Shock and Resuscitation: Part II

Patrick M Reilly MD FACS
Professor of Surgery
Trauma Patient 1823 / 18

- Police Dropoff
- Torso GSW
  - Lower Midline / Right Buttock
- Shock

This Monday
Trauma Patient 1823 / 18

- IV Access
- Whole Blood x 2 / TEP Activated
- Left Groin A Line
- REBOA Inflated 18 minutes in
  - Zone 1
- Vital Signs Stabilize / More Responsive
- RSI in Bay
- OR 30 minutes in
Trauma Patient 1823 / 18

- IV Access
- Whole Blood x 2
- Left Groin A Line
- REBOA Inflated 18 minutes in
  - Zone 1
- Vital Signs Stabilize
- RSI in Bay
- OR 30 minutes in
Trauma Patient 1823 / 18

• OR
  • Right Iliac Artery and Vein Transections
    • Shunt x 2
  • Hollow Viscus Injuries
    • Resected
  • To ICU

• OR PID # 1
  • Vein Graft in Artery / Vein Primary Repair
Trauma Exsanguination Protocol

• Multidisciplinary Team
• Unique Aspects of the Institution
  – PennComm
  – Perfusion Team
  – Hospital Size / Acuity
• Ongoing Evaluation / Evolution
Trauma Exsanguination Protocol

• Initiation: Inhouse Trauma Faculty
• Notification: PennComm
  – Blood Bank
  – Perfusion Team
  – Key Information
    • Demographics
    • Location
Trauma Exsanguination Protocol 2018

• Initial Response
  – 4 Units Uncrossed pRBCs
  – 4 Units Stored Plasma
  – Pack Platelets

• Delivery to Bedside
  – One “Bolus”
Stored Plasma

• Thawed / Refrigerated
• Replaced as Used
  – Ongoing TEP vs. Replacement
• Utilization / Wastage Monitored
• Additional Uses
  – Coumadin Reversal
**Stored Plasma**

**Serial Factor Levels**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor VIII</td>
<td>60%*</td>
</tr>
<tr>
<td>Factor II</td>
<td>99%</td>
</tr>
<tr>
<td>Factor V</td>
<td>84%</td>
</tr>
<tr>
<td>Factor VII</td>
<td>80%</td>
</tr>
<tr>
<td>Factor X</td>
<td>94%</td>
</tr>
<tr>
<td>Fibrinogen</td>
<td>100%</td>
</tr>
</tbody>
</table>

*Transfusion 2001*

* p<0.05
Dilutional Coagulopathy in Exsanguination: Computer Simulation

- Modeling of Hemorrhage with Resuscitation
- Hemodynamic Module
- Hemodilution Module
- Coagulation Module

J Trauma 2003
Dilutional Coagulopathy in Exsanguination: Computer Simulation

- Prothrombin Time
- Fibrinogen
- Platelets
- Range of Replacement of Options

J Trauma 2003
Dilutional Coagulopathy in Exsanguination: Computer Simulation

- “Prolongation of the PT is the sentinel event of dilutional coagulopathy and occurs early in the operation”

J Trauma 2003
Dilutional Coagulopathy in Exsanguination: Computer Simulation

• Suggested Solutions
  – More Factor Replacement
  – Earlier Factor Replacement
  – Concurrent Factor Replacement
    • Whole Blood?

J Trauma 2003
Herman Hospital Review

- 200 Patients Resuscitated with MT Protocol / Resuscitation Protocol
  - No Plasma until After 6 units pRBCs
- Comparison Live vs Die
  - ICU admit INR only Difference
- Recommendation
  - Give FFP Earlier to MT Patients

J Trauma 2007
Trauma Exsanguination Protocol 2018

• Subsequent Response
  – Question: Continue TEP?
• 4 Units pRBCs
• 4 Units FFP
• Pack Platelets
• Repeat Cycle
The Prospective, Observational, Multicenter, Major Trauma Transfusion (PROMMTT) Study

