Lessons from a Learning System for Trauma Care

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Stories / Examples

- Highlight some specific recommendations in the NAS report.
  - Military lessons learned
  - Translation to the civilian trauma arena

- Are there similar opportunities in other areas of health care?
Military and Civilian Trauma Centers since 1985

Somalia, 1993

Baghdad, 2006

Houston, 2017
EMERGENCY SURGERY
THE MILITARY SURGERY OF THE WORLD WAR
ADAPTED TO CIVIL LIFE

BY
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HOSPITAL, 1912-1915; AUTHOR OF MEDICAL WAG MANUAL NO. 7, MILITARY
SURGERY OF THE ZONE OF THE ADVANCE.

ILLUSTRATED WITH 324 ENGRAVINGS

LEA & FEBIGER
PHILADELPHIA AND NEW YORK

A NATIONAL TRAUMA CARE SYSTEM
Integrating Military and Civilian Trauma Systems to Achieve ZE
Preventable DEATHS After Injury

The National Academies of
SCIENCE, ENGINEERING, MEDICINE
• In 2010, there were 5.1 million deaths from injuries
  > the total number of deaths from HIV, TB and malaria combined (3.8 million).
• Overall, the number of deaths from injuries increased by 24% between 1990 and 2010.
• WHO = leading cause of death worldwide by 2020
Epidemiology

- Military burden: ~7,850 service member deaths in war
  - Nearly 1,000 were potentially survivable

- US Civilian burden: 147,790 U.S. trauma deaths in 2014
- 2.3 million civilian deaths during the war
- Leading cause of death 1-47
- Leading cause of life years lost
  -> 30,000 may have been preventable with optimal trauma care
  - Every day epidemic vs
- Increased threats from active shooter and mass casualty events
Framework for a Learning Trauma Care System

Committee built upon the components of a continuously learning health system articulated by IOM (2013) report *Best Care at Lower Cost.*

Components of a **continuously learning trauma care system:**

- Data capture of the patient care experience
- PI and research to generate evidence-based best trauma care practices
- Timely dissemination of knowledge
- Systems for ensuring an expert trauma care workforce
- Patient-centered trauma care
- Leadership-instilled culture of learning
- Transparency and incentives aligned for quality trauma care
- Aligned authority and accountability for trauma system leadership

Patient centeredness is the core of a learning trauma care system.
Major scientific lessons learned in the trauma field over the last two decades

John B. Holcomb*

Center for Translational Injury Research, Department of Surgery, McGovern Medical School, UT Health, Houston, Texas, United States of America

- Leadership
- Systems of care
- Stopping bleeding
- Transfusion
- Training
- Research Funding
- Surgery
- Rapid Transport
Leadership lessons learned in Tactical Combat Casualty Care

Frank K. Butler, MD, FAAO, FUHM, Pensacola, Florida

J Trauma 2017

- No single point of responsibility for Combat Casualty Care in the DoD
- Same situation in the civilian community
- Wonderful leadership opportunity
White House, Military and Civilian Leadership working together on the Stop the Bleed Program
• The DoD did not have trauma system when the war started
• Leveraged our experience in the civilian trauma system
  – Which came from the Vietnam experience
• Goals of the new Trauma System
  – Optimize placement of surgical assets within theater.
  – Develop triage criteria for casualty evacuation to get
    “the right patient to the right place at the right time.”
  – Develop and implement trauma practice guidelines.
  – Develop and maintain the DoD trauma registry
  – Use data/PI to improve outcomes
The impact of the development of a DoDTS has been called by the Military Healthcare System as the seminal battlefield innovation of the war.
The Vision: A National Trauma Care System

To both avoid military lessons lost and improve the civilian system, this is the system we need.

