Modern Military Trauma Care: Lessons Learned from 16 Years of Conflict

Joe DuBose MD, FACS FCCM

Associate Professor of Surgery
Uniformed Services University of the Health Sciences

Lt Col USAF MC
Director
Baltimore Center for the Sustainment of Trauma and Readiness Skills
JAMES C EDGE
CAPT
US MARINE CORPS
DEC 3 1973
APR 14 2005
PURPLE HEART
OPERATION
IRAQI FREEDOM
CARLOS BROWN IS A HERO

I've known him since the seventh grade, when he was awkward, obnoxious, and unpopular with the girls (okay, we both were). He always said he was going to be a surgeon, and when the Navy sent him to Iraq, I flew there to see him. I watched him work around the clock to save soldiers and civilians. Americans and Iraqis—even insurgents. Through it all, his mission never changed: Ignore the politicians, take care of the patients, kick butt at PlayStation, and get home safely.

by JOHN SPONG

NO MATTER WHAT HE SAYS
The only one to benefit from war is a young surgeon. Hippocrates
Ten years: Terror and war

**Sept. 11, 2001**

Nineteen hijackers aboard four airliners attack the Twin Towers in New York and the Pentagon.

The passengers on Flight 93 fight the hijackers for control of the plane, which crashes going down near Shanksville, Pa.

Nearly 3,000 people are killed in the attacks.

**Oct. 7, 2001**

U.S. war in Afghanistan “Operation Enduring Freedom” begins

**Oct. 9, 2001**

Anthrax letters are mailed to U.S. Sens. Tom Daschle and Patrick Leahy

**Oct. 26, 2001**

USA Patriot Act becomes law

**Nov. 22, 2001**

Shoe bomber Richard Reid attempts to light explosives contained in his shoe while on board a transoceanic flight

**Dec. 11, 2001**

Color-coded terror threat level system instituted

**Jan. 11, 2002**

First detainees arrive at Guantanamo

**Nov. 25, 2002**

Department of Homeland Security formed

**Feb. 5, 2003**

Colin Powell addresses the United Nations, making the United States’ case for war against Iraq

**March 1, 2003**

Suspected mastermind of the September 11 attacks, Khalid Sheikh Mohammed, is arrested in Pakistan

**March 13, 2003**

Saddam Hussein is captured in Tikrit

**March 20, 2003**

U.S. war in Iraq “Operation Iraqi Freedom” begins

**April 6, 2004**

Images of torture at Abu Ghraib prison are revealed

**Aug. 14, 2004**

Alleged mastermind of the 2002 Bali bombings, Indonesian Abdurrafaqan Isamuddin, is arrested in Thailand

**Nov. 23, 2004**

President Bush elected to second term

**Oct. 7, 2004**

“Iraq did not have the weapons that our intelligence believed were there.” — President Bush

**July 7, 2005**

London bombings on public transport kill 57

**Sources:**
- CNN; Associated Press
- McClatchy Tribune
- Washington Post; Fox News
- Agence France-Presse; Los Angeles Times; New York Times
- Staff research
How the Army cares for your boy

IF HE IS WOUNDED

If he is wounded... these are the words that run through your mind as you read the headlines... the thought that often steals out of the darkness as you lie awake wondering, hoping.

If he is wounded... Yes, you must face that possibility. But face it realistically. Face it with faith.

The U.S. Army Medical Department is the best trained, best equipped in the world. Within minutes, often seconds, after a fighter falls, courageous and expert Army medical soldiers are at his side, easing his pain, giving him intelligent emergency treatment.

Then, he is rushed back where skilful doctors and surgeons speed him on the road to recovery...

A tribute to the members of the U.S. ARMY MEDICAL DEPT.

