Damage Control Resuscitation
Lessons Learned and the Way Forward After More Than a Decade of War

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OBJECTIVES

• Pathophysiology of the lethal triad
• Principles of Damage Control Resuscitation (DCR)
• Early indicators for massive transfusion
• Optimal ratios of blood component transfusion
• Complications of MTP
• Current trends and future directions

Signature Injury of GWOT
Dismounted Complex Battle Injury (DCBI)

He who desires to practice surgery must go to war
Hippocrates, c. 400 BC
Major leading cause of potentially preventable death was truncal hemorrhage

Breakout of Potentially Survivable Hemorrhagic Deaths N = 85

- 4,493 trauma admissions
- 1024 (23%) required transfusion
- 243 (5.4%) MASSIVE TRANSFUSIONS
  - Most did not receive MT

Mortality in patients requiring massive transfusion 25.4%
  - Majority in first six hours
Bleeding to death is an acute problem
Earlier control of hemorrhage should save lives

Coagulopathy Develops over Time - 1997

Coagulopathy

• Derangements in coagulation occur rapidly after trauma even after adjusting for ISS
• By the time of arrival at the ED, 1/3 (2,994 of 10,790) of trauma patients had a coagulopathy associated with a poor outcome

Early Coagulopathy Predicts Mortality in Trauma

Acute Traumatic Coagulopathy


**Acute Coagulopathy of Trauma Shock (ACoTS)**

- Endothelial dysfunction
- Glycocalyx degradation
  - Release of heparin-like substances
- Activation of Protein C
  - Inactivates FVIIIa, FVa,
  - Promotes fibrinolysis via PAI-1 inhib.
  - Reduces inflammation
- Coagulation factor deficiency
  - As early as 25 min post injury!
  - Factor Va proteolysis by APC
- Platelet dysfunction

**Acute Coagulopathy of Trauma Shock**

- TIC distinct from DIC
- Elevated INR
- Elevated PTT
- Zero patients with DIC
- 15% with TIC (ACoTS)
- Potentially adaptive
  - Evolutionary pressure
Damage Control Resuscitation: Directly Addressing the Early Coagulopathy of Trauma

- Rapid progress in trauma care occurs during a war.
- Damage control resuscitation addresses diagnosis and treatment of the entire lethal triad immediately upon admission.
- High FFP & platelet to PRBC ratio (balanced resusc.)

Holcomb, JB. J Trauma. 2007; 62(2): 307-310

The “Lethal Triad” Revisited

Acidosis, coagulopathy, & hypothermia are symptoms

Treat the central causes of the lethal triad

Damage Control Concept

US Navy: capacity of a ship to absorb damage and maintain mission integrity

Early and Aggressive

"In massive insults to the organism, treat the patient for the insult, without waiting for the response to the insult."

Mark Ravitch, 1910-1989
Damage Control Resuscitation

- Mindset which involves
  - Permissive hypotension
  - Minimizing aggressive crystalloid use
  - Early use blood products such as PRBC and empiric use of component therapy

- Continued prioritization of **surgically** controlling bleeding sources

6 Core Principles of DCR

- Compressible hemorrhage control
- Hypotensive resuscitation (Permissive hypotension)
- Rapid surgical control of bleeding
- Avoidance of the overuse of crystalloids and colloids
- Prevention or correction of acidosis, hypothermia & hypocalcemia
- **Hemostatic resuscitation**

Avoiding the “He looked good until…” phenomenon

**DCR**

Within the first five minutes in the ED
- Identify patients in trouble
- Identify patients with increased mortality
- Identify patients with increased probability of massive transfusion

Diagnosis

- Easy in moribund group
- Much harder in the talking & looking good group
- Predictive model
- Err on side of MT

- **Damage Control Resuscitation**
  1. Hypotensive resuscitation
  2. Hemostatic resuscitation
**Damage Control Resuscitation Pattern Recognition**

- Weak or absent radial pulse
- Abnormal mental status
- Age ≥ 55

**Class of Shock**

<table>
<thead>
<tr>
<th>%age loss</th>
<th>Pulse</th>
<th>B/P</th>
<th>Urinary output</th>
<th>replacement</th>
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<tbody>
<tr>
<td>I</td>
<td>&lt; 15%</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>II</td>
<td>15-30%</td>
<td>↑</td>
<td>Normal</td>
<td>Normal</td>
</tr>
<tr>
<td>III</td>
<td>30-40%</td>
<td>↑↑</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>IV</td>
<td>&gt; 40%</td>
<td>↑↑</td>
<td>↓</td>
<td>↓</td>
</tr>
</tbody>
</table>