Comparative Effectiveness of a Time-Varying Treatment With Competing Risks

John B. Holcomb, MD; Deborah J. del Junco, PhD; Erin E. Fox, PhD; Charles E. Wade, PhD; Mitchell J. Cohen, MD; Martin A. Schreiber, MD; Louis H. Alarcon, MD; Yu Bai, MD, PhD; Karen J. Brasel, MD, MPH; Eileen M. Bulger, MD; Bryan A. Cotton, MD, MPH; Nena Matijevic, PhD; Peter Muskat, MD; John G. Myers, MD; Herb A. Phelan, MD, MSCS; Christopher E. White, MD; Jiajie Zhang, PhD; Mohammad H. Rahbar, PhD; for the PROMMTT Study Group
The Prospective, Observational, Multicenter, Major Trauma Transfusion (PROMMTT) Study

Comparative Effectiveness of a Time-Varying Treatment With Competing Risks

JAMA Surg 2013
# Online First

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

*Comparative Effectiveness of a Time-Varying Treatment With Competing Risks*

## Table 3. Multivariable Cox Regression Models Examining the Association of Plasma and Platelet Transfusion Ratios With In-hospital Mortality

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Continuous Transfusion Ratio Variables</th>
<th>Categorical Transfusion Ratio Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR (95% CI)</td>
<td>(P) Value</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minute 31 to Hour 6 After ED Admission (n = 876)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.31 (0.16-0.58)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Early initial and time-varying plasma:RBC ratios</td>
<td>0.55 (0.31-0.98)</td>
<td>.04</td>
</tr>
<tr>
<td>Early initial and time-varying platelet:RBC ratios</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hour &gt;6 to Hour 24 After ED Admission (n = 809)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.34 (0.14-0.81)</td>
<td>.02</td>
</tr>
<tr>
<td>6-h cumulative plasma:RBC ratio</td>
<td>0.81 (0.46-1.43)</td>
<td>.46</td>
</tr>
<tr>
<td>6-h cumulative platelet:RBC ratio</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*JAMA Surg 2013*
Trauma Exsanguination Protocol 2018

• Trauma Bay Blood Refrigerator
  • Immediate Access to pRBCs
  • Immediate Access to Stored Plasma
  • Immediate Access to Whole Blood
• Quicker to 1:1 Ratio
  • Platelet Issue - Agitator
An Emergency Department Thawed Plasma Protocol for Severely Injured Patients

Zayde A. Radwan, BS; Yu Bai, MD, PhD; Nena Matijevic, PhD, PharmD; Deborah J. del Junco, PhD; James J. McCarthy, MD; Charles E. Wade, PhD; John B. Holcomb, MD; Bryan A. Cotton, MD, MPH

Table 3. Primary and Secondary Outcome Data<sup>a</sup>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Median (IQR)</th>
<th>TP-ED (n = 164)</th>
<th>TP-BB (n = 130)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to first unit of RBCs, min</td>
<td>18 (11-73)</td>
<td>20 (10-72)</td>
<td>.85</td>
<td></td>
</tr>
<tr>
<td>Time to first unit of plasma, min</td>
<td>43 (21-106)</td>
<td>89 (48-192)</td>
<td>&lt;.001</td>
<td></td>
</tr>
<tr>
<td>24-h RBC transfusions, U</td>
<td>5 (2-10)</td>
<td>6 (3-11)</td>
<td>.13</td>
<td></td>
</tr>
<tr>
<td>24-h Plasma transfusion, U</td>
<td>6 (3-11)</td>
<td>7.5 (4-14)</td>
<td>.08</td>
<td></td>
</tr>
<tr>
<td>24-h Platelet transfusion, U</td>
<td>12 (6-18)</td>
<td>12 (6-18)</td>
<td>.77</td>
<td></td>
</tr>
<tr>
<td>24-h Cryoprecipitate transfusion, U</td>
<td>0</td>
<td>0</td>
<td>.03</td>
<td></td>
</tr>
<tr>
<td>Massive transfusion rate, %</td>
<td>27.0</td>
<td>39.0</td>
<td>.04</td>
<td></td>
</tr>
<tr>
<td>24-h Mortality, %</td>
<td>9.7</td>
<td>6.9</td>
<td>.39</td>
<td></td>
</tr>
<tr>
<td>30-d Mortality, %</td>
<td>20.7</td>
<td>22.3</td>
<td>.74</td>
<td></td>
</tr>
<tr>
<td>Hemorrhage-related mortality, %</td>
<td>14.7</td>
<td>27.5</td>
<td>.21</td>
<td></td>
</tr>
</tbody>
</table>
An Emergency Department Thawed Plasma Protocol for Severely Injured Patients