FROM FRONT LINE TO RECOVERY THE ARMY SPEEDS ITS WOUNDED

Johnson & Johnson

In the world's largest maker of surgical dressings
Point of Injury to Definitive Care

**Surgical Capability**

- **BAS** Level 1
- **CASEVAC** 1 Hour
- **Forward Surgical Teams** Level 2
- **Intratheater EVAC** 24 Hours
- **Intertheater EVAC** 48-72 Hours
- **CSH, EMF, Theater Hospital** Level 3
- **CONUS/OCONUS MTF** Level 4/5

---

**FROM FRONT LINE TO RECOVERY THE ARMY SPEEDS ITS WOUNDED**

- Heroic litter-bearers rush to Battalion Aid Stations
- Sulfa drugs prevent infection. Plasma reduces shock
- Jeeps hurry stretchers to Collecting Stations, Ambulances
- Planes near Clearing Stations fly to Evacuation Hospitals
- Ships and planes homeward bound to General Hospitals
A Story of Military – Civilian Exchange
Lessons learned from 16 years of combat casualty care

- **Prehospital care**
  - Tourniquet utilization
  - Hemostatics
  - Needle thoracostomy
  - Hypothermia prevention

- **Hospital Care**
  - Resuscitation / Transfusion
  - Vascular Injury care / Shunting
  - Damage Control Surgery

- **En route Care**
  - Critical Care Air Transport (CCAT)

- **Organization and Structure**
  - Joint Trauma System
Early lessons learned in GWOT (2001-2005)

• Complex mechanisms and injuries

• Time lag to definitive care

• Need to optimize coordination of care
Opportunity to improve organization

Point of Injury
Major trauma

UNDER-triage

MAJOR

Evac#1

FSMC

Evac #2

FST

Avoidable risk
THEATER EVALUATION

• OEF/OIF
  • 2003 Army SG-Directed Evaluation

• Findings
  • Unorganized delivery of trauma care on the battlefield in the AOR
  • Medical records not reliably following casualties to next care level

• Solution: Creation of a Joint Theater Trauma System Team
**JTTS Mission**

- Improve organization and delivery of trauma care
- Improve communication among clinicians in the evacuation chain to ensure continuity of care and access to data
- Populate the Joint Theater Trauma Registry (JTTR) to evaluate care provided, document outcomes, and facilitate conduct of formal research
- Evaluate and recommend new equipment or medical supplies for use in theater to improve efficiency, reduce cost, improve outcomes
- Facilitate medical performance improvement to promote real-time, data-driven clinical process improvements and improved outcomes
**Cause of Injuries**

**Battle**
- Munitions/Explosive Devices: 65%
- Firearms: 17%
- All Other: 18%

**Non-Battle**
- MVC: 26%
- Falls: 19%
- Machinery: 11%
- Overexertion: 10%
- Struck By / Against: 7%
- All Other: 27%

**Source:** Joint Theater Trauma Registry (JTTR), September 2001 - February 2008
Casualties Requiring Blood

Patients

Jun 06 | Sep 06 | Dec 06 | Mar 07 | Jun 07 | Sep 07 | Dec 07 | Mar 08

Right Patient, Right Place, Right Time, Right Care
### OIF & OEF Battle Injuries by Body Region

**Upper Extremities 22%**
- Shoulder/Upper Arm: 6%
- Forearm/Elbow: 6%
- Wrist/Hand/Fingers: 7%
- Other: 3%

**Spine/Back 3%**
- 3%

**Torso 15%**
- Chest: 5%
- Abdomen: 6%
- Pelvis/Urogenital: 3%
- Trunk/Back/Buttock: 1%

**Head/Neck 27%**
- Face: 7%
- Eye: 3%
- Head/Neck: 2%
- Head/Neck Unspec: 3%

**Lower Extremities 31%**
- Hip/Upper Leg/Thigh: 5%
- Knee/Lower Leg/Ankle: 9%
- Foot/Toes: 5%
- Other: 12%

**Other 2%**

**Brain Injury (TBI) 12%**

Source: JTTR September 2001 - February 2008
JTTS – The Need: The Golden time frame

![Graph showing combat deaths over time](chart)

