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Top 10 Advancements in Trauma Care

Michael Englehart, MD
Trauma Medical Director
Gordon Riha, MD
Assistant Trauma Medical Director

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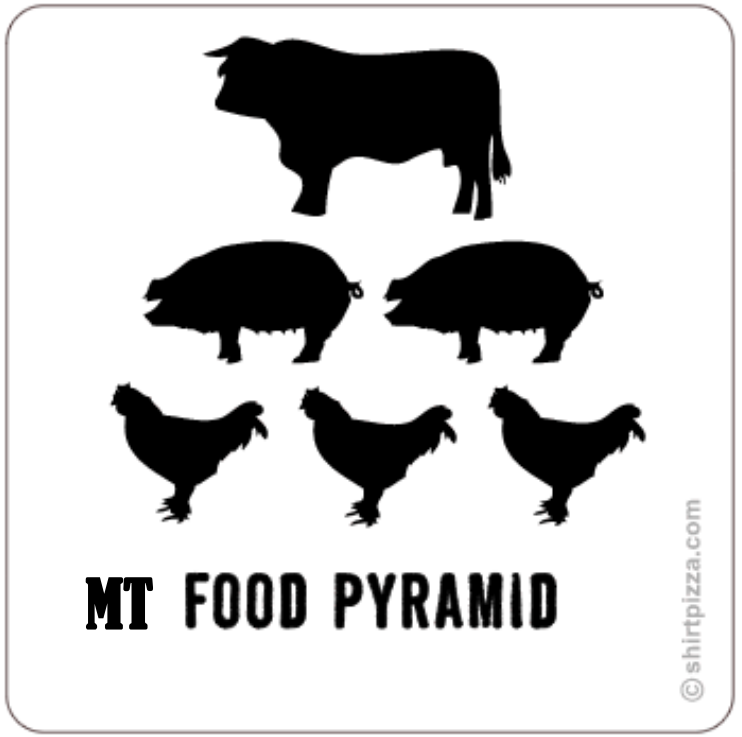
Advancements in Trauma Care

- Recent
- Relevant
- The “Meat of the Matter”



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Advancements in Trauma Care

- 5 minutes per topic
- 10 topics
- 10 minutes for questions at the end

- READY…
- SET…

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REBOA

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REBOA

- Resuscitative
- Endovascular
- Balloon
- Occlusion of the
- Aorta

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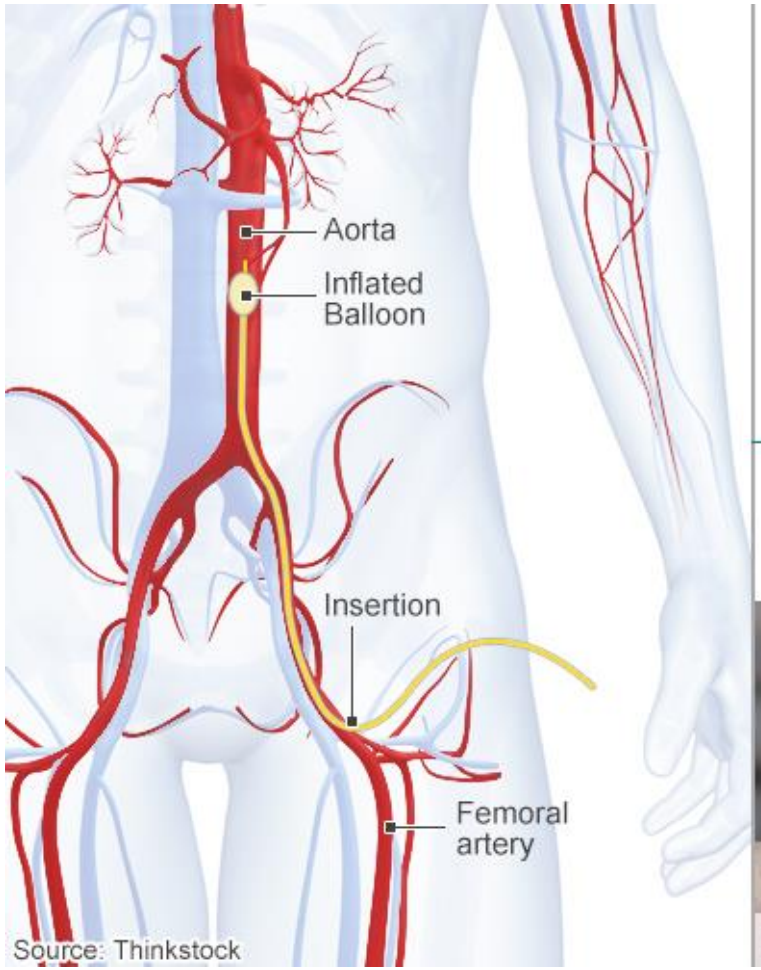
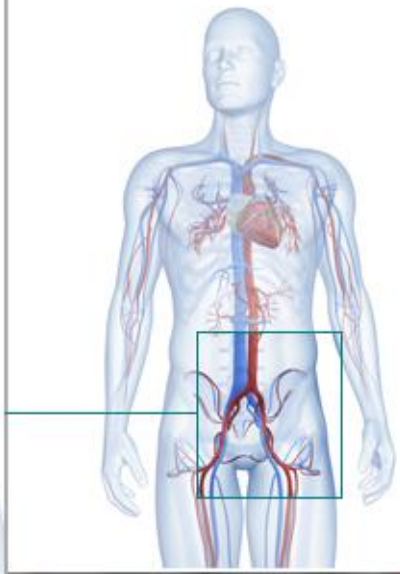
REBOA





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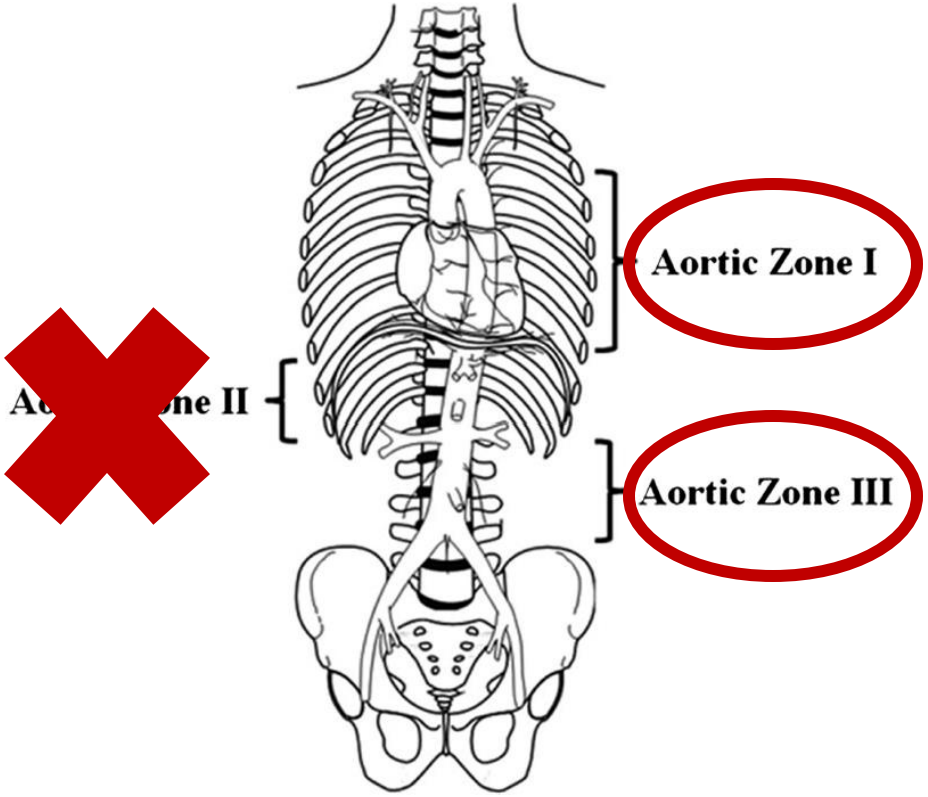
REBOA



- Blunt/penetrating abdominal trauma
- Refractory hemorrhagic shock
- Ruptured AAA
- Pelvic fracture with pelvic hemorrhage