Its starting to happen.
Active Military and Civilian collaboration
- Largely oriented along academic societies
- Active exchange of ideas

Evolving as the war changes
Somalia, 1993

- Mohamed Farah Adid
- War lord and clan leader
- Khat merchant
  - Drug war
  - Man made disaster
- 3-4 Oct 1993
- Published 1999

Movie 2001
United States Army Rangers in Somalia: An Analysis of Combat Casualties on an Urban Battlefield

Robert L. Mabry, MD, John B. Holcomb, MD, Andrew M. Baker, MD, Clifford C. Cloonan, MD, John M. Uhorchak, MD, Denver E. Perkins, MD, Anthony J. Canfield, MD, and John H. Hagmann, MD

The Journal of TRAUMA® Injury, Infection, and Critical Care

Extensive Analysis

- Body armor
- Tourniquets
- Research
- Registry data
- Training

**Whole blood**

- 70 units
Resuscitation
2003 -- 2017
Crystalloid to Whole Blood
• Fresh Whole Blood
• Hypotensive resuscitation
• Limited volume
• Use pulse character instead of blood pressure
  – Normal, weak, absent
Damage Control Resuscitation: Directly Addressing the Early Coagulopathy of Trauma

John B. Holcomb, MD, FACS, Don Jenkins, MD, FACS, Peter Rhee, MD, FACS, Jay Johannigman, MD, FS, FACS, Peter Mahoney, FRCA, RAMC, Sumeru 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. Grathwohl, MD, Phillip C. Spinella, MD, Jeremy G. Perkins, MD, Alec C. Beekley, MD, FACS, Neil R. McMullin, MD, Myung S. Park, MD, FACS, Ernest A. Gonzalez, MD, FACS, Charles E. Wade, PhD, Michael A. Dubick, 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

J Trauma 2007

- Written in Baghdad
  - Rapid progress in trauma care occurs during a war.

- Balanced resuscitation, minimize crystalloid, use plasma as primary resuscitation fluid

- Damage control resuscitation addresses diagnosis and treatment of the entire lethal triad immediately upon admission.
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

> 10,300 units of FWB given in this war

Table 2 Comparison of Individual Blood Products, Volumes and Ratios Between FWB and CT Groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>FWB (n = 100)</th>
<th>CT (n = 254)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stored RBC (U)</td>
<td>9 (7–14)</td>
<td>16 (10–22)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Plasma (U)</td>
<td>4 (3–8)</td>
<td>10 (6–16)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Apheresis platelets (U)</td>
<td>0</td>
<td>2 (1–4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>FWB (U)</td>
<td>5 (3–9)</td>
<td>0 (0–0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cryoprecipitate (U)</td>
<td>0 (0–0)</td>
<td>0 (0–1)</td>
<td>0.007</td>
</tr>
<tr>
<td>Total RBC (U)</td>
<td>16 (11–22)</td>
<td>16 (10–22)</td>
<td>0.44</td>
</tr>
<tr>
<td>Total blood volume (L)</td>
<td>7.4 (5.4–10.4)</td>
<td>9.3 (6.2–13.3)</td>
<td>0.006</td>
</tr>
<tr>
<td>Anticoagulant/ additives (L)</td>
<td>1.7 (1.3–2.5)</td>
<td>2.5 (1.6–3.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Actual blood volume (L)</td>
<td>5.7 (4.1–8.8)</td>
<td>6.8 (4.5–10)</td>
<td>0.03</td>
</tr>
<tr>
<td>PLT:RBC ratio</td>
<td>0.33 (0.2–0.5)</td>
<td>0.86 (0.6–1.3)</td>
<td>0.001</td>
</tr>
<tr>
<td>Plasma:RBC ratio</td>
<td>0.74 (0.55–0.9)</td>
<td>0.73 (0.53–1)</td>
<td>0.73</td>
</tr>
<tr>
<td>Massive transfusion (%)</td>
<td>89/100 (89%)</td>
<td>198/254 (78%)</td>
<td>0.017</td>
</tr>
<tr>
<td>rFVIIa use (%)</td>
<td>42/100 (42%)</td>
<td>101/353 (40%)</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Data presented as Median (IQR) or as percentages.
rFVIIa, recombinant factor VIIa.

