilitate early identification of patients who will require massive transfusion.20,21
The evolution of pediatric transfusion practice during combat operations 2001-2013

Jeremy W. Cannon, MD, SM, Lucas P. Neff, MD, Heather F. Pidcoke, MD, PhD, James K. Aden, PhD, Philip C. Spinella, MD, Michael A. Johnson, MD, PhD, Andrew P. Cap, MD, PhD, and Matthew A. Borgman, MD, Philadelphia, Pennsylvania

Figure 1. Trends in transfusion over time. (A) Percent of the entire patient population receiving any blood product transfusion (TX+) or a massive transfusion (MT+, ≥ 40 mL/kg all blood products) over the entire study period along with median ISS (dashed line). (B) Percent mortality in the overall group (solid line) as well as the TX+ and MT+ subgroups. *p < 0.001; †p = 0.038 by Kruskal-Wallis H test.
Figure 2. Twenty-four-hour volumes of crystalloid, PRBC, PLAS, and PLT in the TX+ and MT+ subgroups (A, B, respectively) of those who were transfused (A) and who received a massive transfusion (B; note the difference in y-axis scale). Median ratios of PLAS:RBC and PLT:RBC as well as mortality in the TX+ and MT+ subgroups (C, D, respectively). Horizontal dashed lines represent the target ratios of 1:2 (TQIP) and 1:1 (Joint Trauma System CPG).
Andrew M, Developmental Hemostasis, Relevance to Hemostatic Problems during Childhood, Sem Throm Hemos 21(4), 1995
Pediatric Hemostasis: Clinical Implications

- Immature hemostatic/fibrinolytic system
  - Little Reserve
- Lower likelihood of thromboembolic complications
- ? Trauma
Andrew M, Developmental Hemostasis, Relevance to Hemostatic Problems during Childhood, Sem Throm Hemos 21(4), 1995
Andrew M, Developmental Hemostasis, Relevance to Hemostatic Problems during Childhood, Sem Throm Hemos 21(4), 1995
Pediatric Coagulation

• Decreased capacity to generate thrombin
• Increased capacity to inhibit thrombin
• tPA to PAI-1 ratio in children 0.37, adults 1.36
• Differences most pronounced in the first 6 months
• Clinical implications in trauma
Trauma Associated Coagulopathy in Children

- UCLA (Strumwasser et al. J Trauma Mar 2016) 1500 children, 8% incidence of coagulopathy (vs. 12% in 20K adults)

<table>
<thead>
<tr>
<th>Pediatric Population (Age &lt; 16 years)</th>
<th>Adult Population (Age ≥ 16 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ Coagulopathy (n = 129)</td>
<td>- Coagulopathy (n = 1,402)</td>
</tr>
<tr>
<td>ICU LOS, mean ± SD; median; (range)</td>
<td></td>
</tr>
<tr>
<td>11.9 ± 16.6; 7; (1–85)</td>
<td>4.2 ± 6.1; 4; (1–51)</td>
</tr>
<tr>
<td>Hospital LOS, mean ± SD; median; (range)</td>
<td></td>
</tr>
<tr>
<td>12.0 ± 17.6; 7; (1–100)</td>
<td>5.7 ± 1.8; 4; (1–73)</td>
</tr>
</tbody>
</table>

Mortality, %

- Adjusted OR (95% CI)

| | | Adjusted OR (95% CI) |
| | | | |
| Mortality, % | | | | 2.8 (1.4, 5.7) | 0.02* | 18.3% (407) | 1.8% (282) | 3.4 (2.6, 3.9) | <0.001* |

*p values are significantly different (p < 0.05)
Acute traumatic coagulopathy in a critically injured pediatric population: Definition, trend over time, and outcomes

Christine M. Leeper, MD, Matthew Kutcher, MD, Isam Nasr, MD, Christine McKenna, MSN, CRNP, Timothy Billiar, MD, Matthew Neal, MD, Jason Sperry, MD MPH,
and Barbara A. Gaines, MD, Pittsburgh, Pennsylvania

Mortality by INR range

% Mortality

INR Range

<1.2 1.3-1.4 1.5-1.7 >1.8

Admission INR
2.0 10.1 66.1 92.0
24 hour INR
2.5 8.0 66.7 64.3
TEG in Pediatrics

What Does TEG® Report?