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REBOA

- Super hot
- TCCACS 2015
- Able to be placed by multiple providers

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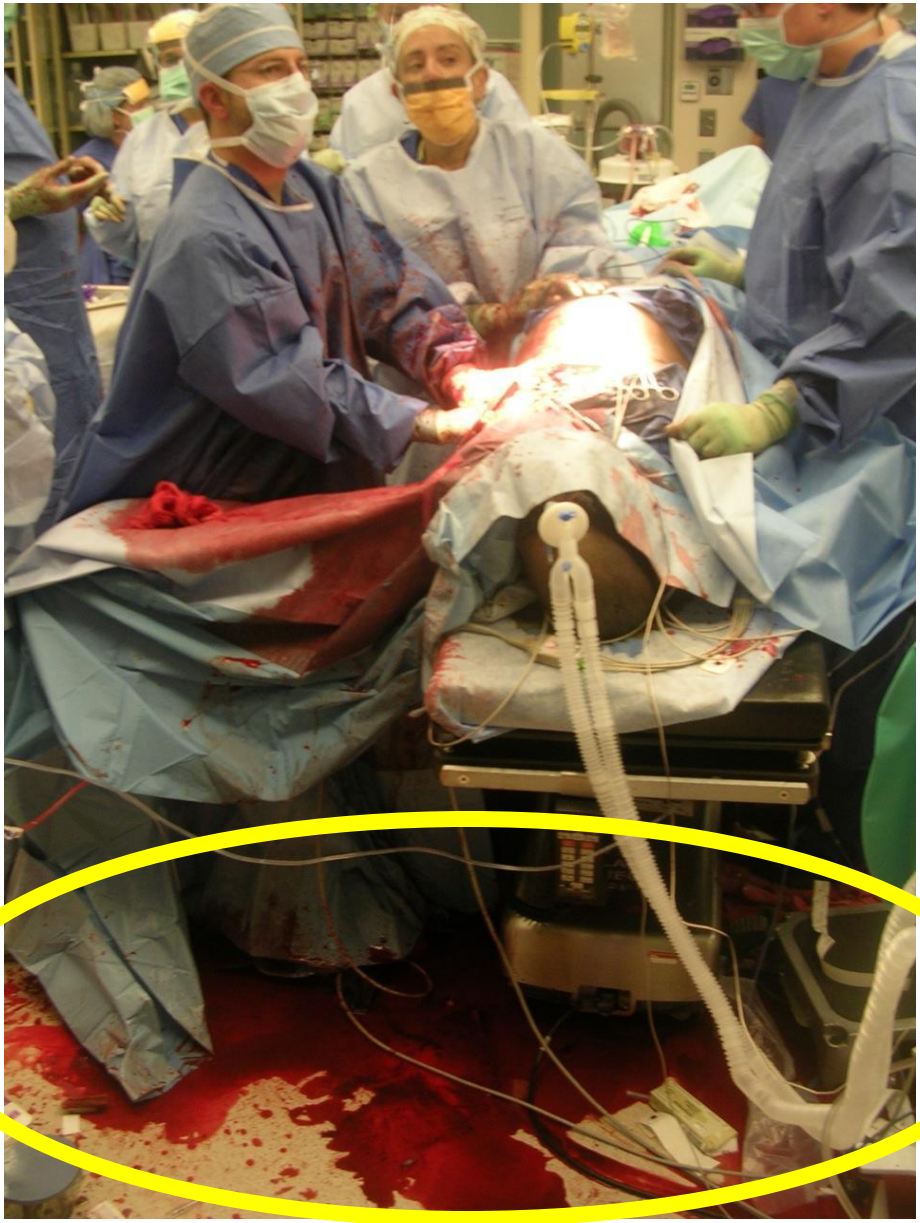

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REBOA

- Standard procedure

- ER physician competency in REBOA placement REQUIRED FOR BOARD CERTIFICATION

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REBOA

ORIGINAL ARTICLE

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

J Trauma Acute Care Surg
Volume 75, Number 3

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REBOA

ORIGINAL ARTICLE

Survival of severe blunt trauma patients treated with resuscitative endovascular balloon occlusion of the aorta compared with propensity score-adjusted untreated patients

Tatsuya Norii, MD, Cameron Crandall, MD, *and* **Yusuke Terasaka, MD,** *Albuquerque, New Mexico*

J Trauma Acute Care Surg
Volume 78, Number 4

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REBOA

- AORTA trial (Aortic Occlusion for Resuscitation in Trauma and Acute Care Surgery)→ ongoing multi-institutional AAST
- Promising technology not yet ready for primetime
- But….stay tuned….

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TEG

(ThromboElastoGraphy)

What????

- A dynamic, real-time assessment of a patient's clot formation, and clot breakdown (fibrinolysis)
- Currently the only test that can evaluate for fibrinolysis
- Test is run at patient's body temperature not room temperature
- Takes into account all aspects of clotting, from factor levels, temperature, platelets (number and function), inhibitors of clotting, RBCs, and fibrin degradation

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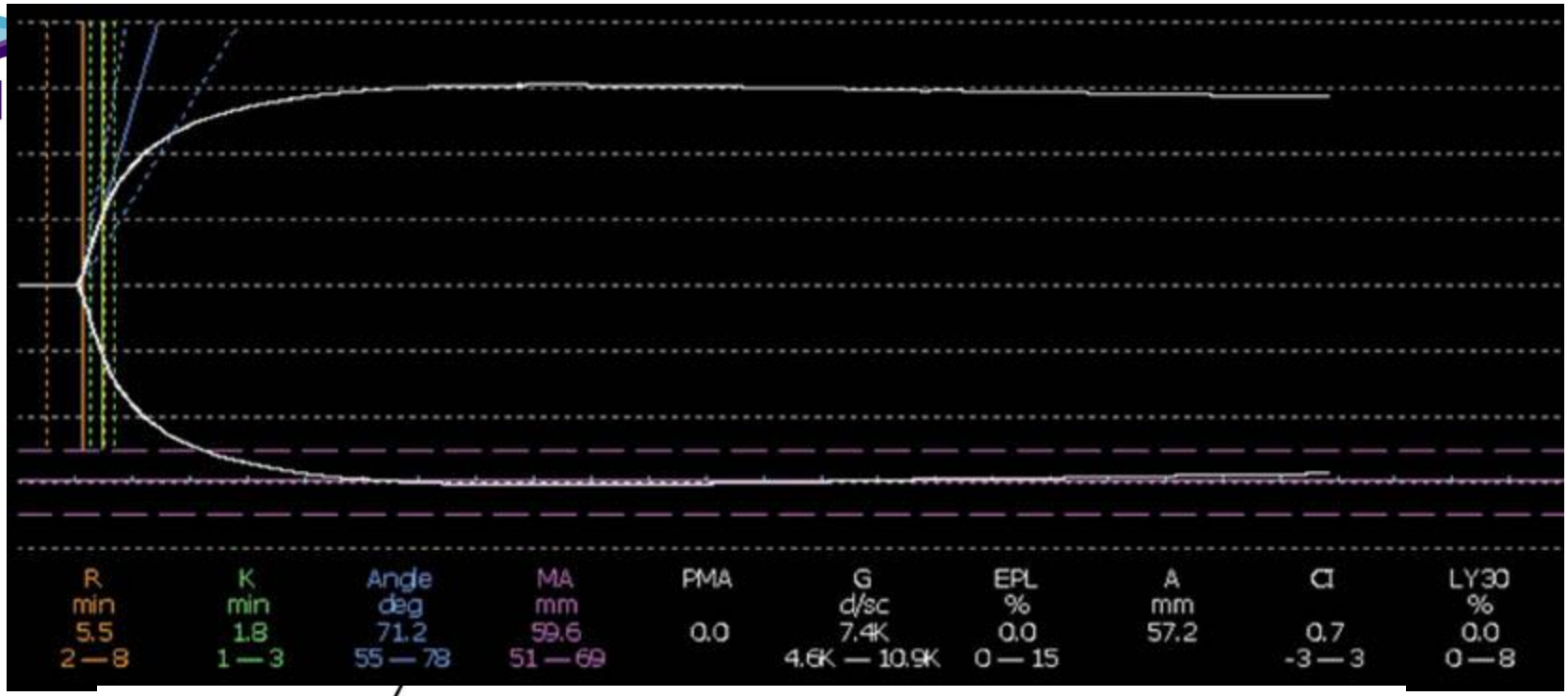
Thromboelastography