Fig. 1. Kaplan-Meier curve of 30-day survival according to study group.
All the military and civilian, single and multicenter retrospective studies

Whole Blood vs Components Study
Frozen Blood vs Stored Blood

Funded by DoD and NIH
• Pragmatic randomized trial of 680 patients at 12 level I trauma centers and predicted to require a MT
• 1:1:1 (338 patients) vs 1:1:2 (342 patients)
• Primary outcomes were 24-hour and 30-day mortality

• Increased deaths from hemorrhage with balanced resuscitation
Is prehospital blood product transfusion effective?

- **N = 505**
- 19 vs 5% 24 hr mortality
- 23 vs 11% 30 day mortality
Whole blood for hemostatic resuscitation of major bleeding

Philip C. Spinella,1,2 Heather F. Pidcocke,2 Geir Strandenes,3,4 Tor Hervig,4 Andrew Fisher,5 Donald Jenkins,6 Mark Yazer,7 James Stubbs,6 Alan Murdock,9 Anne Sailliol,10 Paul M. Ness,11 and Andrew P. Cap2

Trans 2016

• Logistical, economic and clinical benefits of universal donor type O whole blood
• Low titer and cold stored for up to 21 days
  – Platelets OK
• Improved function compared to 1:1:1
Prehospital (Ground and Air) and in Hospital WB in Houston + many more
• DCR (2007) significantly improve outcomes in severely injured bleeding patients.
• After a review of the best available evidence, we recommend the use of a MT/DCR protocol in hospitals that manage such patients and recommend that the protocol target a high ratio of PLAS and PLT to RBC.
• This is best achieved by transfusing equal amounts of RBC, PLAS, and PLT during the early, empiric phase of resuscitation.
Cause of Death
and a Preventable Death Rate
• Improved methods of intravenous or intra-cavitary, noncompressible hemostasis combined with rapid evacuation to surgery may increase survival.
  – Truncal hemorrhage = 50% of causes of death

• Analysis identified improved methods of truncal hemorrhage control as the principal research requirement.
Death on the battlefield (2001–2011): Implications for the future of combat casualty care

Brian J. Eastridge, MD, Robert L. Mabry, MD, Peter Seguin, MD, Joyce Cantrell, MD, Terrill Tops, MD, Paul Uribe, MD, Olga Mallett, Tamara Zubko, Lynne Oetjen-Gerdes, Todd E. Rasmussen, MD, Frank K. Butler, MD, Russell S. Kotwal, MD, John B. Holcomb, MD, Charles Wade, PhD, Howard Champion, MD, Mimi Lawnick, Leon Moores, MD, and Lorne H. Blackbourne, MD

• 2001-2011, 4,596 battlefield deaths were reviewed

These data drove the rapid use of tourniquets and focused research into truncal hemorrhage control
Methodology to reliably measure preventable trauma death rate

Stacy A Drake,¹ Dwayne A Wolf,² Janet C Meininger,¹ Stanley G Cron,³ Thomas Reynolds,⁴ Charles E Wade,⁵ John B Holcomb⁵

- NAS trauma report estimated at 20% but No national PDR
- > 5 million persons in Harris County, Houston, TX
- 85% trauma autopsy rate
- All fire, EMS and police records
- All hospital records, trauma center and non TC
  - 15 TCs and 30 non TCs
- Reviewed all 1848 trauma deaths in 2014

37% PDR in Harris county
Improved Hemorrhage Control
Hemorrhage Control Devices in 1993
Dry Fibrin Sealant Dressings Reduce Blood loss, Resuscitation Volume, and Improve Survival in Hypothermic Coagulopathic Swine with Grade V liver Injuries