Zayde A. Radwan, BS; Yu Bai, MD, PhD; Nena Matijevic, PhD, PharmD; Deborah J. del Junco, PhD; James J. McCarthy, MD; Charles E. Wade, PhD; John B. Holcomb, MD; Bryan A. Cotton, MD, MPH

Table 4. Multiple Logistic Regression Model Predicting 30-Day Mortality

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thawed plasma in ED</td>
<td>0.43 (0.194-0.956)</td>
<td>.04</td>
</tr>
<tr>
<td>Injury severity (ISS)</td>
<td>1.12 (1.070-1.174)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Physiologic status (w-RTS)</td>
<td>0.84 (0.694-1.012)</td>
<td>.07</td>
</tr>
<tr>
<td>Admission base deficit</td>
<td>0.99 (0.921-1.070)</td>
<td>.84</td>
</tr>
<tr>
<td>Blunt mechanism of injury</td>
<td>2.32 (0.608-8.825)</td>
<td>.22</td>
</tr>
</tbody>
</table>
US Military Damage Control
Resuscitation

Fresh Whole Blood Transfusion: A Controversial Military Practice

David S. Kauvar, MD, John B. Holcomb, MD, Gary C. Norris, MPH, and John R. Hess, MD

J Trauma 2006
Warm Fresh Whole Blood Is Independently Associated With Improved Survival for Patients With Combat-Related Traumatic Injuries

Philip C. Spinella, MD, Jeremy G. Perkins, MD, Kurt W. Grathwohl, MD, Alec C. Beekley, MD, and John B. Holcomb, MD

J Trauma 2009
US Military: Whole Blood

Warm Fresh Whole Blood is Independently Associated With Improved Survival in Traumatic Injury

Philip C. Spinella, MD, and John B. Holcomb, MD

Fig. 1. Kaplan-Meier curve of 30-day survival according to study group.

Log-Rank Test, (p=0.002)
Warm Fresh Whole Blood is Independently Associated With Improved Survival After Traumatic Injury

Philip C. Spinella, MD, and John B. Holcomb, MD,

J Trauma 2009

Fig. 1. Kaplan-Meier curve of 30-day survival according to study group.

Log-Rank Test, (p=0.002)
Civilian Trauma : Whole Blood

Initial safety and feasibility of cold-stored uncrossmatched whole blood transfusion in civilian trauma patients

Mark H. Yazer, MD, Byron Jackson, MD, Jason L. Sperry, MD, Louis Alarcon, MD, Darrell J. Triulzi, MD, and Alan D. Murdock, MD, Pittsburgh, Pennsylvania

J Trauma 2016
Initial safety

**TABLE 2. Blood Transfusion Demographic Information for the WB and Component Therapy Groups**

<table>
<thead>
<tr>
<th>Blood group</th>
<th>Component Therapy (n = 145)</th>
<th>WB (n = 47)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>57</td>
<td>19</td>
<td>0.0002</td>
</tr>
<tr>
<td>B</td>
<td>20</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>65</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>AB</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>0</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

**Received blood products, n (%)**

<table>
<thead>
<tr>
<th></th>
<th>Component Therapy (n = 145)</th>
<th>WB (n = 47)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBC</td>
<td>129 (89.0)</td>
<td>40 (85.1)</td>
<td>0.45</td>
</tr>
<tr>
<td>Plasma</td>
<td>96 (66.2)</td>
<td>28 (59.6)</td>
<td>0.48</td>
</tr>
<tr>
<td>Platelets</td>
<td>74 (49.0)</td>
<td>24 (51.0)</td>
<td>0.87</td>
</tr>
<tr>
<td>Cryoprecipitate</td>
<td>26 (17.9)</td>
<td>11 (23.4)</td>
<td>0.40</td>
</tr>
</tbody>
</table>