- Coagulation
- Fibrinolysis

Platelets (MA)

Clot strength (Platelet function)

Enzymatic (R)
Fibrinogen (K, α)
Thrombolysins (Ly30, EPL)

Clotting time (clotting factors)
Clot kinetics
Clot stability/Clot breakdown
Abnormalities in fibrinolysis at the time of admission are associated with deep vein thrombosis, mortality, and disability in a pediatric trauma population.

Christine M. Leeper, MD, MS, Matthew D. Neal, MD, Christine McKenna, MSN, CRNP, Jason L. Sperry, MD, MPH, and Barbara A. Gaines, MD, Pittsburgh, Pennsylvania.
Prevalence and Impact of Admission Acute Traumatic Coagulopathy on Treatment Intensity, Resource Utilization, and Mortality: An Evaluation of 956 Severely Injured Children and Adolescents

Ioannis N Liras, BS¹, Henry W Caplan, MD¹, Jakob Stensballe, MD, PhD²,³, Charles E Wade, PhD¹,⁴, Charles S Cox, MD, FACS⁵,⁶, Bryan A Cotton, MD, MPH, FACS¹,⁴

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Coagulopathic (n=507)</th>
<th>Control (n=449)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median ICU-free days (IQR)</td>
<td>29 (23, 30)</td>
<td>29 (27, 30)</td>
<td>0.042</td>
</tr>
<tr>
<td>Median ventilator-free days (IQR)</td>
<td>29 (26, 30)</td>
<td>30 (28, 30)</td>
<td>0.007</td>
</tr>
<tr>
<td>VTE, %</td>
<td>1.5</td>
<td>1.7</td>
<td>0.671</td>
</tr>
<tr>
<td>VAP, %</td>
<td>4.0</td>
<td>3.8</td>
<td>0.809</td>
</tr>
<tr>
<td>Wound complications, %</td>
<td>3.8</td>
<td>4.7</td>
<td>0.489</td>
</tr>
<tr>
<td>Sepsis, %</td>
<td>2.1</td>
<td>2.1</td>
<td>0.896</td>
</tr>
<tr>
<td>Respiratory failure, %</td>
<td>13.7</td>
<td>15.4</td>
<td>0.456</td>
</tr>
<tr>
<td>ARDS, %</td>
<td>9.0</td>
<td>11.2</td>
<td>0.208</td>
</tr>
<tr>
<td>30-day mortality, %</td>
<td>12</td>
<td>3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cause of death, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brain injury</td>
<td>73</td>
<td>55</td>
<td>0.170</td>
</tr>
<tr>
<td>Hemorrhage</td>
<td>21</td>
<td>22</td>
<td>0.935</td>
</tr>
</tbody>
</table>
### Logistic Regression for all 956 patients for Mortality

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Odds ratio</th>
<th>95% CI</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coagulopathic on admission</td>
<td>3.67</td>
<td>1.768-7.632</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age, y</td>
<td>0.99</td>
<td>0.940-1.047</td>
<td>0.783</td>
</tr>
<tr>
<td>Male sex</td>
<td>0.91</td>
<td>0.486-1.689</td>
<td>0.764</td>
</tr>
<tr>
<td>Blunt mechanism</td>
<td>0.49</td>
<td>0.221-1.109</td>
<td>0.088</td>
</tr>
<tr>
<td>Arrival systolic blood pressure</td>
<td>0.97</td>
<td>0.960-0.982</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Injury severity score</td>
<td>1.08</td>
<td>1.057-1.106</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

CI, confidence interval

### Severe Head Injury: N=197

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Odds ratio</th>
<th>95% CI</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coagulopathic on admission</td>
<td>3.20</td>
<td>1.277-7.892</td>
<td>0.013</td>
</tr>
<tr>
<td>Age, y</td>
<td>1.10</td>
<td>0.950-1.090</td>
<td>0.603</td>
</tr>
<tr>
<td>Male sex</td>
<td>1.06</td>
<td>0.476-2.399</td>
<td>0.871</td>
</tr>
<tr>
<td>Head abbreviated injury scale score</td>
<td>5.27</td>
<td>2.094-13.294</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Arrival systolic blood pressure</td>
<td>0.97</td>
<td>0.951-0.983</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Liras et al, JACS Vol. 224, No. 4, April 2017
DCR in Children: Consideration

• Weight based/splitting units
• Hyperkalemia
• Limitations of rapid infusers (small IVs)
• Risks of pressure bags (air embolus)
• Hypothermia
Research Difficulties

Figure – Flow diagram of the pediatric trauma population in the 2010-2012 National Trauma Databank.
Research Difficulties

- Lack of well established clinical triggers
- Lower mortality = higher power
- Heterogeneous patient population
- Survival Bias
Summing up: What did we learn?