R
min
5.5
2 — 8
K
min
1.8
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Angle
deg
71.2
55 — 78
MA
mm
59.6
51 — 69
PMA
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G
d/sc
7.4K
4.6K — 10.9K
EPL
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0 — 15
A
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57.2
CI
0.7
-3 — 3
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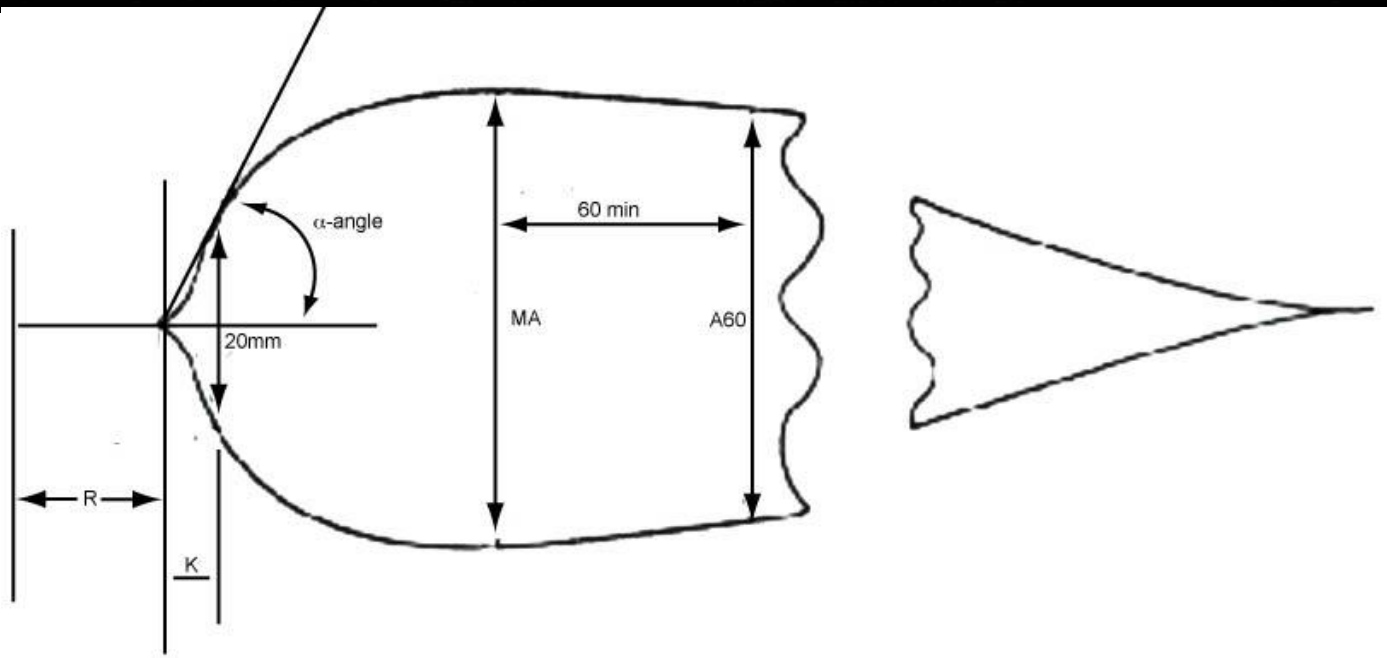
0 — 8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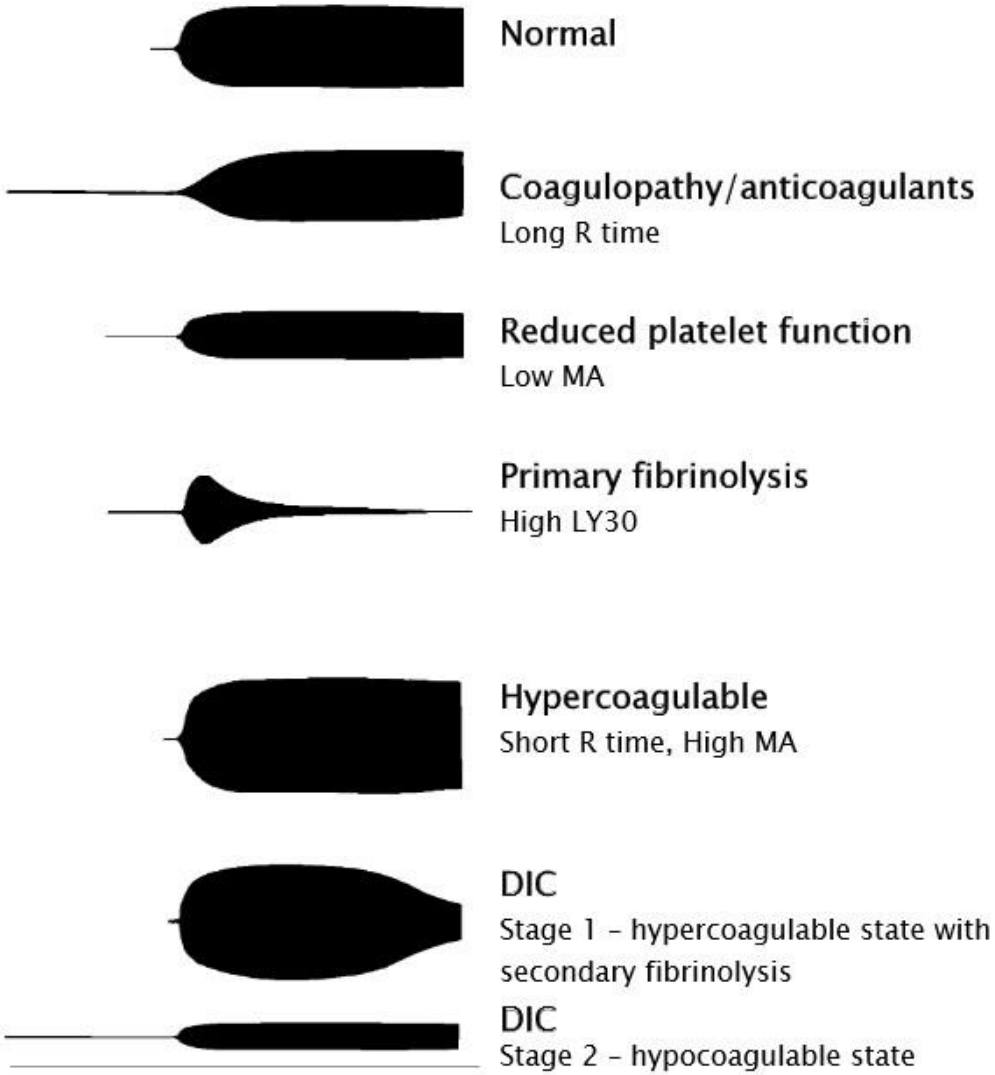
Qualitative Analysis



Normal

Coagulopathy/anticoagulants
Long R time

Reduced platelet function
Low MA

Primary fibrinolysis
High LY30

Hypercoagulable
Short R time, High MA

DIC
Stage 1 – hypercoagulable state with secondary fibrinolysis

DIC
Stage 2 – hypocoagulable state

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This is not new!

- TEG has been around for >60yrs
- Has been recently “discovered” in the past decade and use is now rampant
  - Trauma
  - Open heart surgery
  - DIC, acute coagulopathy
  - OB

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Why is TEG better than other labs tests?

- Performed at the patient's temperature
- PT/INR and PTT only test the plasma not the whole blood
- TEG combines into one test:
  - PT,PTT, fibrinogen, platelet count, platelet inhibition from drugs, …
  - Also adds extent of fibrinolysis which no other test currently measures

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Why is TEG better than other labs tests?

