Military Contributions to Trauma

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Objectives:
• Identify the role of military conflicts on the research and advancement of trauma triage and care
• Review military trauma care in Afghanistan / Iraq / other conflicts for aspects that may influence civilian practice at home
• Discuss clinical practice guidelines which have emerged from military trauma care during times of conflict
Medical Lessons From Recent Military Operations

Bill Beninati
Intermountain Life Flight
6 September 2014

Appreciation to Dr. Warren Dorlac
University of Cincinnati
Scenario

- SWAT Team serves high-risk warrant in small Utah town
- Officer sustains gunshot wounds in firefight
  - Delayed rescue due to active shooting
- Active bleeding -- large amount of blood at scene
  - Left groin and right arm above elbow – arterial bleeding
  - Confused, BP 60/-
Scenario

- Utah resident returns from trip to West Africa
- Develops severe febrile illness at his home in a rural county
- EMS called – find him confused, temp 104.5, vomiting blood
Military Deployed Care System

• Characteristics
  – Geographically distributed/clinically integrated
  – Flow-through with continuous enroute care
  – Modular
  – Rapidly-deployable
  – Performance improvement
Flow-through Care System

Level 1

Forward surgical teams
Level 2

Combat Support Hosp
Fleet Hosp
Level 3

AF Theater Hospital
Level 3

Definitive Care
Level 4/5

CASEVAC

TACTICAL EVAC

STRATEGIC EVAC
Levels of Care

- Self-aid/buddy care
- Combat Medic/Corpsman
- MEDEVAC
- Field/Theater Hospital
- Critical Care Air Transport
- Restorative/Reconstructive Care
East Baghdad – Beirut Square
Case

• 38 y/o male on dismounted patrol in East Baghdad
  – Responded to recent bomb blast
• “Punched” in head
  – Subdued perpetrator
  – Noticed pewter-colored object in peripheral vision
Some Areas of Progress in Casualty Care

- System integration
- Blood product resuscitation
- Tourniquets
- Hemostatic dressings
- Advanced prosthetics and rehabilitation
- Modular/deployable surgical resuscitation
- Sustained/mass critical care in the air
Focus on

• Integrated System of Care
  – *Deployable trauma system*
  – *Critical care transport*

• Hemostatic resuscitation
  – Stop hemorrhage
  – Resuscitation
Battlefield Trauma Care: Then (2001) – “Civilian-Based Care”

- Based on trauma courses NOT developed for combat
- No emphasis for combining good medicine with good tactics
- Medics taught NOT to use tourniquets
- No hemostatic agents
- Large volume crystalloid fluid resuscitation for shock
- Two large bore IVs on all casualties with significant trauma
- No focus on prevention of trauma-related coagulopathy
- 1867 vintage technology for battlefield analgesia (intramuscular morphine)
- Aggressive spinal immobilization for all neck and back trauma
- No specific first responder resuscitation guidance for Traumatic Brain Injury
Evac 1 - FOB Shield
Evac 2 – Green Zone
Ibn Sina Hospital
EVAC 3 – Air Force Theater Hospital
Balad, Iraq

[Map of Iraq with Balad marked]
MEDEVAC Environment
Air Force Theater Hospital – Balad, Iraq
JTS Directorate
Operational Cycle
Continuous Communication

DSN

VTC

INK

Joint Patient Tracking Application

TMDS and Encrypted email
System wide Military Teleconference
Trauma Case Reviews and Performance Improvement

- **Weekly Clinical VTC** (video and audio teleconference)
  - Deployed JTTS Trauma Director and Program Manager
  - Afghanistan Role IIb & III, CCATT, Medevac
  - NATO Role III, CCATT and Medevac
  - Trauma coordinators at each Role III
  - Role IV facility at LRMC
  - Role V facilities at Walter Reed and San Antonio
  - VA Polytrauma Centers

- **System Wide VTC** (monthly)
JTS & CCAT Clinical Practice Guidelines

The Joint Trauma System (JTS) provides the following listed Clinical Practice Guidelines. Opposing viewpoints are encouraged in the interest of advancing medical treatment.