- **Time (from Wounding):** Immediate, <5 min, 30 min, 2 hr, 6 hr, 1 d, 1 wk, >1 wk
- **Combat Deaths (% of Total):**
  - KIA: Immediate > 30 min > 2 hr
  - DOW: Immediate > <5 min > 30 min > 2 hr > 6 hr > 1 d > 1 wk > >1 wk
Military Evolution – Topical Hemostatics

4 yard x 3” non woven gauze Kaolin coated

Individual First Aid Kit (IFAK)
Combat Gauze

• Kheirabadi BS, et al. - J Trauma, 2009
  • Porcine arterial hemorrhage model
    • Hemcon
    • Celox-D
    • Trauma-Stat
    • Combat Gauze
    • Placebo gauze

• CG superior to all comparisons
Combat Gauze in Clinical Action

- Ran Y, et al. – Prehospital Disaster Med, 2010

- Experience during Operation Cast Lead
  - ALS providers
  - 14 uses of CG to different sites
  - 93% blast or GSW
  - Success rate 79% (11/14)
  - No complications or adverse events
“We saw 1 tourniquet per 8h ED shift, that is, in 8% of the casualties admitted.”

Dr. John Kragh, March 2007, Iraq Protocol 06-10:
232 patients, 309 limbs, 428 tourniquets in 1 tour
Historical Problems with tourniquets

- Limited available tourniquet science
- Outdated user knowledge
- Inadequate device designs
- No doctrine
- Little or no training
- Little experience
- Rare clinical research

All the essentials were inadequately addressed
Fixing the problem: Tourniquets Tested by IUSA ISR

A. The Combat Application Tourniquet (CAT)
B. The Special Operations Forces Tactical Tourniquet (SOFTT)
C. The Emergency & Military Tourniquet (EMT)
D. Self-Applied Tourniquet System (SATS)
E. The One Handed Tourniquet (H-Dyne)
F. Mechanical Advantage Tourniquet (MAT)
G. The Last Resort Tourniquet (LRT)
Combat Application Tourniquet (CAT)
January 2007

640,000 CAT tourniquets sold to:

- US Army, Navy, Marines, Reserves, SOF
- Canadian Forces
- Australian Forces
- British Royal Army
- Iraqi Defense Forces
- FBI
Military Tourniquet use

  - 428 tourniquets, 232 patients
  - Transient nerve palsies – 1.7%
  - No association between tourniquet time and morbidity
  - No amputations solely from tourniquet use
Military Tourniquet use


• Tourniquet placement survival
  • Overall = 87%
  • Without shock = 90%
  • After onset of shock = 10%

• Location of placement and mortality
  • Pre-hospital = 11%
  • In ED = 24%

• Indication present but tourniquet not utilized
  • (5 casualties) = No survivors
Keys to Tourniquet Use on the Battlefield

• **BEFORE** shock onset: better survival
  – Tourniquet prevents shock onset

• **Use tourniquet as soon as it is indicated**
  – Before extraction and transport
  – Speed is associated with survival

• “C-A-B”
  – Circulation, then Airway and Breathing
Why Everyone Should Be Trained in Military First Aid

A practical approach to making mass shootings less deadly
If we can teach these folks....
Why can’t we teach these folks....
Las Vegas Mass Shooting – 2017
58 killed; more than 500 injured
The 2017 Vegas example....

• 10 minutes of active shooting

• Emergency responders
  • Initially confused about nature and even location of incident

• Some estimates say that EMT’s didn’t reach the actual concert grounds until 30 MINUTES after shooting took place
Who was available to respond?

- Of 595 injured, only 200 were transported ambulance
- Delivered in commandeered pickup trucks, private cars, taxis and on foot
Who responded?

• Some concertgoers were off-duty medical professionals

• “We had people who were shot holding pressure on other peoples wounds” - local EMT as quoted by New York Times
The only thing more tragic than a death from bleeding... IS A DEATH THAT COULD HAVE BEEN PREVENTED.
What is “life-threatening” bleeding?