- Can detect coagulation/clotting dysfunction well before any traditional test (increased sensitivity)
  - Better predicts who needs blood products, who doesn't, and why
- Reduces blood product utilization (in trauma, CV surgery)
- Streamlined and enhanced transfusion practices
- Lower fluid volume means less pulmonary complications
- TEG directed massive transfusion more rapidly corrects coagulopathy

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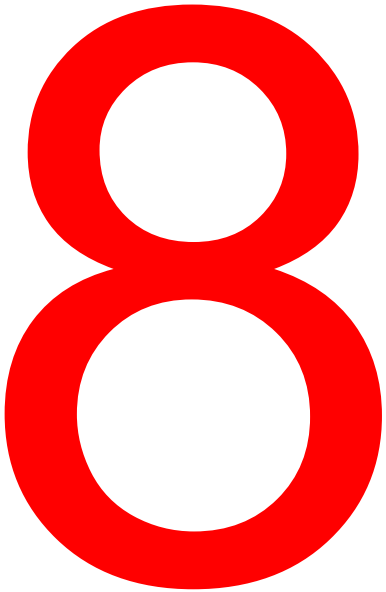

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PREPARATION FOR THE ACTIVE SHOOTER

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Disasters in the United States today

- ~~Hurricanes~~
- ~~Tornadoes~~

- Active shooters

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Hospital Shootings

INJURY PREVENTION/ORIGINAL RESEARCH

Hospital-Based Shootings in the United States: 2000 to 2011

Gabor D. Kelen, MD, Christina L. Catlett, MD, Joshua G. Kubit, MD, Yu-Hsiang Hsieh, PhD

Annals *of* Emergency Medicine Volume 60, NO. 6 : December 2012

- 154 Hospital-related shooting events
- 235 victims

- Occurred in 40 states

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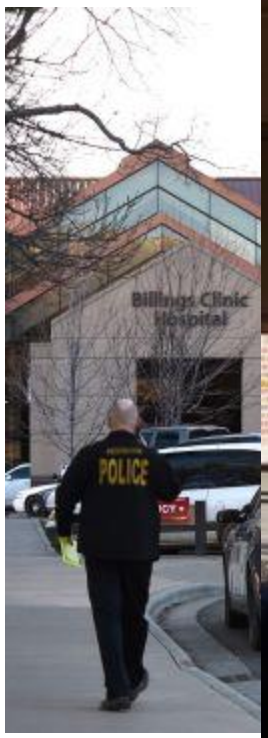
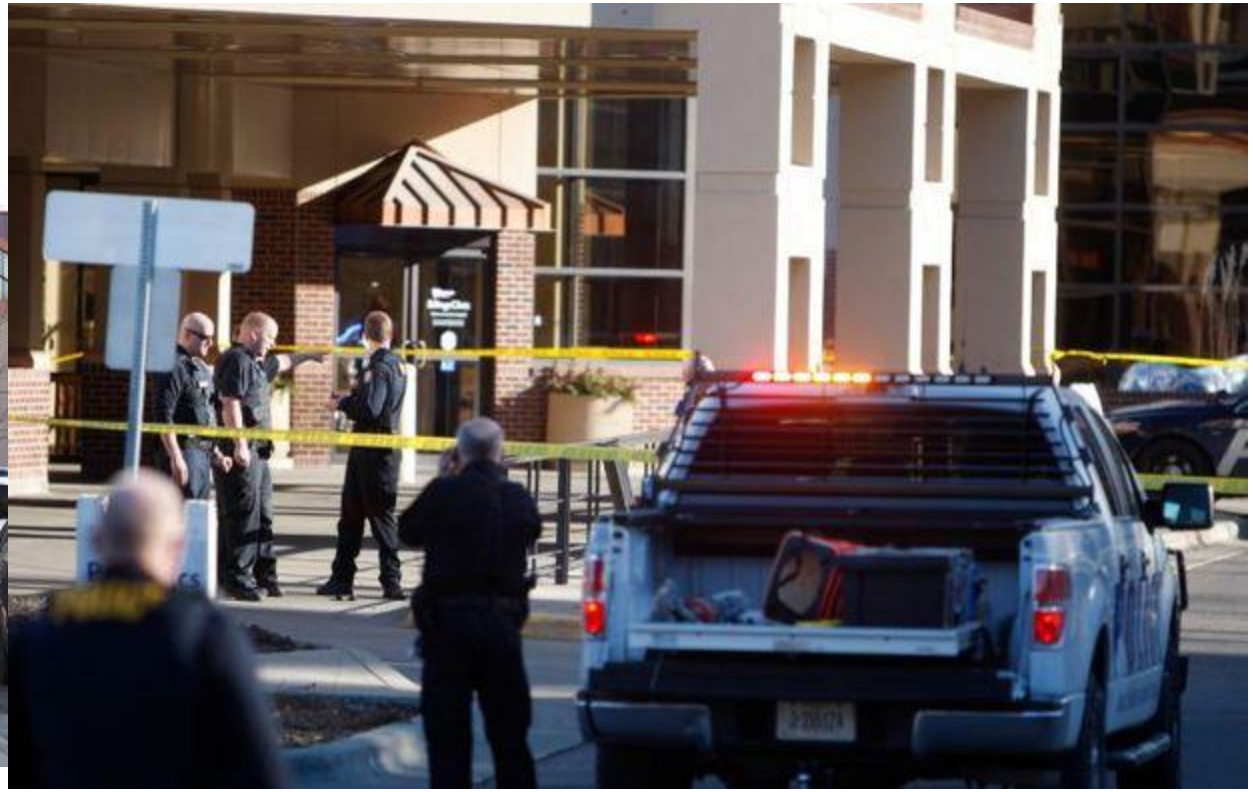
Close to Home





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Preparation for the Active Shooter

- JACHO → mandates that active shooter preparedness be a part of every hospital overall emergency mgmt program
- US Dept Homeland S
  - "Run, Hide, Fight"

Fire/Emergency Medical Services Department Operational Considerations and Guide for Active Shooter and Mass Casualty Incidents

September 2013

FEMA

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The Hartford Consensus I & II

- American College of Surgeons + FBI
- Experts in:
  - Medical
  - Law enforcement
  - Fire/rescue
  - EMS first responders
  - Military tactics

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The Hartford Consensus I & II

- Responses not optimally aligned in past
- Number one cause of preventable death:
  - HEMORRHAGE
- Initial actions and core knowledge centered on hemorrhage control

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The Hartford Consensus I & II

- Integrated active shooter response acronym THREAT:
  - **T**hreat suppression
  - **H**emorrhage control
  - **R**apid **E**xtrication to safety
  - **A**ssessment by medical providers
  - **T**ransport to definitive care

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The Hartford Consensus I & II

- Education of all groups required →
- **Anyone** could be an initial responder

- Education tailored to level of responder

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Why does this affect you?

- This awareness concept is something relatively new in the world of trauma
- Planning “in the pipeline”
- YOU will likely be asked in the near future to provide education
  - Law enforcement
  - Lay persons

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The Active Shooter

- The Bottom Line:
- PREPARATION
- EDUCATION

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LR vs NS

Choice of Crystalloid

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ATLS

- Give 1 or 2 L “warmed fluid bolus”
- Not specific about LR or NS
- If pt remains hypotensive, then will need “blood transfusion and continued fluid administration”

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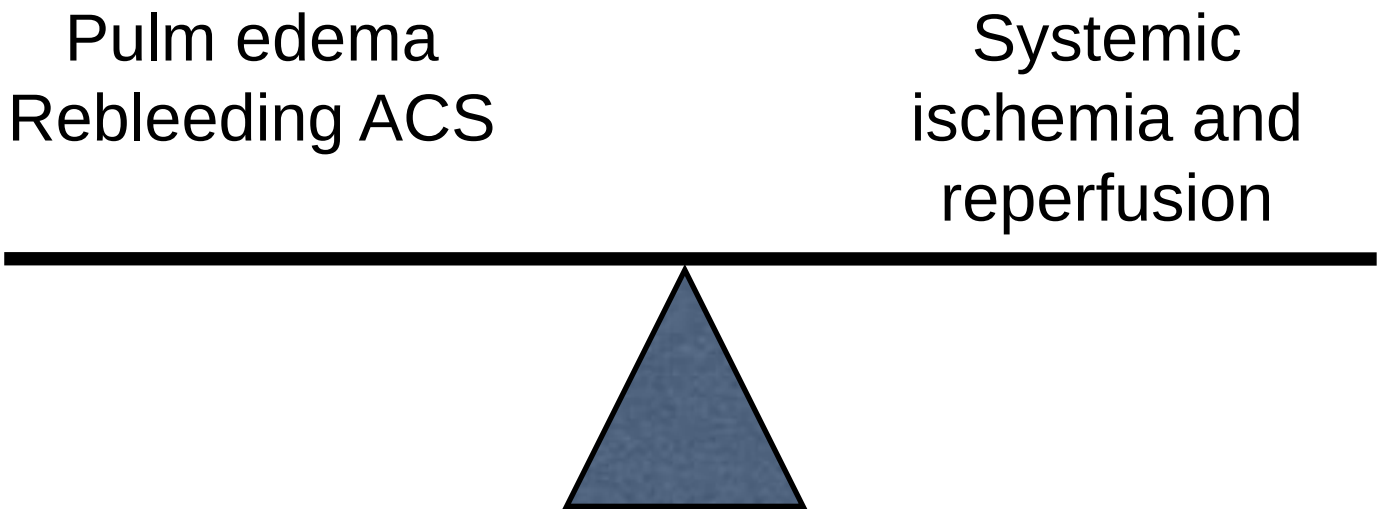
Resuscitation is a balance



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Fluid Resuscitation

- Hypovolemia results in tissue ischemia
- Ongoing ischemia results in marked acidosis and free-radical generation
  - Significant cellular injury
  - Profound activation of inflammatory cascade
  - Can rapidly lead to ARDS, and organ failure (lung, kidneys, brain)

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- Patients arriving in shock already have profound systemic inflammation, acidosis, and early coagulopathy
- ANY intervention that improves O2 delivery to tissues will produce some degree of reperfusion injury
- Issue becomes not which resuscitation strategy/fluid is best but which will be the least harmful

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True or False?