John B. Holcomb, MD, Anthony E. Pusateri, PhD, Richard A. Harris, DVM, MS, Thomas J. Reid, MD, PhD, L. Dawson Beall, MS, John R. Hess, MD, MPH, and Martin J. MacPhee. PhD

J Trauma, 1999
> 10 Hemostatic Agents

- ACS+
- InstaClot
- Woundstat
- CELOX
- X-Sponge
- HemCon
- Chitoflex
- Blood STOP
- Alpha Bandage
- FP-21

Hemostatic Agents
Current Recommended Hemostatic Agent on the Battlefield

2013

Significantly better than Gauze dressings
Practical Use of Emergency Tourniquets to Stop Bleeding in Major Limb Trauma

John F. Kragh, Jr., MD, Thomas J. Walters, PhD, David G. Baer, PhD, Charles J. Fox, MD, Charles E. Wade, PhD, Jose Salinas, PhD, and COL John B. Holcomb, MC

- 232 patients
  - 220 males
  - ages: 4–70
    - median 28
- 309 limbs
- 428 tourniquets

Survival: Prehospital vs. ED Tourniquet Use (1st 25 Days)

\[ p = 0.05 \]
Transition of “new military” devices to Civilian use (2008)
CAT tourniquet and Combat Gauze

ED’s
Helicopters
Ground Ambulances
Police and Fire
Schools
Malls
Theaters
Stadiums
Airports
etc
The trauma center is too late: Major limb trauma without a pre-hospital tourniquet has increased death from hemorrhagic shock

J Trauma, 2017

Michelle H. Scerbo, MD, MS, John B. Holcomb, MD, Ethan Taub, DO, Keith Gates, MD, Joseph D. Love, DO, Charles E. Wade, PhD, and Bryan A. Cotton, MD, MPH, Houston, Texas

306 patients received 326 tourniquets over 7 years

![Graph showing number of tourniquets by year]

- PH = 252
  - 3% died of hemorrhage

- TC = 29
  - 14% died of hemorrhage
The focus of this program is on:
- Immediate response to bleeding patients
- Recognizing life-threatening bleeding
- Appropriate ways to stop the bleeding

The help given by an immediate responder can often make the difference between life and death even before professional rescuers arrive.

With the right training, YOU can help save lives!

Conceptually similar to Bystander CPR
But for bleeding trauma patients
> 7000 trained instructors
International effort
Data and Information
United States Army Rangers in Somalia: An Analysis of Combat Casualties on an Urban Battlefield

Robert L. Mabry, MD, John B. Holcomb, MD, Andrew M. Baker, MD, Clifford C. Cloonan, MD, John M. Uhorchak, MD, Denver E. Perkins, MD, Anthony J. Canfield, MD, and John H. Hagmann, MD

Extensive Analysis

• Body armor
• Tourniquets
• Whole blood
• Training

• Research
• Registry data
2001- Redesign a Monitor
Rubber Bands, PDA’s and Duct Tape
Heart Rate Variability and Its Association with Mortality in Prehospital Trauma Patients

William H. Cooke, PhD, Jose Salinas, PhD, Victor A. Convertino, PhD, David A. Ludwig, PhD, Denise Hinds, RN, James H. Duke, MD, Fredrick A. Moore, MD, and John B. Holcomb, MD

**Fig. 2.** Arterial pressures and pulse pressures are shown for 13 patients who died and 15 patients who survived traumatic injuries requiring transport to a level one trauma center. *p = 0.001.
Trauma System Development in a Theater of War: Experiences From Operation Iraqi Freedom and Operation Enduring Freedom

Brian J. Eastridge, MD, Donald Jenkins, MD, Stephen Flaherty, MD, Henry Schiller, MD, and John B. Holcomb, MD

Fig. 1. Improvised patient information communication strategy.

