Advanced Resuscitative Care in TCCC

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Joint Trauma System Teleconference
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Disclaimers

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- No financial interests in items discussed
Bottom Line
Up Front

The new Advanced Resuscitative Care plan in Tactical Combat Casualty Care could prevent at least 40 out of every 100 potentially preventable deaths in US combat casualties, IF performed at or near the point of wounding.

* Based on data from the 2012 J Trauma paper by COL Brian Eastridge et al “Death on the Battlefield”
Potentially Preventable Prehospital Deaths in Combat Casualties

- Most combat fatalities (88% in the Eastridge study) die before they reach a hospital or a surgeon.

- Remarkable progress has been made in reducing preventable prehospital deaths by TCCC and through reducing casualty evacuation times.

- MOST OF THE REMAINING PREHOSPITAL DEATHS COULD BE PREVENTED BY THIS NEW CHANGE TO TCCC.
Battlefield Trauma Care: 2001

- Based on trauma courses NOT developed for combat
- **Medics taught NOT to use tourniquets**
- No hemostatic agents
- No junctional tourniquets
- Large volume crystalloid fluid resuscitation for shock
- Civil War-vintage technology for battlefield analgesia (IM morphine)
- SOF medics – IV cutdowns for difficult venous access
- No tactical context for care rendered
- 2 large bore IVs on all casualties with significant trauma
- No focus on prevention of trauma-related coagulopathy
- Heavy emphasis on endotracheal intubation
Battlefield Trauma Care:
2018

• Phased care in TCCC
• Aggressive use of tourniquets in CUF
• Combat Gauze as hemostatic agent
• Aggressive needle thoracostomy
• Sit up and lean forward airway positioning
• Extraglottic airways – i-gel
• Surgical airways for maxillofacial trauma
• Hypotensive resuscitation with blood products
• IVs only when needed/IO access if required
• PO meds, OTFC, ketamine as “Triple Option” for battlefield analgesia
• Hypothermia prevention; avoid NSAIDs
• Battlefield antibiotics
• Tranexamic acid – given ASAP when indicated
• Junctional Tourniquets/XStat
The Improvement In Casualty Survival

* The orange curve is the percentage of survival for critically injured casualties (ISS >25) for Afghanistan ... smoothed over time from October 2001 through December 2017.

Howard et al - JAMA Surgery 2019
• YES – evacuating urgent casualties to surgical care in 60 minutes or less helps save lives.
• BUT – not all critically injured casualties will live for 60 minutes without hemorrhage control and blood
The Goal

ZERO Preventable Deaths!

Thanks:
SFC (R)
Dom Greydanus
Preventable Prehospital Deaths in Combat Casualties

For 100 Preventable Combat Deaths (Eastridge 2012):

- 7 are due to airway obstruction
- 1 is due to tension pneumothorax
- 92 are due to hemorrhage
  - 12 are due to extremity hemorrhage
  - 18 are due to junctional hemorrhage
  - 62 are due to non-compressible torso hemorrhage
    - 22 are due to thoracic bleeding
      - Might be helped by whole blood resuscitation
  - 40 are due to abdominopelvic bleeding

* These 40 lives could be saved by ARC (whole blood resuscitation and Zone 1 REBOA – if these interventions are provided soon after wounding.
If We Can Just Get the Casualty to the Hospital Alive.....

- Stephen Ambrose – *Citizen Soldiers* – Normandy 1944
- But 13% of the fatalities in the Eastridge study were DOWs
Hemorrhagic Shock and Mortality

• Martin 2008 – 32% of deaths in Level 3 MTFs are due to hemorrhage (Military)

• Buehner 2017 – Hypotension on arrival at a Level 3 MTF = 23% mortality (Military)

• Harvin 2018 – Emergent trauma laparotomy + hypotension = 46% mortality (Civilian)

• Marsden 2018 - Emergent trauma laparotomy + hypotension = 26% mortality (Military)
Advanced Resuscitative Care in Tactical Combat Casualty Care: TCCC Guidelines Change 18-01
14 October 2018

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• Journal of Special Ops Medicine 2019
• THANKS to the ARC author team!
Whole Blood for Hemorrhagic Shock

- A proven lifesaver
- Prehospital whole blood now transitioning to the civilian sector
- No Golden Hour for internal hemorrhage - MINUTES MATTER!

- The overwhelming majority of US ground forces DO NOT HAVE whole blood at the point of injury!