What were the Causes of Preventable Death?

91% (n=888)

- Extremity [119/888] = 13.5%
- Junctional [171/888] = 19.2%
- Truncal [598/888] = 67.3%

Lethal Triad

- **Hypothermia** – many contributors
  - Enzyme clotting factors decreas. activity 10%/1 C° drop

- **Acidosis**
  - Reduced blood clotting

- **Coagulopathy**
  - Blood loss, dilution, consumption
  - Worsens acidosis
A Modified Primary Survey

- Massive hemorrhage management
- Airway control with C-spine stabilization
- Respiration
- Circulation
- Hypothermia

Tactical Combat Casualty Care
Combat Application Tourniquet (C-A-T®)
Survival With Emergency Tourniquet Use to Stop Bleeding in Major Limb Trauma

COL John F. Kragh, Jr., MC, USA,* Thomas J. Walters, PhD,* David G. Baer, PhD,* MAJ Charles J. Fox, MC, USA,† Charles E. Wade, PhD,* Jose Salinas, PhD,* and COL John B. Holcomb, MC, USA*
Does is matter if you use a tourniquet?

Patients with no tourniquet use died faster and more often. p<0.001
Location of Tourniquet Placement

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

Halved mortality, a +16% improvement in survival, p=0.05
Tourniquet – Practical Points

• Tourniquet before shock onset saves more lives than after shock
  – use them before extraction or transport.

• Use scientifically designed, laboratory tested, and clinically validated tourniquets.

• Of tourniquets evaluated in this work, the CAT is the best prehospital tourniquet

Kragh J Trauma 2008
Tourniquet – Practical Points

• Tourniquet education, training, and doctrine
• The goal of emergency tourniquet use is to stop bleeding and stop the distal pulse.
• Avoid tourniquet use over thigh near the knee – ineffective.
• Side-by-side use if needed to stop bleeding
Tourniquet – Practical Points

• Tourniquets work on the forearm or leg
• Clothing near tourniquet should be removed at the first opportunity to detect all wounds.
• Materials under a tourniquet should be removed at the first opportunity to avoid looseness.
Tourniquets Work!
Hemostatic Dressings

- Dressing impregnated with a substance to stimulate clot formation
- Z-fold onto bleeding site
- Apply direct pressure 2-3 minutes
- Stops major arterial bleeding
Safety of Two Hemostatic Agents

Figure 5. Composite micrographs of carotid arteries treated with KX (A), CG (B), or WS (C and D). Damaged endothelium, intraluminal blood clots, WS residue, and necrosis of smooth muscle cells are evident in the WS-treated vessels.
Combat Ready Clamp™ (CRoC™)

- Applied midpoint between anterior superior iliac spine and the pubic tubercle.
- 1.5 pounds
- Collapsible
- Easy to apply, remove and adjust
- $445
Combat Ready Clamp™ (CRoC™)

- FDA approved for control of groin hemorrhage
- Adopted by CoTCCC August 2011
- Fielded by U.S. Special Operations Forces
Junctional Emergency Treatment Tool – JETT™

- FDA approved
- 1.9 pounds
- Low profile
- Bilateral
- $359.99
SAM® Junctional Tourniquet

- FDA approved
  - Groin
  - Pelvic stabilization
  - Axilla
- 1.1 pounds
- Easily applied
- $260.00
Balanced/Hypotensive and Hemostatic Resuscitation

- Target Blood Pressure 80-90 mm Hg
- Limit crystalloids
- Early use of blood products
  - Red Cell: Plasma: Platelets in 1:1:1 ratio
- Active warming
- Mortality can drop from 60% to 20%
- Use of “young blood”
Crystalloid Resuscitation

- No hemostatic effect
- pH of fluids
  - NS – 4-6, LR – 5.5-7
  - Effect on organ function
- Pathologic neutrophil activation
  - Severe with LR – not with d-LR
  - Less with hypertonic saline
- Association with multi-compartment syndrome and pulmonary edema
Hypotensive Resuscitation (Pre-hospital)

The New England Journal of Medicine

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IMMEDIATE VERSUS DELAYED FLUID RESUSCITATION FOR HYPOTENSIVE PATIENTS WITH PENETRATING TORSO INJURIES

William H. Bickell, M.D., Matthew J. Wall, Jr., M.D., Paul E. Pepe, M.D.,
R. Russell Martin, M.D., Victoria F. Ginger, M.S.N., Mary K. Allen, B.A.,
and Kenneth L. Mattox, M.D.