Fig. 2. Improvised patient information communication strategy.
JTS Registry data
Injuries by Body Region,
Real time, wide distribution, actionable

Number of US Military Warriors with Injuries by Body Region

FOR OFFICIAL USE ONLY

Denominators:
All Warriors with Injuries = 16499; Warriors with Battle Injuries (BI) = 10560; Warriors with Non-Battle Injuries (NBI) = 5939

Head & Neck
Overall = 37.6%
BI = 43.6%
NBI = 22.1%

TBI: 11.0%; 13.8%; 6.0%
Eyes: 10.3%; 13.5%; 4.8%
Neck: 5.8%; 8.7%; 0.6%
Face: 23.6%; 30.5%; 11.3%
Head, Neck Face Unspecified: 8.6%; 10.0%; 6.0%

Spine & Back
Overall = 8.1%
BI = 7.8%
NBI = 8.6%

Spinal Cord Injury: 1.4%; 1.5%; 1.1%
Vertebral Column Injury: 7.4%; 7.0%; 8.0%

Torso
Overall = 26.4%
BI = 33.8%
NBI = 13.0%

Chest (Thorax): 12.4%; 16.1%; 9.9%
Abdomen: 11.3%; 15.3%; 4.6%
Pelvis & Urogenital: 9.1%; 12.2%; 3.7%
Trunk: 2.7%; 3.2%; 1.8%
Back & Buttock: 4.4%; 5.8%; 1.7%

Others %
Unspecified

Other Multiples: 2.8%; 3.7%; 1.2%
Unspecified Sites: 13.4%; 17.0%; 7.0%
System Wide & Late Effects: 9.9%; 9.9%; 7.8%

Extremities
Overall = 65.1%
BI = 74.0%
NBI = 49.3%

Upper Extremities
Overall = 43.8%
BI = 50.3%
NBI = 32.1%

Shoulder & Upper Arm: 15.4%; 20.7%; 5.8%
Forearm & Elbow: 15.1%; 19.4%; 7.5%
Wrist, Hand, Finger: 21.4%; 22.5%; 19.5%
Other & Unspecified: 16.6%; 21.8%; 7.2%

Lower Extremities
Overall = 40.4%
BI = 50.7%
NBI = 22.0%

Hip: 2.1%; 2.1%; 2.0%
Upper Leg & Thigh: 7.3%; 8.4%; 3.4%
Knees: 2.4%; 2.7%; 2.0%
Lower Leg & Ankle: 11.8%; 14.2%; 7.8%
Foot & toes: 6.2%; 7.1%; 4.7%
Other & Unspecified: 27.9%; 39.2%; 2.8%

Burns: 9.3% 11.6% 5.3%

Data Source: Joint Theater Trauma Registry (JTTR) 2002-OCT 2008

October 2008
# of Warriors with Injuries: Black-Overall %; Red – BI %; Blue- NBI %

54
Leadership and Distributed Actionable Information
Data Visualization at the Bedside
No double entry

DecisioHealth.com
I am a founder and on BoD
All data elements already exist in the EHR— but Hidden

- Real time – actionable
- Widely distributed
- Entire HC team sees the information and can act
- Red = Bad
- Green = good
- No one wants to be red

- Compliance with bundles of care increased
- AKI decreased
- Time to Antibiotics decreased
- Sepsis rate and mortality decreased
Dedicated 5-6 person research teams in Iraq and Afghanistan

70 IRB approved protocols……
  - Collected data on thousands of patients
  - Hundreds of papers and presentations at scientific meetings
  - Disseminated results and changed care
Research Team (Unhappy) on a Broke Down Convoy just Outside of Fallujah
Teams of People
Combat Support Hospital

1993

2003
Teams of people take care of patients
Summary

• The NAS report is really important
  - Thank you Don

• Rapid progress in trauma care occurs in war

• Issues identified on the battlefield can and **must** transition to civilian world

• We can improve injury outcomes with leadership, actionable information and a learning health care system
Thank You for this Opportunity