**Blood product ratios, mean (SD)**

<table>
<thead>
<tr>
<th></th>
<th>Component Therapy (n = 145)</th>
<th>WB (n = 47)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma:RBC</td>
<td>0.77 (0.73)</td>
<td>0.99 (0.47)</td>
<td>0.006</td>
</tr>
<tr>
<td>PLT:RBC</td>
<td>0.51 (0.74)</td>
<td>0.72 (0.40)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

**Volume of incompatible plasma, median (range), mL**

<table>
<thead>
<tr>
<th></th>
<th>Component Therapy (n = 145)</th>
<th>WB (n = 47)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>800 (400–4600)</td>
<td>1000 (200–10400)</td>
<td>0.38</td>
</tr>
</tbody>
</table>
PPMC : Whole Blood

Whole Blood Resuscitation for patients with Severe Traumatic Injury

- Male ≥18
- Female ≥50

- CPR/EDT
- Severe TBI

- ABC* ≥2
- OR from Trauma Bay

- CONSIDER EMPIRIC WHOLE BLOOD (4 UNITS MAX)

*ABC=1 point ea for
  - Penetrating
  - FAST+
  - SBP ≤ 90 mmHg
  - HR ≥ 120 BPM
TXA

Effects of tranexamic acid on death, vascular occlusive events, and blood transfusion in trauma patients with significant haemorrhage (CRASH-2): a randomised, placebo-controlled trial

CRASH-2 trial collaborators*

The importance of early treatment with tranexamic acid in bleeding trauma patients: an exploratory analysis of the CRASH-2 randomised controlled trial

The CRASH-2 collaborators*

Lancet 2010 and 2011
In bleeding trauma patients:

- Coagulation occurs rapidly at the site of damaged blood vessels.
- Fibrinolysis breaks down blood clots.
- In patients with serious bleeding fibrinolysis can make bleeding worse.
Plasminogen activators from injured blood vessel convert plasminogen to plasmin.

Plasmin binds to the fibrin blood clot and breaks it down. This is fibrinolysis.
Tranexamic acid inhibits plasmin and reduces clot breakdown.
Methods

- Over 20,000 bleeding trauma patients were randomly allocated to get tranexamic acid or matching placebo.

- We included all adult trauma patients who were within 8 hours of their injury, if their doctor thought that they had or could have significant haemorrhage.

- We then collected data on death in hospital within 4 weeks of injury and all important side effects.
### We used this dose of tranexamic acid

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Tranexamic acid dose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Loading</strong></td>
<td>1 gram over 10 minutes (by slow intravenous injection or an isotonic intravenous infusion)</td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td>1 gram over 8 hours (in an isotonic intravenous infusion)</td>
</tr>
</tbody>
</table>
We randomised many trauma patients

Patient enrolment

- 20,211 patients
- from 274 hospitals
- in 40 countries
We had excellent follow up

20,211 randomised

10,096 allocated TXA
- 3 consent withdrawn
- 10,093 baseline data
- 33 lost to follow-up
- Followed up = 10,060 (99.7%)

10,115 allocated placebo
- 1 consent withdrawn
- 10,114 baseline data
- 47 lost to follow-up
- Followed up = 10,067 (99.5%)
This is what we found

<table>
<thead>
<tr>
<th>Cause of death</th>
<th>TXA 10,060</th>
<th>Placebo 10,067</th>
<th>Risk of death</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleeding</td>
<td>489</td>
<td>574</td>
<td>0.85 (0.76–0.96)</td>
<td>0.0077</td>
</tr>
<tr>
<td>Thrombosis</td>
<td>33</td>
<td>48</td>
<td>0.69 (0.44–1.07)</td>
<td>0.096</td>
</tr>
<tr>
<td>Organ failure</td>
<td>209</td>
<td>233</td>
<td>0.90 (0.75–1.08)</td>
<td>0.25</td>
</tr>
<tr>
<td>Head injury</td>
<td>603</td>
<td>621</td>
<td>0.97 (0.87–1.08)</td>
<td>0.60</td>
</tr>
<tr>
<td>Other</td>
<td>129</td>
<td>137</td>
<td>0.94 (0.74–1.20)</td>
<td>0.63</td>
</tr>
<tr>
<td><strong>Any death</strong></td>
<td><strong>1463</strong></td>
<td><strong>1613</strong></td>
<td><strong>0.91 (0.85–0.97)</strong></td>
<td><strong>0.0035</strong></td>
</tr>
</tbody>
</table>
Most of the benefit is for bleeding deaths