- Randomized trial with 598 subjects
- Delayed (hypotensive) vs. immediate resuscitation improved (70% vs 62%, \( p=0.04 \))
- Don’t “pop the clot”, dilute clotting factors, etc
Prospective Observational Multicenter Major Trauma Transfusion (PROMMTT) study  
Callcut et al, J Trauma Acute Care Surg Jan 2013

- 1,245 patients prospectively enrolled with 297 receiving a Massive Transfusion
- Massive Transfusion Score (1 point each)
- Initial emergency department value:
  - International normalized ratio [INR] > 1.5
  - Systolic blood pressure < 90 mmHg
  - Hemoglobin < 11 g/dL
  - Base deficit > 6
  - Positive result for FAST (+)
  - Heart rate > 120 bpm
  - Penetrating injury mechanism (+)
Prospective Observational Multicenter Major Trauma Transfusion (PROMMTT) study
Callcut et al, J Trauma Acute Care Surg Jan 2013

- Data available for all triggers in 66%
- INR the most predictive (adjusted OR, 2.5; 95% confidence interval, 1.7-3.7).
- If any two triggers were present (MTS ≥ 2), sensitivity for predicting MT was 85%.
- MT present in 33% with MTS of ≥ 2
- MT present in 11% with MTS of < 2 (OR, 3.9; 95% confidence interval, 2.6-5.8; p < 0.0005).
PROPPR - Pragmatic, Randomized Optimal Platelet and Plasma Ratios

- Study completed
- Stay tuned for results . . .
Tranexamic Acid

- Anti-fibrinolytic agent
  - Stops breakdown of clots
- Room temperature storage
- Administer within 3 hours
- Active/Severe Bleeding
Tranexamic Acid Survival

Figure 3. Kaplan-Meier survival curve of the overall cohort, including patients receiving tranexamic acid (TXA) vs no TXA. $P=0.006$, Mantel-Cox log-rank test.
Tranexamic Acid

• CRASH-2 – Shakur Lancet 2010
  – Reduces mortality – use within 3 hours of injury

• MATTERS – Morrison Arch Surg 2012
  – Improves survival in massive transfusion

• Israeli Defense Force – Nadler J Trauma 2014
  – Practical to use of point of injury
Aortic Balloon Occlusion

Carl Hughes *Surgery* 1954
UT Houston and U Maryland experience

- December 2012 to March 2013
- Blunt (4), Penetrating (2)
- Zone I (3), Zone III (3)
- Percutaneous (3), Cutdown (3)
- No REBOA-related complications and no hemorrhage-related mortality

Brenner et al, J trauma and acute care surgery 2013; 75(3):506-511
A clinical series of resuscitative endovascular balloon occlusion of the aorta for hemorrhage control and resuscitation

Megan L. Brenner, MD, Laura J. Moore, MD, Joseph J. DuBose, MD, George H. Tyson, MD, Michelle K. McNutt, MD, Rondel P. Albarado, MD, John B. Holcomb, MD, Thomas M. Scalea, MD, and Todd E. Rasmussen, MD

Figure 2. CT image showing REBOA in Zone 1 of aorta with no distal flow.
Technique REBOA
(resuscitative endovascular balloon occlusion of the aorta)

• Arterial access
  – Percutaneous femoral artery, 8 Fr

• Balloon selection & positioning
  – Fluoroscopic guidance
  – Long wire
  – Coda Balloon; Cook Medical Inc.