Whole Blood - don’t go to war without it!
Among medically evacuated US military combat causalities in Afghanistan, blood product transfusion prehospital or within minutes of injury was associated with greater 24-hour and 30-day survival than delayed transfusion or no transfusion.”

Shackelford et al
JAMA 2017
“Regardless of conflict, early delivery of blood transfusion was associated with increased survival. Thus, timely treatment capability was paramount for casualty survival on the battlefield of Iraq, as it was in Afghanistan.”

Kotwal J Trauma 2018
Far-Forward Whole Blood: MINUTES MATTER

• COL Jennifer Gurney et al
• Paper pending
Far-Forward Whole Blood Options in Order of Preference

#1 FDA-Compliant cold-stored LTOWB

#2 LTOWB from a walking blood bank

#3 Untitered Type O whole blood from a walking blood bank

#4 Type-specific whole blood from a walking blood bank
Whole Blood - Indications

4. Indications for whole blood transfusion in ARC:

* Follow the JTS Damage Control and Whole Blood Transfusion Clinical Practice Guidelines (CPGs) except as follows:

* TCCC-specific considerations:
  - Casualty has known prior external hemorrhage (even if that hemorrhage is now controlled) or suspected noncompressible torso hemorrhage (NCTH)

    AND

  - Systolic Blood Pressure (SBP) is less than 90 mmHg

    OR

  - Point of Injury lactate is 4 mmol/L or greater
Cold-Stored Low-Titer Type O Whole Blood (LTOWB)

- The best option for far-forward blood.
- Identify Type O, Low-titer donors.
- Collect the blood in CONUS or closer to theater.
- Screened for pathogens (FDA compliant).
- Advocates: Cap, Holcomb, Jenkins, Spinella, Strandenes, THOR, AABB
- Blood can be moved far-forward in a long-duration or powered blood cooler.
• Fresh low-titer Type O whole blood is another option for far-forward whole blood.
• 75th Ranger Regiment “ROLO” program:
  – Type O, Low-Titer Anti-A, Anti-B antibodies
  – Donors pre-screened for type, titers, and infectious diseases
  – The donor pool is used to transfuse casualties in shock.
Whole Blood in TCCC in The 75th Ranger Regiment

“The Regiment has 11 cases of prehospital whole blood transfusions to date – all cold-stored WB units.”
Other Options for Forward Whole Blood

Fresh whole blood use by forward surgical teams in Afghanistan is associated with improved survival compared to component therapy without platelets


- Can also use untitered Type O whole blood from a walking blood bank
- Commonly done by forward surgical teams
- Risk of reaction due to incompatible ABO antibodies is very low

Nessen et al, Transfusion 2013
Other Options for Far-Forward Whole Blood

- MASCAL fm helo crash
- 15 August 2017
- 4 casualties transfused
- 16 units RBCs
- 10 FFP
- 54 units type-specific WB
- No casualty in shock given NS, LR, or Hextend

* ABO mismatch may cause fatal hemolytic reaction
What do you mean you don’t have a whole blood program!!
REBOA – MINUTES MATTER Here as Well

• A relatively new technology
• Can control abdominal and pelvic hemorrhage – the #1 remaining cause of potentially preventable death in combat casualties. Keeps blood from getting to the bleeding site.

• If you meet the TCCC criteria for REBOA, you are already well on your way to bleeding to death.

Zone 1 Balloon Occlusion of the Aorta
REBOA – But Isn’t It Potentially Dangerous?

• Yes – continuous occlusion of the aorta for 60 minutes or longer can cause sudden death when blood flow is resumed.
• BUT – 30 minutes occlusion is safe.

• AND – new research findings from the Army research laboratory at Madigan indicate that intermittent aortic occlusion can enable 100% survival out to 120 minutes even in the presence of an otherwise lethal vascular injury in the abdomen or pelvis.
• AND – an additional modification proposed by Col Todd Rasmussen at USUHS makes the procedure even safer.
### Case Details