<table>
<thead>
<tr>
<th>Group</th>
<th>Patients</th>
<th>Event Rate</th>
<th>RR (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TXA (n=10,060)</td>
<td>10,060</td>
<td>489 (4.9%)</td>
<td>0.85 (0.76–0.96)</td>
<td>0.0077</td>
</tr>
<tr>
<td>Placebo (n=10,067)</td>
<td>10,067</td>
<td>574 (5.7%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
For bleeding deaths – early treatment is better

- ≤1 hour: 0.68 (0.54–0.86)
- >1 to ≤ 3 hours: 0.79 (0.60–1.04)
- >3 hours: 1.44 (1.04–1.99)

RR (99% CI)  \( p=0.000008 \)
There was no increase in thrombosis

<table>
<thead>
<tr>
<th>Condition</th>
<th>TXA allocated (10,060)</th>
<th>Placebo allocated (10,067)</th>
<th>Risk ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVT</td>
<td>40 (0.40%)</td>
<td>41 (0.41%)</td>
<td></td>
</tr>
<tr>
<td>PE</td>
<td>72 (0.69%)</td>
<td>71 (0.70%)</td>
<td></td>
</tr>
<tr>
<td>MI</td>
<td>35 (0.35%)</td>
<td>55 (0.52%)</td>
<td></td>
</tr>
<tr>
<td>Stroke</td>
<td>57 (0.56%)</td>
<td>66 (0.65%)</td>
<td></td>
</tr>
<tr>
<td>Any</td>
<td>168 (1.63%)</td>
<td>201 (1.95%)</td>
<td></td>
</tr>
</tbody>
</table>
Tranexamic acid is highly cost effective

Cost-Effectiveness Analysis of Administering Tranexamic Acid to Bleeding Trauma Patients Using Evidence from the CRASH-2 Trial

Carla Guerriero¹*, John Cairns¹, Pablo Perel², Haleema Shakur², Ian Roberts², on behalf of CRASH 2 trial collaborators

¹ Department of Health Services Research and Policy, London School of Hygiene and Tropical Medicine, London, United Kingdom, ² Clinical Trials Unit, London School of Hygiene and Tropical Medicine, London, United Kingdom
What we concluded

- Tranexamic acid reduces mortality in bleeding trauma patients
- Tranexamic acid does not seem to increase unwanted clotting
- Tranexamic acid needs to be given early – within 3 hours of injury
- Tranexamic acid is not expensive and could save hundreds of thousands of lives each year around the world
Tranexamic acid is now being used

- After the CRASH-2 trial, tranexamic acid was added to the WHO List of Essential Medicines (March 2011)
- The military are using tranexamic acid to treat combat casualties
- Tranexamic acid is being used in hospitals around the world
- Tranexamic acid could be given in ambulances
- PennSTAR Protocol
Clinical Enhancements for Hemorrhagic Shock

- Blood Kiosk in the Trauma Bay - 2015
- IO - 2015
- REBOA - 2016
- Peri-op Education - 2017
- Whole Blood - 2017
- TEG - 2018
REBOA: Catheter Overview

GUIDEWIRE-FREE Aortic Occlusion Balloon

WHITE = Balloon

RED = Proximal Pressure

“P” Tip

“P” Tip

15mm 20mm 25mm 30mm 32mm
5cc 8cc 13cc 20cc 24cc

Fill syringe with appropriate volume
Never more than 24cc

The REBOA Company™
REBOA Cart
Prepare Catheter: Insertion Depth

Zone I: When using the mid-sternum as a landmark the catheter was successfully deployed in between the Subclavian and Celiac arteries 100% of the time.