- You can’t give LR with PRBCs
- LR can’t be used for lactic acidosis
- NS is preferred over LR for pts with brain injury
- LR and NS are equivalent

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LR

- 130 mEq Na
- 109 mEq Cl
- 28 mEq lactate (buffer)
- 4 mEq potassium
- 3 mEq Ca

- pH = 6.5
- “not for use in lactic acidosis”

NS

- 154 mEq NaCl

- pH = 5.0
- Hyperchloremic metabolic acidosis

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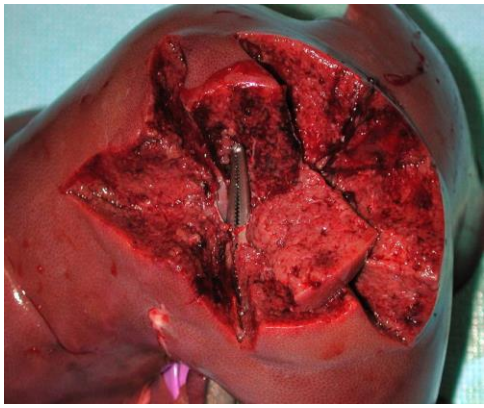
Crystalloid Comparison

- Swine model of uncontrolled hemorrhagic shock
- Animals randomized to LR or NS for resuscitation
- NS resuscitation:
  - dilutional coagulopathy (not seen with LR)
  - Greater blood loss
  - Hyperchloremic acidosis
  - Required more NS total volume just to maintain same BP
- LR caused elevated lactate that was not associated with acidosis



Kiraly LN et al, J Trauma 2006; 61(1): 57-65

Todd SR et al, J Trauma 2007; 62(3): 639-9

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RCT Human Studies

- Healthy volunteers given 2L LR vs.. NS
  - LR - higher UOP, less fluid retention
  - NS - higher Cl^- levels, lower HCO_3
- GYN surgery LR vs.. NS
  - NS pts: higher Na^+ and Cl^-, much lower pH
- Aortic aneurysm repair LR vs.. NS
  - NS pts: needed more platelets, and HCO_3 , pH still lower
- Inappropriate over-use of either one can quickly lead to abd compartment syndrome, pulm edema, CHF, and multiple organ failure

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Isotonic Crystalloids: Human Studies

- Causes severe dysfunctional inflammation (further tissue injury)
- Can worsen acidosis
  - hyperchloremic acidosis
  - restores perfusion but no oxygen carrying capacity
- Can worsen coagulopathy
  - dilutional at even modest fluids
  - hypothermic coagulopathy that is refratory to plasma
- Most common and fastest cause of iatrogenic hypothermia
- Minimal retention in intra-vascular space following trauma

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There’s nothing normal about Normal Saline!

Martin Schreiber, MD

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Choice of Fluids

- The best fluid to give your trauma patient is the fuel in the ambulance. Just get them to the hospital!” - Peter Rhee, MD

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UTILIZATION OF HEMOSTATIC DRESSINGS PRIOR TO DEFINITIVE SURGICAL CARE

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The Search for the Ideal Hemostatic Dressing

- Quickly stops bleeding
- Can be delivered into pool of blood
- No mixing or preparation
- Simple to apply
- Lightweight and durable
- Long shelf-life
- Doesn’t cause secondary injury or disease
- Inexpensive

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No disclosures

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"1st Generation" Hemostatic Dressings

- QuikClot
  - Granular product inert materials → volcanic rock
  - Absorbs water → ↑ local concentration clot factors
- Problems:
  - High pressure bleeding blows away granules
  - Severe exothermic reaction
    - 158° F !!!!

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"1st Generation" Hemostatic Dressings

- WoundStat
  - Granules enter circulatory system → thrombosis of distal organs
- HemCon
  - Flat, not flexible
  - Break when applied in wounds

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“Next Gen” Hemostatic Dressings

- Combat Gauze
  - Kaolin activated gauze roll
- Chitoflex/ChitoGauze
  - Hemcon → like flat pad but rolled form
- Celox Gauze
  - Popular in UK

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“Next Gen” Hemostatic Dressings

- Combat Gauze
  - Endorsed by Tactical Combat Casualty Care Committee
  - Carried by US soldiers

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Hemostatic Dressings

- Direct pressure A MUST!!!!

- No good head-to-head human trials/data to support one vs. another

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Hemostatic Dressings

An Evidence-based Prehospital Guideline for External Hemorrhage Control: American College of Surgeons Committee on Trauma

Eileen M. Bulger, MD, FACS, David Snyder, PhD, Karen Schoelles, MD, FACP, Cathy Gotschall, ScD, Drew Dawson, BA, Eddy Lang, MD, CM CCFP (EM) CSPQ, Nels D. Sanddal, PhD, NREMT, Frank K. Butler, MD, FAAO, FUHM, Mary Fallat, MD, FACS, Peter Taillac, MD, Lynn White, MS, CCRP, Jeffrey P. Salomone, MD, FACS, NREMT-P, William Seifarth, MS, NREMT-P, Michael J. Betzner, MD, FRCPC, Jay Johannigman, MD, FACS, Norman McSwain, Jr., MD, FACS, NREMT-P

Prehospital Emergency Care April/June 2014 Volume 18 / Number 2

- Rec 1: Hemostatic agents + pressure for hemorrhage in areas where tourniquets not possible and direct pressure ineffective

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Hemostatic Dressings

An Evidence-based Prehospital Guideline for External Hemorrhage Control: American College of Surgeons Committee on Trauma

Eileen M. Bulger, MD, FACS, David Snyder, PhD, Karen Schoelles, MD, FACP, Cathy Gotschall, ScD, Drew Dawson, BA, Eddy Lang, MD, CM CCFP (EM) CSPQ, Nels D. Sanddal, PhD, NREMT, Frank K. Butler, MD, FAAO, FUHM, Mary Fallat, MD, FACS, Peter Taillac, MD, Lynn White, MS, CCRP, Jeffrey P. Salomone, MD, FACS, NREMT-P, William Seifarth, MS, NREMT-P, Michael J. Betzner, MD, FRCPC, Jay Johannigman, MD, FACS, Norman McSwain, Jr., MD, FACS, NREMT-P

Prehospital Emergency Care April/June 2014 Volume 18 / Number 2

- Rec 2: Utilize gauze format hemostatic dressings that support packing
- Rec 3: Only use products determined safe by animal models