<table>
<thead>
<tr>
<th>Case Details</th>
<th>Patient 1</th>
<th>Patient 2</th>
<th>Patient 3</th>
<th>Patient 4</th>
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<tbody>
<tr>
<td>Mechanism of injury</td>
<td>Gunshot</td>
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<td>Gunshot</td>
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<td>SBP before REBOA inflation</td>
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<td>70mmHg</td>
<td>50mmHg</td>
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<td>Means of femoral artery access</td>
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<td>Depth (cm)/intended zone</td>
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<td>Time to aortic occlusion</td>
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<td>SBP after REBOA inflation</td>
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<td>Duration of aortic occlusion</td>
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<td>Mesenteric bleeding source control</td>
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<td>REBOA provider</td>
<td>Surgeon</td>
<td>Emergency medicine</td>
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<td>Surgeon</td>
</tr>
</tbody>
</table>

*All 4 casualties survived to next level of care*
Recent advances in austere combat surgery: Use of aortic balloon occlusion as well as blood challenges by special operations medical forces in recent combat operations

David Marc Northern, MD, Justin D. Manley, MD, Regan Lyon, MD, Daniel Farber, MD, Benjamin J. Mitchell, MD, Kristopher J. Filak, MD, Jonathan Lundy, MD, Joe J. DuBose, MD, Todd E. Rasmussen, MD, and John B. Holcomb, MD, Pensacola, Florida

- 20 combat casualties treated with prehospital REBOA; mean SBP 71
- Large majority Zone 1; 19 of 20 successful; #20 balloon rupture
- Mean SBP increase on balloon inflation was 56 mmHg
- Mean balloon time was 21 minutes (range 7-34 min)
- No procedural complications – 7 done by EM physicians
- Also resuscitated with whole blood
- 100% survival to the next level of care
REBOA Indications in ARC

Per TCCC Change 18-01

- External hemorrhage controlled AND
- TXA given AND
- Pelvic binding done if indicated AND
- Electronic BP monitoring established AND
- Whole blood resuscitation initiated AND
- Still in shock (SBP < 90) after first unit of whole blood AND
- The casualty has penetrating or severe blunt force injury to the abdomen or pelvis and a positive FAST exam or is judged to be at high risk for NCTH or is noted to have difficult-to-control junctional hemorrhage. AND
- Intra-thoracic bleeding and cardiac tamponade have not been found on bilateral chest tube insertion and an EFAST exam.
“If new techniques and/or technologies can be developed to significantly prolong the duration of tolerable therapeutic REBOA, it may be utilized to limit ischemia reperfusion prior to definitive surgical care in the pre-hospital or prolonged field care scenario. We hypothesized that the development of alternative strategies involving intermittent aortic occlusion and restoration of flow based off simple bedside measurements may significantly extend the tolerable duration of zone 1 REBOA placement.”
Kuckelman 2018
Zone 1 REBOA + Survival

- Controls – 100% mortality (Mean time to death 15 min after hemorrhage initiated)

- 60 minute REBOA – 100% mortality (Mean 63 min – 3 min after balloon deflated)

- 120 minutes of intermittent (15 min inflation - then repeated 3 min deflation/10 min inflation) cycles of Zone 1 REBOA had 100% survival
Kuckelman 2018
The Rasmussen Modification

• Rather than follow the exact protocol used at Madigan for intermittent REBOA, Col Todd Rasmussen from USU proposed the following:

  After the initial 15 minute inflation period, when the balloon is deflated - *if the systolic blood pressure (SBP) remains above 80 mmHg, there is no need to re-inflate the balloon.*

• BUT - what if SBP *does* drop below 80 mmHg? That presents two options.
The Modified Madigan Technique: Option 1

• If the SBP drops below 80 mmHg after balloon deflation, **re-inflate** the balloon and continue resuscitation with whole blood.

• As long the periods of balloon deflation continue to be 3 minutes or more, use 10-minute inflation periods (as per Kuckelman) followed by another deflation up to a maximum of 120 minutes.
The Modified Madigan Technique: Option 2

• If the SBP drops below 80 mmHg immediately after balloon deflation, re-inflate the balloon and continue resuscitation with whole blood.