• Balloon inflation
  – 30 ml of 50:50 (contrast:saline)
  – Inflate until edges change from convex to parallel
  – Secure balloon
Technique REBOA
(resuscitative endovascular balloon occlusion of the aorta)

- Balloon deflation
  - Perform in coordination with surgical/anesthesia team
- Sheath removal
  - Remove Balloon & wire
  - Flush sheath with heparinized saline (1-10U/ml)
  - Obtain proximal and distal control
  - Remove sheath via surgical exposure
  - Surgical repair arteriotomy
Rasmussen: Innovation/Technology Transfer

Technology Opportunity

Controlling Non-compressible Torso Bleeding

The University of Michigan and the U.S. Air Force seek to commercialize through patent licensing an aortic occlusion system for controlling non-compressible torso hemorrhaging.
A novel fluoroscopy-free, resuscitative endovascular aortic balloon occlusion system in a model of hemorrhagic shock

Daniel J. Scott, MD, Jonathan L. Eliason, MD, Carole Villamaria, MD, Jonathan J. Morrison, MRCS, Robert Houston, IV, MD, Jerry R. Spencer, BS, and Todd E. Rasmussen, MD, Ann Arbor, Michigan
Battlefield Trauma Care: Now (2014) – “Tactical Combat Casualty Care-Based Concepts”

- Phased “tactical” care in Tactical Combat Casualty Care
- Aggressive use of tourniquets
- Combat Gauze as a hemostatic agent
- Aggressive needle chest decompression
- Improved non-surgical airway interventions
- Surgical airways as needed for facial trauma
- IVs only when needed, and intraosseous access if required
- Permissive hypotensive resuscitation with Hextend (6% Hetastarch, balanced)
- Much improved analgesia (IV morphine, Oral transmucosal fentanyl citrate, ketamine)
- Battlefield antibiotics; hypothermia prevention
- First responder resuscitation guidance for traumatic brain injury
- Tranexamic acid for torso hemorrhage
- Junctional hemorrhage devices
- Avoid Non Steroidal Anti Inflammatory Drugs (acetylsalicylic acid, ibuprofen)

Flow-through Care System

System functions as:
- 1 hospital
- 1 medical staff
- 1 set of practice guidelines
- Capacity measured by flow rate not beds

Level 1
Forward surgical teams
Level 2
CASEVAC
TACTICAL EVAC
Combat Support Hosp
Fleet Hosp
Level 3
AF Theater Hospital
Level 3
Definitive Care
Level 4/5
STRATEGIC EVAC
Case – Flow-through Hospital

- CASF
  - Contingency Aeromedical Staging Facility
  - Patient care/preparation
    - Doctors/Nurses/Techs
  - Interface with Command and Control
- Theater Hospital
  - Resuscitation
  - Surgical stabilization
  - Pre-flight preparation
Case – Head CT
Case – Proximal vascular control
Case - Craniotomy
Case – Angiogram
Evacuation for neurovascular intervention

C-17: Balad to Bethesda = 13 Hrs
Critical Care Air Transport Teams: Provide ICU Care in the Air

- Deliver High-Tech Medicine in Combat Conditions
  - ICU level physician, Respiratory Technician & Nurse

- High Demand Team
  - 50 Total Force Teams
CCATT Transport: A Challenging Environment

- Long Distances
  - Baghdad to Germany 2,500 Miles
  - Germany to Wash, DC 4,000 Miles
- Cargo Aircraft: Austere Conditions
  - Temperature, Noise, Vibration, Lighting, Power
- “Stabilized” Patients: Injuries in Evolution
  - Patients are Hemodynamically Labile
  - Presence of Multi-system Trauma
Care and Documentation Challenge

C-130 Night TACEVAC

Tactical Maneuvering
Case – Outcome

Return to active duty and jump status!
Summary

• Hemostatic resuscitation saves lives
  – Do – place high priority on stopping exsanguinating hemorrhage
    • Tourniquets
    • Hemostatic dressings
  – Don’t – over-resuscitate with crystalloids
    • Blood products, tranexamic acid

• System-wide performance improvement works
  – Analysis drives change
  – Communicate across the system
DISCUSSION

• Expand case reviews in Utah to include more members of the care team?
• Multi-agency Performance improvement?
• Other?