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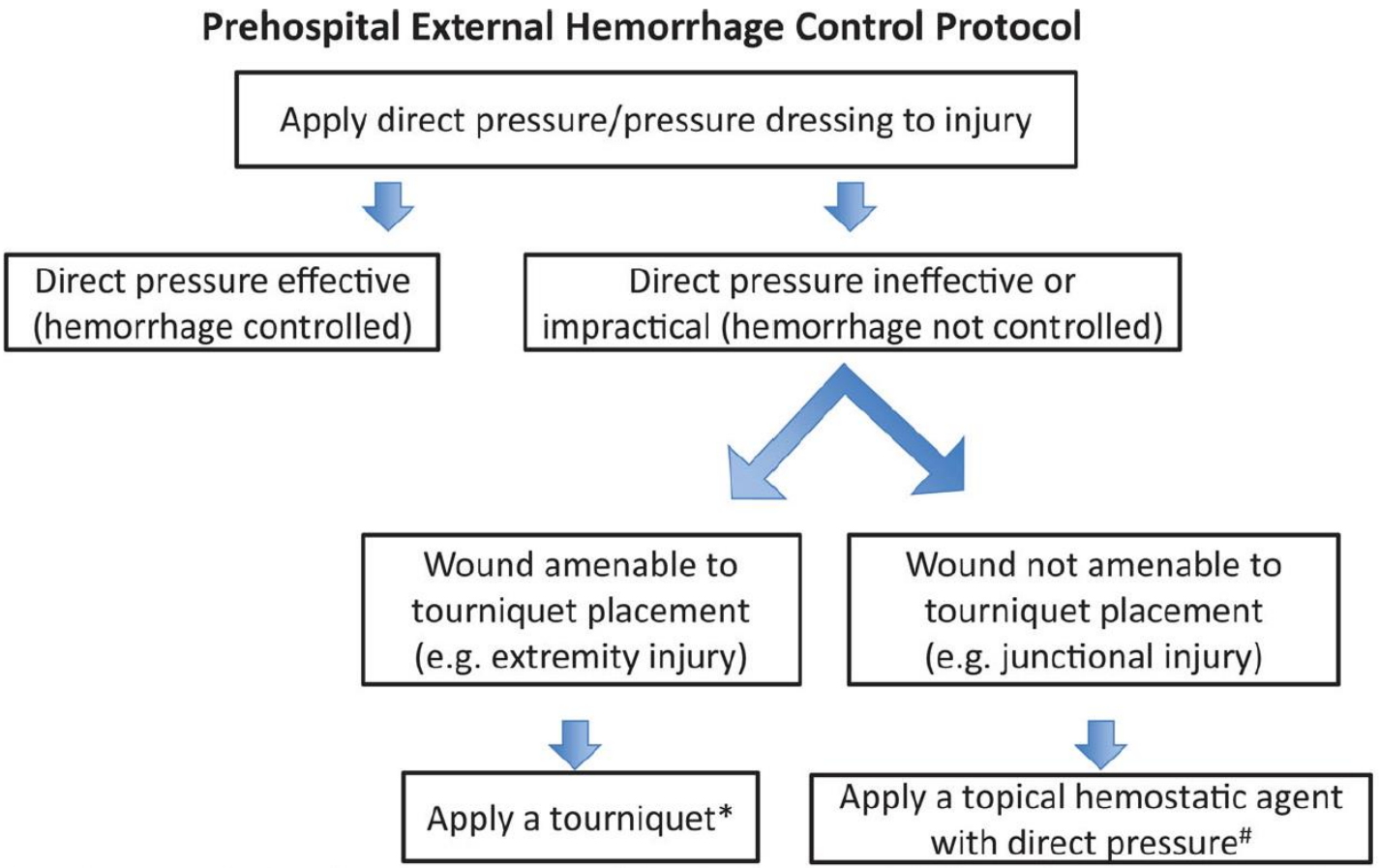
Hemostatic Dressings



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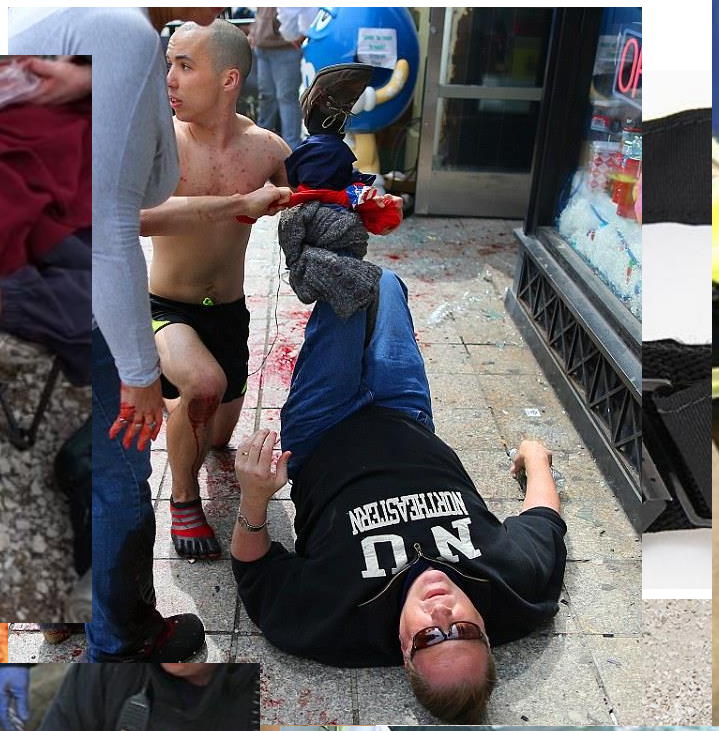
Tourniquets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Broadway
IT'S A STATE OF MIND
adidas
© Boston Globe via Getty Images

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How do tourniquets work?

- Do tourniquets prevent arterial hemorrhage?
- Do tourniquets prevent venous hemorrhage?

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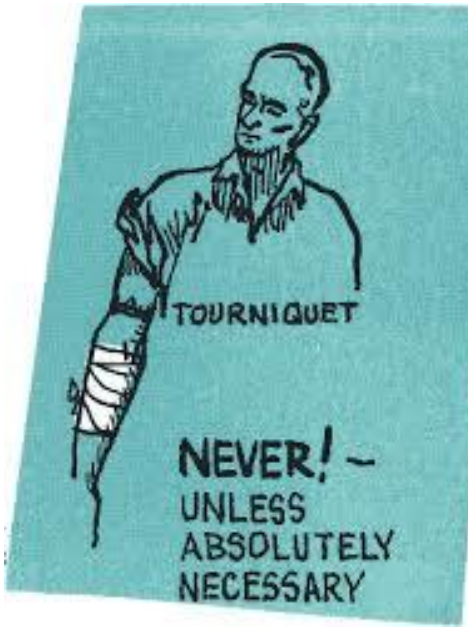
Tourniquets- Why renewed interest?

- Tourniquet use was prevalent for military use and amputations for centuries
- Recently, civilian use thought not to mirror military use
  - increased hemorrhage
  - Higher amputation rate?
- Likely due to home-made tourniquets or not placed tight enough
  - Allows occlusion of venous blood but not arterial
  - Can lead to more rapid exsanguination as venous blood has nowhere to go but out the wound



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Evidenced-Based Prehospital Guideline for External Hemorrhage control: ACS COT

- Use tourniquets in the prehospital setting if direct pressure is ineffective or impractical in controlling significant extremity hemorrhage
- Use a commercially produced windlass, pneumatic, or ratcheting device
  - Tourniquets that impede venous return without adequate arterial occlusion may only worsen hemorrhage
- Recommend against narrow, elastic, bungee-type devices
- Improvised tourniquets should be applied only if no commercial device available
- Don't release a properly applied tourniquet until the patients has reached definitive care
  - Exceptions if transport time is prolonged

Prehosp Em Care 2014, 18:163-173

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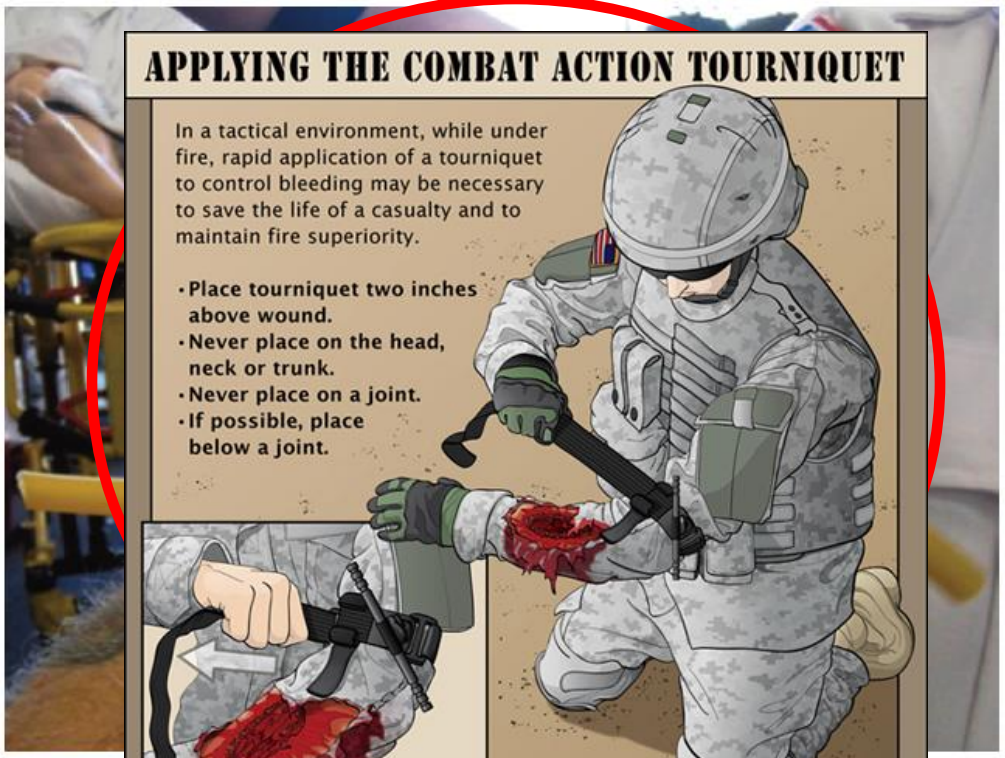

APPLYING THE COMBAT ACTION TOURNIQUET

In a tactical environment, while under fire, rapid application of a tourniquet to control bleeding may be necessary to save the life of a casualty and to maintain fire superiority.