Zone I MINIMUM: 42 cm

Zone III MINIMUM: 23 cm

Practical Rules of Thumb

Zone I: Mid-sternum or about 45-50 cm

Zone III: Supra-umbilical/Sub-xiphoid or about 25 cm
REBOA: Contraindications

• Major thoracic injuries
  – Blunt aortic injury
  – Massive hemothorax
  – Cardiac laceration

• Neck/Axilla vascular injuries
REBOA: Human Data

The AAST prospective Aortic Occlusion for Resuscitation in Trauma and Acute Care Surgery (AORTA) registry: Data on contemporary utilization and outcomes of aortic occlusion and resuscitative balloon occlusion of the aorta (REBOA)

Joseph J. DuBose, MD, Thomas M. Scalea, MD, Megan Brenner, MD, Dimitra Skiada, MD, Kenji Inaba, MD, Jeremy Cannon, MD, Laura Moore, MD, John Holcomb, MD, David Turay, MD, Cassra N. Arbabi, MD, Andrew Kirkpatrick, MD, James Xiao, MD, David Skarupa, MD, Nathaniel Poulin, MD, and the AAST AORTA Study Group, Davis, California


<table>
<thead>
<tr>
<th></th>
<th>Total (n = 114)</th>
<th>Endovascular (n = 46)</th>
<th>Open (n = 68)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>In hospital mortality, n (%)</td>
<td>90/114 (78.9%)</td>
<td>33/46 (71.7%)</td>
<td>57/68 (83.8%)</td>
<td>0.120</td>
</tr>
<tr>
<td>Mortality, hours after admission, median/IQR</td>
<td>1.0/1.0</td>
<td>2.0/3.0</td>
<td>1.0/1.0</td>
<td>0.481</td>
</tr>
<tr>
<td>Mortality hospital day, median/IQR</td>
<td>1.0/2</td>
<td>1.0/2</td>
<td>1.0/0</td>
<td>0.757</td>
</tr>
<tr>
<td>Mortality location, ED, n (%)</td>
<td>57/114 (50.0%)</td>
<td>25/46 (54.3%)</td>
<td>31/68 (45.6%)</td>
<td>0.043</td>
</tr>
<tr>
<td>Mortality location, OR, n (%)</td>
<td>23/114 (20.2%)</td>
<td>12/46 (26.1%)</td>
<td>11/68 (16.2%)</td>
<td>0.043</td>
</tr>
<tr>
<td>Mortality location, intensive care unit, n (%)</td>
<td>34/114 (29.8%)</td>
<td>9/46 (19.6%)</td>
<td>25/68 (36.8%)</td>
<td>0.043</td>
</tr>
</tbody>
</table>
REBOA: Human Data

Favors REBOA        Favors Open

Thromboelastography

- R
- K
- Alpha angle
- MA
- LY30

Coagulation
Fibrinolysis
Thromboelastography

A: Normal
B: Factor Issue
C: Platelet Issue
D: Fibrinolysis
E: Hypercoagulability
Rapid Thrombelastography Delivers Real-Time Results That Predict Transfusion Within 1 Hour of Admission

Bryan A. Cotton, MD, MPH, Gabriel Faz, MD, Quinton M. Hatch, MD, Zayde A. Radwan, BS, Jeanette Podbielski, BSN, Charles Wade, PhD, Rosemary A. Kozar, MD, PhD, and John B. Holcomb, MD

Conclusions: Graphical r-TEG results are available within minutes, correlate with conventional coagulation test that are not as rapidly available, and are predictive of early transfusions of packed red blood cells, plasma, and platelets.
Admission rapid thrombelastography predicts development of pulmonary embolism in trauma patients

Bryan A. Cotton, MD, MPH, Kristin M. Minei, BA, Zayde A. Radwan, BS, Nena Matijevic, PhD, PharmD, Evan Pivalizza, MD, Jeanette Podbielski, BSN, Charles E. Wade, PhD, Rosemary A. Kozar, MD, PhD, and John B. Holcomb, MD, Houston, Texas

• 2000 Consecutive Patients
• 2.5% PE Rate
• Increased mA Independent Predictor
  • Odds Ratio 3.5 / 5.8

J Trauma 2012
Massive Transfusion - Outcomes

- 44 Patients with > 50 Units / 24 Hours
- 57% Mortality
- Risk Factors
  - Base Excess < -12
  - Not Amount Transfused
- 63% of Survivors DC’d Home
- 21% of Survivors DC’d Rehab