- Blood that is spurting out of the wound.
- Blood that won’t stop coming out of the wound.
- Blood that is pooling on the ground.
- Clothing that is soaked with blood.
Massive Transfusions
Defined as ≥ 10 units PRBCs in 24 hours

(N=368)

1 Year’s Data: Rolling 12 Months

Number of Admissions

Oct-13, Nov-13, Dec-13, Jan-14, Feb-14, Mar-14, Apr-14, May-14, Jun-14, Jul-14, Aug-14, Sep-14

US Mil
NATO
Others
Dilution

- Traditional teaching suggested that dilution is not commonly an issue until over one blood volume (10 to 12 units PRBC’s) has been given
The Ratio of Blood Products Transfused Affects Mortality in Patients Receiving Massive Transfusions at a Combat Support Hospital

Matthew A. Borgman, MD, Philip C. Spinella, MD, Jeremy G. Perkins, MD, Kurt W. Grathwohl, MD, Thomas Repine, MD, Alec C. Beekley, MD, James Sebesta, MD, Donald Jenkins, MD, Charles E. Wade, PhD, and John B. Holcomb, MD


RATIO : 2007
Damage Control Resuscitation

Mortality by Plasma : RBC Ratio
n = 252


Civilian results

- Holcomb et al. – J Trauma, 2011

- 22 Level 1 Trauma Centers
  - 12 months
  - N = 2,312 patients requiring transfusion
  - N = 643 Massive transfusions

- Lower ratio practices associated with:
  - Decreased truncal hemorrhage as cause of death
  - Overall 30 day survival
Causes of dilution after trauma

- Movement of interstitial fluid into the intravascular space with reduced BP
- Administration of resuscitation fluids
- Administration of IV fluids as carriers for drugs
- Administration of blood components
Reality: Dilution is inevitable when giving blood products

- Whole blood 500 mL
  - Hct 38%–50%
  - Plts 150 K–400 K
  - Plasma coagulation factors = 100%

Thus: 1 U PRBC + 1 U Plts + 1 U FFP

660 mL with Hct 29%,
Plts 88 K/µL
Coagulation activity 65%.

- Components
  - 1 U PRBC = 335 mL with Hct 55%
  - 1 U Plts = 50 mL with 5.5 x 10^{10} Plts
  - 1 U plasma = 275 mL with 80% coagulation activity
Fresh Whole Blood

- Potential benefits
  - Warm
  - Appropriate ratios present
  - Fresh = No age-related degradation

- Risks higher
  - Mismatch
    - pre-screened donors preferred
Military Experience – Whole blood utilization

- Spinella PC, et al.
  - World J Surg - 2008

- 87 patients
  - Coalition soldiers
  - Foreign nationals
  - Enemy combatants

- 545 units FWB
WBT Military Experience

• Spinella PC, et al. – J Trauma, 2009
  • Retrospective study
  • Combat casualties receiving at least 1 u PRBC
    • N = 354
    • 100 received WBT; 254 component therapy

• WBT group had significantly higher 24h and 30 survival

• Multivariate logistic regression analysis
  – WBT and volume of WBT transfused independently associated with improved 30 day survival
Civilian Whole Blood Utilization?

• Barriers exist

• Under investigation

• Some centers presently utilizing
  • UT Houston – *Anesth Analg, 2018 May 15*

• Potential value for mass casualty incidents? Rural trauma?
Death on the Battlefield
Implications for Prevention, Training, and Medical Care

US Army Institute of Surgical Research
and
Armed Forces Medical Examiner Service

Brian Eastridge
COL, MC, USA
Trauma Consultant
US Army Surgeon General

2012
Battlefield Acute Lethality
Potentially Survivable n=1,075
Potentially survivable combat deaths due to hemorrhage (n=984)
It’s a civilian problem as well....