- **Place tourniquet two inches above wound.**
- **Never place on the head, neck or trunk.**
- **Never place on a joint.**
- **If possible, place below a joint.**

Pull the free end of the self-adhering band through the loop and securely fasten it.

Twist the Windlass Rod until all bright red bleeding stops.

Snap the Windlass Rod into the Windlass Clip, securing in place with the Windlass Strap.

ALWAYS write a letter "T" and the time a tourniquet was applied on a casualty's forehead.


Broadway
IT'S A STATE OF MIND
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Boston

- Almost all tourniquets placed at bombing were home-made
- Essentially ineffective at hemorrhage control
- Timely and orderly evacuation of bombing scene and hospitals was critical to patient survival
- Boston has 6 Level I trauma centers!
- Anyone who came into the hospital alive left the hospital alive

Tourniquet use at the Boston Marathon bombing: Lost in translation

David Richard King, MD, Andreas Larentzakis, MD, Elie P. Ramly, MD,
and **The Boston Trauma Collaborative,** *Boston, Massachusetts*

- 243 injured, 152 ER visits, 66 with at least 1 extremity injury
- 17 LE traumatic amputations in 15 pts
- 12 major LE vascular injuries in 10 pts
- 27 tourniquets applied (all improvised even those placed by EMS):
  - 16 of 17 traumatic amputations
  - 5 of 12 major vascular injuries
  - 6 with major soft tissue injury
- Among 243 pts presenting to ER, **mortality: 0%**

J trauma Acute Care Surg; 2015; 78: 594-599

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Conclusion:

- “After the Boston Marathon bombings, extremity exsanguination at the point of injury was either left untreated or treated with an improvised tourniquet in the prehospital environment. An effective, prehopsital extremity hemorrhage control posture should be translated to all civilian first responders in the United States and should mirror the military’s posture toward extremity bleeding control. The prehospital response to extremity exsanguination after the Boston Marathon bombing demonstrates that our current practice is an approach, lost in translation, from the battlefield to the homeland.”

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What will the future hold?

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THE RISE OF THE ORAL ANTICOAGULANTS

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Oral Anticoagulants

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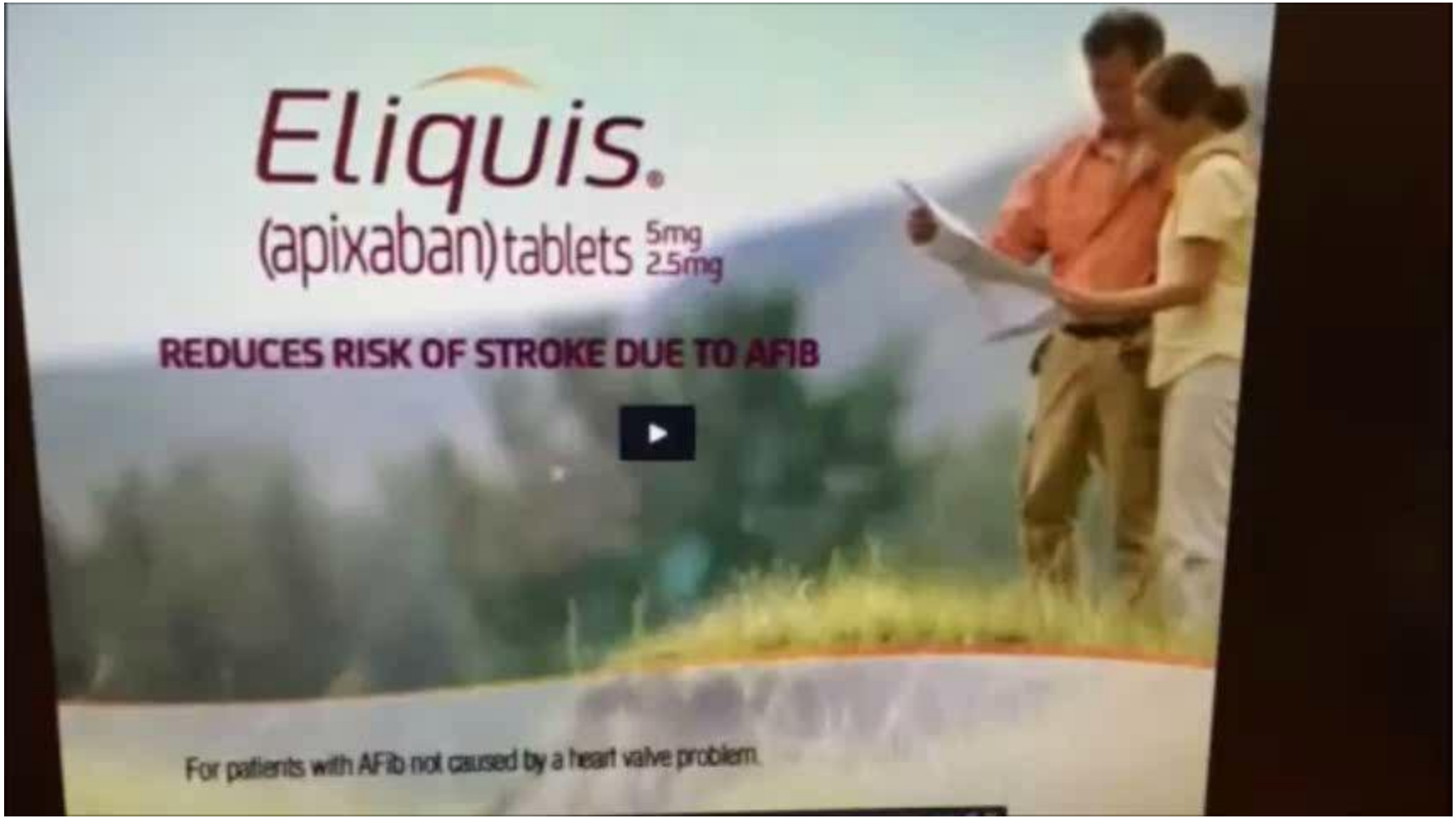
Oral Anticoagulants



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Oral Anticoagulants

If this guy falls and hits his head, he is &#$%@* !!!!!

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Oral Anticoagulants

- Directly inhibit thrombin
  - Dabigatran
- Directly inhibit factor **Xa**
  - Rivaro**xa**ban
  - Ap**ixa**ban

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Oral Anticoagulants

- Why????
  - Administered at fixed doses
  - Relatively predictable serum levels
  - No lab monitoring required
  - Not affected by food
- $ 7 **B**illion a year market

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Oral Anticoagulant ISSUES

1. No specific antidote
2. Laboratory measurement of their levels and effect is frequently not possible

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Management of the Bleeding Patient on New Oral Anticoagulants

 Most important thing to remember: 

There is no substitute for prompt control of mechanical bleeding and appropriate fluid and blood transfusions

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Management of the Bleeding Patient on New Oral Anticoagulants

- 1. Ask about timing of last dose:
  - If < 2 hours → oral activated charcoal
  - If > 3-3.5 days → no anticoagulation effect
  - If Dabigatran → consider HD…??