J Trauma 2002
Massive Transfusion - Outcomes

• 45 Patients with > 50 Units / 48 Hours
• Two Time Periods (88-92 vs 93-97)
• 84% vs 55% Mortality
• Factors
  – Aggressive Rewarming
  – Damage Control Concept
  – More Aggressive Factor Replacement

Arch Surg 1999
Massive Transfusion - Outcomes

- 45 Patients with Damage Control at HUP
- Two Time Periods (88-91 vs 97-00)
- 42% vs 10% Mortality
- Factors
  - Aggressive Rewarming
  - Increased IR Utilization
  - More Aggressive Factor Replacement

J Trauma 2001
Massive Transfusion - Outcomes
ICU Arrival Labs

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<td>ICU PT</td>
<td>19.6</td>
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<td>ICU PTT</td>
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<td>ICU Temp</td>
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<td>35.3*</td>
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J Trauma 2001

*p < 0.05
Massive Transfusion - Outcomes

Damage Control Hematology: The Impact of a Trauma Exsanguination Protocol on Survival and Blood Product Utilization

Bryan A. Cotton, MD, Oliver L. Gunter, MD, James Isbell, MD, Brigham K. Au, BS, Amy M. Robertson, MD, John A. Morris, Jr., MD, Paul St. Jacques, MD, and Pampee P. Young, MD, PhD

74 % Reduction in Odds of Mortality with TEP

J Trauma 2008
Massive Transfusion - Outcomes

J Trauma 2008
Transfusion of Plasma, Platelets, and Red Blood Cells in a 1:1:1 vs a 1:1:2 Ratio and Mortality in Patients With Severe Trauma
The PROPPR Randomized Clinical Trial

John B. Holcomb, MD; Barbara C. Tilley, PhD; Sarah Baraniuk, PhD; Erin E. Fox, PhD; Charles E. Wade, PhD; Jeanette M. Podbielski, RN; Deborah J. del Junco, PhD; Karen J. Brasel, MD, MPH; Eileen M. Bulger, MD; Rachael A. Callcut, MD, MSPH; Mitchell Jay Cohen, MD; Bryan A. Cotton, MD, MPH; Timothy C. Fabian, MD; Kenji Inaba, MD; Jeffrey D. Kerby, MD, PhD; Peter Muskat, MD; Terence O’Keeffe, MBChB, MSPH; Sandro Rizoli, MD, PhD; Bryce R. H. Robinson, MD; Thomas M. Scalea, MD; Martin A. Schreiber, MS; Deborah M. Stein, MD; Jordan A. Weinberg, MD; Jeannie L. Callum, MD; John R. Hess, MD, MPH; Nena Matijevic, PhD; Christopher N. Miller, MD; Jean-Francois Pittet, MD; David B. Hoyt, MD; Gail D. Pearson, MD, ScD; Brian Leroux, PhD; Gerald van Belle, PhD; for the PROPPR Study Group
Transfusion of Plasma, Platelets, and Red Blood Cells in a 1:1:1 vs a 1:1:2 Ratio and Mortality in Patients With Severe Trauma
The PROPPR Randomized Clinical Trial

24-h Mortality

![Graph showing 24-hour mortality with time to death from randomization in hours and number at risk for each group.](image)

No. at risk
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JAMA 2015
Transfusion of Plasma, Platelets, and Red Blood Cells in a 1:1:1 vs a 1:1:2 Ratio and Mortality in Patients With Severe Trauma
The PROPPR Randomized Clinical Trial
Risk-Adjusted Major Complications Including Death by Cohort - Fall 2017

TQIP Report ID: 76

Patient Cohort

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<tr>
<th>OR</th>
<th>All Patients</th>
<th>Blunt Multisystem</th>
<th>Penetrating</th>
<th>Shock</th>
<th>Severe TBI</th>
<th>Elderly</th>
<th>Elderly Blunt Multisystem</th>
<th>Isolated Hip Fracture</th>
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<tr>
<td>OR</td>
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<td>0.77</td>
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<td>0.78</td>
<td>0.90</td>
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Summary

• Outcomes After Exsanguination can be Quite Good

• Systems Must Be in Place
  – Rapid Mobilization
  – Early Factor Replacement
  – Aggressive Rewarming

• Role for New Agents

• Role for New Technology

• Plenty of Research Opportunities
Thank You

Heal like a champion today