NTDB Study:

Mortality from hemorrhage at non-compressible sites = 44.6%
Resuscitative Thoracotomy for Trauma

- The only hope for a patient in / nearing extremis despite resuscitation after NCTH?
- Indications?
- Threshold for use?
Innovations in EDT – last 40 years
Resuscitative Endovascular Occlusion of the Aorta (REBOA)
Basic Concept

- Preservation perfusion to brain / heart
- Occlusion of arterial flow above bleeding source
• What can we translate from modern approach to ruptured abdominal aortic aneurysms?
10 Years of Emergency Endovascular Aneurysm Repair for Ruptured Abdominal Aortoiliac Aneurysms: Lessons Learned

Dieter Mayer, MD,* Thomas Pfammatter, MD,† Zoran Rancic, PhD,* Lukas Hechelhammer, MD,† Markus Wilhelm, MD,* Frank J. Veith, MD,‡ and Mario Lachat, MD*

Conclusion: In this 102 patient contemporary series of eVAR for RAAA, endografting proved to be safe with 30-day mortality of 13%. Key components of this favorable outcome result were adequate preoperative diagnostic imaging, hypotensive hemostasis, selective transfemoral suprarenal aortic balloon occlusion, predominantly local anesthesia, detection and treatment of ACS, and attention to logistics. Widespread adoption of these treatment components is recommended.

Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) for Trauma - History

Resuscitative thoracotomy and REBOA
The spectrum of decompensation

REBOA

Resuscitative Thoracotomy
Resuscitative Endovascular Balloon Occlusion of the Aorta for Hemorrhagic Shock

Todd E. Rasmussen, MD; Curtis J. Franklin, BS; Jonathan L. Eliason, MD

JAMA Surg 2017; Published online Sept 20 2017

Canadian Medical Devices Conformity Assessment System (CMDCAS) Certified
Evolution of Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) to a Wartime, Pre-Hospital Hemorrhage Control & Resuscitation Adjunct

Justin D. Manley, MD, Benjamin J. Mitchell, Joseph J. DuBose, MD
Todd E. Rasmussen, MD

Air Force Special Operations Command; University of Alabama Birmingham Medical Center, Birmingham, Alabama

David Grant Medical Center, Travis, AFB; University of California – Davis, California

DoD Combat Casualty Care Research Program, Fort Detrick, Maryland

Uniformed Services University - Walter Reed Department of Surgery
Bethesda, Maryland
Breakthrough in Pre-Hospital Combat Casualty Care

• Case series of resuscitative endovascular balloon occlusion of the aorta (REBOA) in a pre-hospital, combat casualty care setting in Operation Inherent Resolve
Care Setting

- Resuscitation room 3km (10-15 minutes) from point of injury & 2 hours from next higher echelon of care which is level II equivalent
Special Operations Surgical Team (SOST)

• Six member, surgical & resuscitation team
  - General surgeon (MD)
  - Emergency medicine (MD)
  - Anesthesia provider (CRNA)
  - Respiratory therapist (CRT)
  - Registered nurse (CCRN)
  - Registered nurse (CCRN)

• Team composition may vary depending on operational scenario but is not dependent on sub-specialty trained surgeon
Ultrasound Guided Percutaneous Access

- Vscan ultrasound device (GE Healthcare, Inc.)
Intraoperative Bleeding Control & Blood Pressure

- **ER-REBOA™** catheter secured in femoral artery sheath & inflated during damage control laparotomy
Patients & Course of Resuscitation

• There were no ER-REBOA catheter-related complications and all patients survived through their transport to and arrival at the next higher echelon of care

• 50% placed by EM providers
• 50% placed by general surgeons
20 combat casualties, 18 months
- Mean SBP 71 mm Hg
- Explosion and GSW

20 successful REBOA utilization in conjunction with Whole Blood use

100% survival to next echelon of care
- No access or REBOA complications
The evolution continues

• Prehospital care
  • Tourniquet utilization
  • Hemostatics
  • Needle thoracostomy
  • Hypothermia prevention

• Hospital Care
  • Resuscitation / Transfusion
  • Vascular Injury care / Shunting
  • Damage Control Surgery

• En route Care
  • Critical Care Air Transport (CCAT)

• Organization and Structure
  • Joint Trauma System