**Who Needs DCR?**

- Acidosis
- Coagulopathy
- Hypotension
- Anemia (blood loss)
- Hypothermia

Base Deficit > 5
INR > 1.5
Systolic B/P < 90 (110?)
HgB < 11
< 96.5°

Presence of any 2 predicts need for DCR
3 or more should mandate DCR

**A Predictive Model for Massive Transfusion in Combat Casualty Patients**

- 3442 total patients
- 680 received 1+ units blood in first 24 hours
- 204 transferred from another facility
- 29 known under age 18
- 81 Security internees
- 44 Incomplete data
- Total of 302 patients - study population
  — 80 patients (26.5%) required MT
  — Received 63% of blood products transfused

McLaughlin, et al, J Trauma 2008; 64:S57-63
MT Scoring System

- SBP < 110
- HR > 105
- Hct < 32
- pH < 7.25

AUROC = .839

ABC Score

(Assessment of Blood Consumption)

- Four Parameters assigned a score of 0-1
  - Penetrating Mechanism
  - Positive FAST
  - Arrival SBP <90
  - Arrival HR >120

- A score of 2 was predictive for MT

Which is a better resuscitative fluid?

Electrolytes (mmol/L) avg.
unit of FFP ~ 300cc

- Na 165 (48mmol/unit)
- K 3.3 (1.0mmol/unit)
- Glucose 20
- Calcium 1.8
- Citrate 20
- Lactate 3
- pH 7.2-7.4
- Phos 3.63

**HYPOTHESIS:** Normal resuscitation, compared with supranormal, requires less crystalloid volume, decreasing the incidence of intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS).

- 1999-2001, n = 85 vs 2001-02, n = 71

**CONCLUSION:** Supranormal resuscitation, compared with normal resuscitation, was associated with more lactated Ringer infusion, decreased intestinal perfusion (higher GAPCO2), and an increased incidence of IAH, ACS, multiple organ failure and death.

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**Indications For Early FFP, Cryoprecipitate, And Platelet Transfusion In Trauma**

Lloyd Ketchum, John R. Hess and Seppo Hiippala  
J Trauma, 2006

- If clinically evident coagulopathy is prevented by the early use of FFP, subsequent blood product consumption is likely to be less.

- In massive transfusion, early 1:1:1  
  - PRBC : Plasma : platelets are indicated
• Increased risk for those patients requiring less than four units PRBC

• No increased risk for those patients requiring more than 4 units
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- Hemostatic resuscitation

Civilian Experience
1:1:1 Transfusion protocol

<table>
<thead>
<tr>
<th>Author</th>
<th>Location</th>
<th>Year</th>
<th>Beneficial</th>
<th>Optimal FFP:PRBC</th>
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<tbody>
<tr>
<td>Kashuk</td>
<td>Denver</td>
<td>2008</td>
<td>No</td>
<td>1:2</td>
</tr>
<tr>
<td>Gunter</td>
<td>Nashville</td>
<td>2008</td>
<td>Yes</td>
<td>2:3</td>
</tr>
<tr>
<td>Duchesne</td>
<td>NOLA</td>
<td>2008</td>
<td>Yes</td>
<td>1:1</td>
</tr>
<tr>
<td>Sperry</td>
<td>Pittsburg</td>
<td>2008</td>
<td>Yes</td>
<td>1:1.5</td>
</tr>
<tr>
<td>Scalea</td>
<td>Baltimore</td>
<td>2009</td>
<td>No</td>
<td>TBD</td>
</tr>
<tr>
<td>Snyder</td>
<td>Birmingham</td>
<td>2009</td>
<td>No</td>
<td>Survival bias</td>
</tr>
</tbody>
</table>

- 11,185 screened and 680 were randomized
  - Blood product ratios of 1:1:1 (338) vs 1:1:2 (342)
- No significant difference in mortality, ARDS, MODS, VTE, sepsis, and transfusion-related complications
- No difference in PRBC transfused
- 1:1:1 ratio
  - higher rate of hemostasis at 24 hours
  - Shorter time to hemostasis
• 34,000 patients in 10 medical centers

• 94% hemorrhagic deaths occurred within 24hrs
  – 58% within the first three hours (mean 2.6 hours)