• In the recent conflicts children took up 7-10% of hospital admissions
  – Most non combat related
• Combat trauma usually due to blast
• Mortality and surgery rates high
• Outcomes?
Blast Injury in Children

• Most children with blast injury can be treated by general/orthopedic surgeons with pediatric assistance
• Toddlers and infants: special needs
DCR in Children

- TAC clearly exists in children
  - Heterogeneous??
- Benefit of DCR elusive in clinical studies
- Studies in adults will be difficult to replicate in pediatrics
- Understanding when to initiate DCR
  - Animal Data
  - Retrospective data
  - Education re: hazardous unique to children
Most Importantly:

Combat Casualty Care = Care of the Injured Child
ARMY HEALTH SYSTEM SUPPORT TO STABILITY AND DEFENSE SUPPORT OF CIVIL AUTHORITIES TASKS

June 2014

DISTRIBUTION RESTRICTION: Approved for public release; distribution is unlimited.
3-20. Determination of eligibility for medical treatment and whether reimbursement is required for services rendered are made at the highest level possible in conjunction with the supporting staff judge advocate. Representatives from the Department of State and other military staff sections (such as the assistant chief of staff, civil affairs) may also need to be involved in the determination process. Each operation is unique, and the authorization for care is based on appropriate U.S. and international law, DODDs and DODIs, applicable Army regulations, doctrine, and standard operating procedures. Determination of eligibility is also based on command guidance, practical humanitarian and medical ethics considerations, availability of U.S. medical assets (in relationship to the threat faced by the force), and potential training opportunities for medical forces. See FM 4-02 for additional information on eligibility for care determinations.

Note. Any individual requesting medical care should receive a timely medical assessment of his condition. Even though the individual may not be eligible for treatment, life-, limb-, or eyesight-saving procedures warranted by the individual’s medical condition are provided for stabilization and transfer to the appropriate civilian or host-nation MTF.
## Admission totals by age and Country

### Number of patients (n=6273) by age and type of injury

<table>
<thead>
<tr>
<th>Injury type</th>
<th>Age in years</th>
<th>&lt;1</th>
<th>1 to 3</th>
<th>4 to 7</th>
<th>8 to 11</th>
<th>12 to 14</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iraqi Group 1: Combat trauma</td>
<td></td>
<td>1</td>
<td>105</td>
<td>725</td>
<td>378</td>
<td>381</td>
<td>1590 (53%)</td>
</tr>
<tr>
<td>Iraqi Group 2: Non combat trauma</td>
<td></td>
<td>1</td>
<td>178</td>
<td>305</td>
<td>217</td>
<td>131</td>
<td>832 (28%)</td>
</tr>
<tr>
<td>Iraqi Group 3: Non trauma admission</td>
<td></td>
<td>58</td>
<td>84</td>
<td>192</td>
<td>152</td>
<td>73</td>
<td>559 (19%)</td>
</tr>
<tr>
<td>Iraqi Total</td>
<td></td>
<td>60</td>
<td>367</td>
<td>1222</td>
<td>747</td>
<td>585</td>
<td>2981 (100%)</td>
</tr>
<tr>
<td>Afghan Group 1: Combat trauma</td>
<td></td>
<td>0</td>
<td>65</td>
<td>261</td>
<td>444</td>
<td>325</td>
<td>1095 (33%)</td>
</tr>
<tr>
<td>Afghan Group 2: Non combat trauma</td>
<td></td>
<td>0</td>
<td>208</td>
<td>435</td>
<td>369</td>
<td>258</td>
<td>1270 (39%)</td>
</tr>
<tr>
<td>Afghan Group 3: Non-trauma admission</td>
<td></td>
<td>11</td>
<td>202</td>
<td>286</td>
<td>268</td>
<td>160</td>
<td>927 (28%)</td>
</tr>
<tr>
<td>Afghan Total</td>
<td></td>
<td>11</td>
<td>475</td>
<td>982</td>
<td>1081</td>
<td>743</td>
<td>3292 (100%)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>71</td>
<td>842</td>
<td>2204</td>
<td>1828</td>
<td>1328</td>
<td>6273 (100%)</td>
</tr>
</tbody>
</table>