• If the casualty does not maintain an SBP of 80 mmHg or higher for at least 3 minutes of balloon deflation, then use a maximum of 30 minutes total balloon inflation time.
Zone 1 vs Zone 3
REBOA: Hemodynamics

Location is everything: The hemodynamic effects of REBOA in Zone 1 versus Zone 3 of the aorta

Emily M. Tibbits, MD, Guillaume L. Hoareau, DVM, PhD, Meryl A. Simon, MD, Anders J. Davidson, MD, Erik S. DeSoucy, DO, E. Robert Faulconer, MBBS, Joseph J. DuBose, MD, Lucas P. Neff, MD, J. Kevin Grayson, DVM, PhD, Timothy K. Williams, MD, and M. Austin Johnson, MD, PhD, Sacramento, California

• CONCLUSIONS: In our swine model of hemorrhagic shock, Zone 3 REBOA provided minimal proximal hemodynamic support when compared with Zone 1 REBOA, albeit with less ischemic burden and instability upon reperfusion. In cases of impending hemodynamic collapse, Zone 1 REBOA placement may be more efficacious regardless of injury pattern, whereas Zone 3 should be reserved only for relatively stable patients with ongoing distal hemorrhage.
Early Common Femoral Artery Access!

- Over 4000 uses of REBOA have taught that early common femoral artery (CFA) access is a critical first step
- Allows continuous arterial pressure monitoring
- Technically much easier to do early vs late
- Early CFA access does not mandate REBOA catheter placement
The Biggest Challenge in ARC

• Getting specially trained and equipped teams with an ARC capability as close as possible to the point of wounding

• **Minutes Matter!**

• Options:
  - Purposed advanced trauma care teams
    - Casualty Collection Point teams
    - Battalion Aid Station teams
    - Loitering insertion helicopter
    - Advanced capability TACEVAC platforms
    - Others?
• ARC is **NOT** envisioned as a single combat medic working out of an aid bag.

• Too complex; too much equipment

• ARC requires a specially trained and equipped TEAM. This team would not require (or replace) a surgeon, but may serve to keep the casualty alive for several hours until he or she reaches a surgeon for definitive care.
What ARC IS NOT

• Advanced Resuscitative Care is also NOT Prolonged Field Care.

• There is no representation intended in this change that ARC can reliably keep a critically injured casualty who has NCTH alive for 72 hours, which is the time frame used as a target for PFC. Rapid transport to surgical care is essential for good outcomes in casualties with NCTH and shock.
Tactical Combat Casualty Care: Leadership Lessons Learned

THOR 2016

Frank Butler, MD
20 June 2016
TCCC Lessons Learned

2. It doesn’t matter how good the plan is – if nobody’s using it.

Are there units in the US military using ARC at present?
Implementing ARC

- Joint Special Operations Command – Oct 2018
- 160th Special Operations Aviation Regiment – Nov 2017
- USASOC SORT Teams – Fall 2018
- USMC FRSS/STP units – March 2019
ARC in the 160th SOAR

Photo courtesy LTC Ted Redman
On 25 March 2019, Senior Medical Leaders at the USMC MEF and MARFOR level unanimously voted to adopt and implement Advanced Resuscitative Care. An Urgent UNS submission is being prepared to implement REBOA for USMC FRSS and STP units and whole blood for all USMC combat units.
Training for ARC: The RAPToR Course

- Dr. Zaffir Qassim  
  443.562.6205
- Sept 9-10 in Houston
- “Designed to train ARC”
- Whole blood administration
- REBOA at point of injury.
- Training on both simulator and cadaver models
- Cutdown training
- Faculty: Qassim, Holcomb, Dubose, Fisher, etc
- Open to military and civilians
- Physicians of all specialties
- Possible NAEMSP affiliation under discussion
ARC – The Long View

• This change to TCCC is a first step into ARC.

• Anticipate continued advances in whole blood availability.

• Also - anticipate increases in the time that hemorrhage can be controlled with Zone 1 REBOA based on further advances in intermittent and partial REBOA techniques.
ARC – The Long View

• The true limits of how long a casualty can be kept alive with intermittent Zone 1 REBOA have not yet been defined

• RAPID delivery of casualties to definitive surgical control remains the objective!!!

• BUT intermittent REBOA may have the potential to extend the survivability of these patients beyond the “Golden Hour”
  • Golden Two Hours? Longer?
ARC Research Priorities
DARPA - 9 April 2019

• ARC Rapid Fielding Initiative
• Optimize prehospital Zone 1 REBOA through the use of partial or intermittent occlusion techniques
• Develop an automated, feedback-based balloon volume controller that would offer the potential to optimize the control of aortic blood pressure above and below the balloon based on the casualty’s bleeding rate and his or her response to whole blood resuscitation (2 MRMC efforts ongoing)
• Improved techniques for Common Femoral Artery access
• Optimize the use of calcium and bicarbonate during REBOA balloon deflation
• Optimized REBOA trainer
Questions?/Discussion