• At 3hrs only 10% of survivors had not received plasma


• Higher FFP and Plt to PRBC transfusion ratios EARLY resulted in higher survival

• After 6 hours, survival advantage of high ratio decreases

• No advantage after 24 hours


• For each hour survived, more likely to have FFP:PRBC ratio > 1:2

  • 30 min  29%
  • 1h     47%
  • 2hr    69%
  • 3hr    78%
  • 6hr    84%

• PLT: PRBC ratio > 1:2

  • 30min  1%
  • 1hr    14%
  • 2hr    40%
  • 3hr    60%
  • 6hr    80%
Wrapped Up in Ratios

• It’s not about exact ratios

• It’s about principles
  – replace blood with blood
  – minimize crystalloid
  – start it early

• Make it AUTOMATIC!

ACoTS - Hyperfibrinolysis

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

Lancet, 2010: 376, 23-32

• 20k patients in 270 hospitals in 40 countries
• Significant reduction in all cause mortality
• No increased risk for vascular occlusive events

CRASH-2 Subgroup Analysis

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


• TXA started within in 1st hour after injury most beneficial

• Increased mortality if started beyond 3h

Joint Theater CPG

Joint Theater Trauma System Clinical Practice Guideline

Damage Control Resuscitation at Level III/IV Treatment Facilities

Pack One: 4u PRBC and 4u FFP, should consider 6pk Platelets, 1 10 unit bag cryo and +/- Factor VII (obtained from Pharmacy) at this time if patient received 4uPRBC/4uFFP Emergency release blood. **Strongly consider the early use of TXA**: Infuse 1 gram of tranexamic acid in 100 ml of 0.9% NS over 10 minutes intravenously in a separate IV line from any containing blood and blood products. (More rapid injection has been reported to cause hypotension.). **Hextend® should be avoided as a carrier fluid.** Infuse a second 1-gram dose intravenously over 8 hours infused with 0.9% NS carrier.

Pack Two: 4u PRBC and 4u FFP

Pack Three: 4u PRBC, 4u FFP, 6pk Platelets, 1x 10 unit bag of cryo and +/- Factor VII (obtained from Pharmacy)

Austere Conditions

Austere Environment

Don’t have FFP or platelets?

• “walking blood bank”
• prescreened donors
• provides fresh, warm red cells, clotting factors, and platelets

Component Therapy vs Whole Blood

Component Therapy:
1U PRBC + 1U PLT + 1U FFP + 1 U cryo
680 COLD mL
• Hct 29%
• Plt 80K
• Coag factors 65% of initial concentration
• 1000 mg Fibrinogen

WWB:
500 mL Warm
Hct: 38-50%
Plt: 150-400K
Coag: 100%
1000 mg Fibrinogen

Whole blood for hemostatic resuscitation of major bleeding

Spinella, et al, Transfusion, 2016;56;S190–S202

• Proven utility of whole blood (WB) transfusion in combat
• Group O whole blood safe universal donor
• Use of PLT preserving leukopore filter
• WB stored at 4°C retains PLT function for 15 days

• Armand & Hess, Transfusion Med. Rev., 2003
**Goal Directed Therapy**

**AAST 2012 Plenary Paper**

TEG-guided resuscitation is superior to standardized MTP resuscitation in massively transfused penetrating trauma patients

Nicole M. Tapia, MD, Alex Chang, MD, Michael Norman, MD, Francis Webb, MD, Bradford Scott, MD, Matthew J. Well, Jr, MD, Kenneth L. Mattos, MD, and James Suliburk, MD, Houston, Texas

- Goal directed therapy offers rapid and targeted therapy
- Potentially reduces allogenic blood product exposure

Tapia NM J Trauma Acute Care Surg 2013; 74(2): 378-386
Schöchl H, Curr Opin Anesthesiol, 2016; 29(2): 234-244

**Pitfalls in Damage Control**

- Failure to recognize coagulopathy at admission
- Prolonged evaluations or operations in the physiologically “exhausted” patient
- Excessive resuscitation with crystalloid
- Failure to obtain surgical hemorrhage control
- Delay in initiating damage control
Summary

- Early identification of patients requiring massive transfusion continues to be problematic

- Balanced/hemostatic resuscitation as early as possible
  - POI administration of FFP?
  - Permissive hypotension

- Avoid unnecessary crystalloid

- Don’t get hung up on the ratio