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Management of the Bleeding Patient on New Oral Anticoagulants

- 2. Order Labs
  - CBC, PT/INR, aPTT, renal function, LFTs
  - If Dabigatran: add thrombin time
  - If factor Xa inhibitor: add anti-Xa activity
  - If you have TEG, use it
- **Normal labs do NOT mean that the anticoagulant effect has resolved**

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Management of the Bleeding Patient on New Oral Anticoagulants

- 3. Treat life threatening bleeding:
  - FEIBA or PCC
  - Tranexamic acid
  - FFP
  - Pray

- Billings Clinic Reversal Protocols

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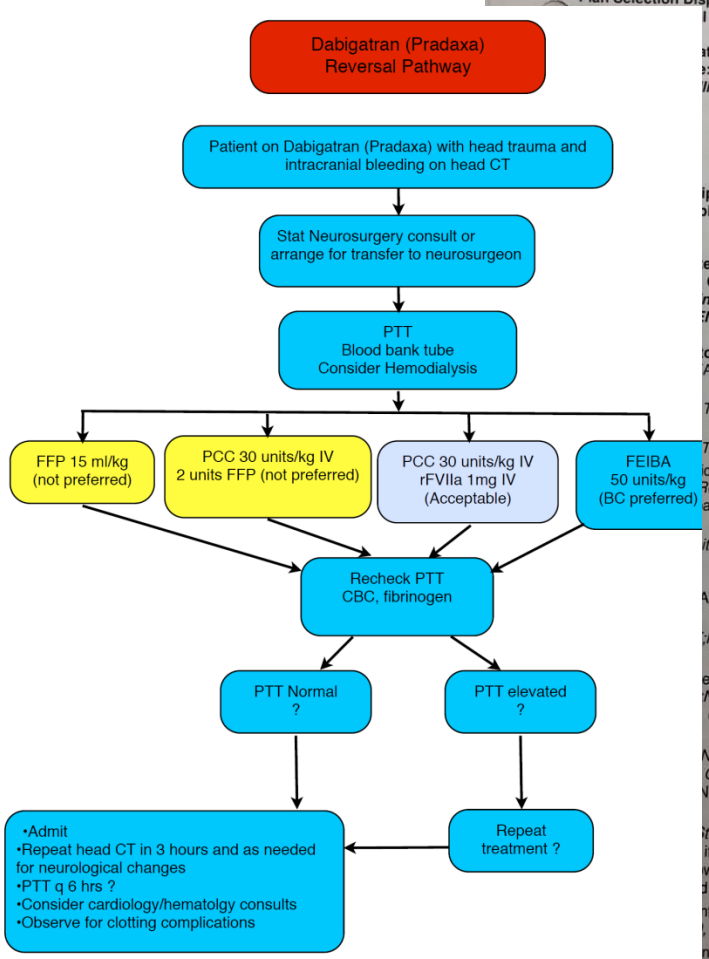

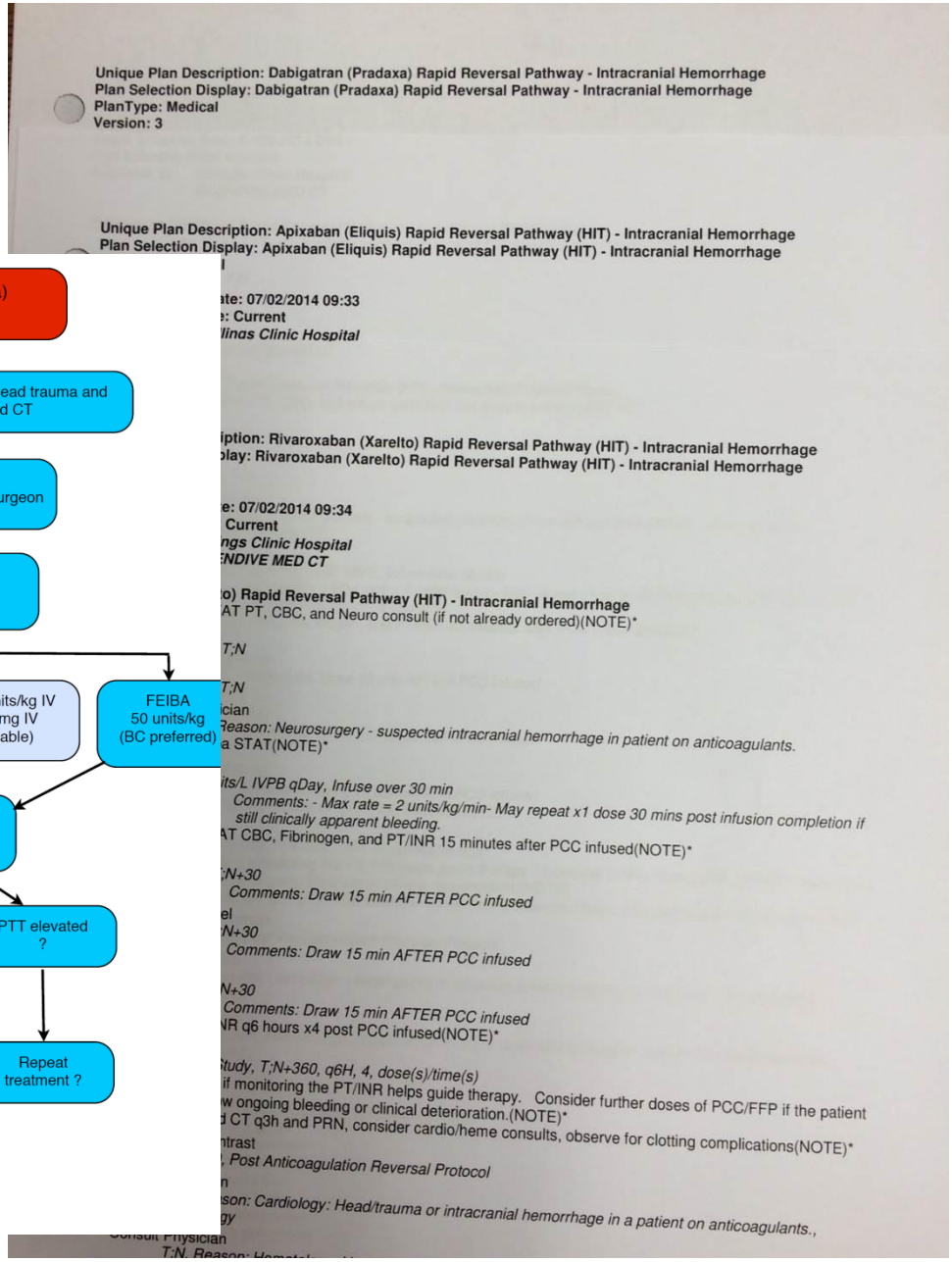

Unique Plan Description: Dabigatran (Pradaxa) Rapid Reversal Pathway - Intracranial Hemorrhage
Plan Selection Display: Dabigatran (Pradaxa) Rapid Reversal Pathway - Intracranial Hemorrhage
PlanType: Medical
Version: 3

Unique Plan Description: Apixaban (Eliquis) Rapid Reversal Pathway (HIT) - Intracranial Hemorrhage
Plan Selection Display: Apixaban (Eliquis) Rapid Reversal Pathway (HIT) - Intracranial Hemorrhage

te: 07/02/2014 09:33
e: Current
linas Clinic Hospital

iption: Rivaroxaban (Xarelto) Rapid Reversal Pathway (HIT) - Intracranial Hemorrhage
lay: Rivaroxaban (Xarelto) Rapid Reversal Pathway (HIT) - Intracranial Hemorrhage

e: 07/02/2014 09:34
Current
ngs Clinic Hospital
NDIVE MED CT

o) Rapid Reversal Pathway (HIT) - Intracranial Hemorrhage
AT PT, CBC, and Neuro consult (if not already ordered)(NOTE)*

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T;N
cian
Reason: Neurosurgery - suspected intracranial hemorrhage in patient on anticoagulants.
a STAT(NOTE)*

its/L IVPB qDay, Infuse over 30 min
Comments: - Max rate = 2 units/kg/min- May repeat x1 dose 30 mins post infusion completion if still clinically apparent bleeding.
AT CBC, Fibrinogen, and PT/INR 15 minutes after PCC infused(NOTE)*

;N+30
Comments: Draw 15 min AFTER PCC infused
el
N+30
Comments: Draw 15 min AFTER PCC infused

N+30
Comments: Draw 15 min AFTER PCC infused
NR q6 hours x4 post PCC infused(NOTE)*

tudy, T;N+360, q6H, 4, dose(s)/time(s)
if monitoring the PT/INR helps guide therapy. Consider further doses of PCC/FFP if the patient
w ongoing bleeding or clinical deterioration.(NOTE)*
d CT q3h and PRN, consider cardio/heme consults, observe for clotting complications(NOTE)*
ntrast
, Post Anticoagulation Reversal Protocol
n
son: Cardiology: Head/trauma or intracranial hemorrhage in a patient on anticoagulants.,
gy
Consult Physician
T;N, Reason: Hematol

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3

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TXA

(tranexemic acid)

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TXA - Mechanism

- Clot formation is always associated with some amount of fibrinolysis
- Hyper-fibrinolysis is often seen in trauma, esp. severe trauma
- Can further exacerbate bleeding
- Tranexemic acid (TXA) is a synthetic derivative of lysine that binds and inhibits plasminogen
- Overall effect is to prevent excessive fibrinolysis and maintain clot formation without over-stimulation of clotting
- Excellent data on reducing PRBC use in elective surgery

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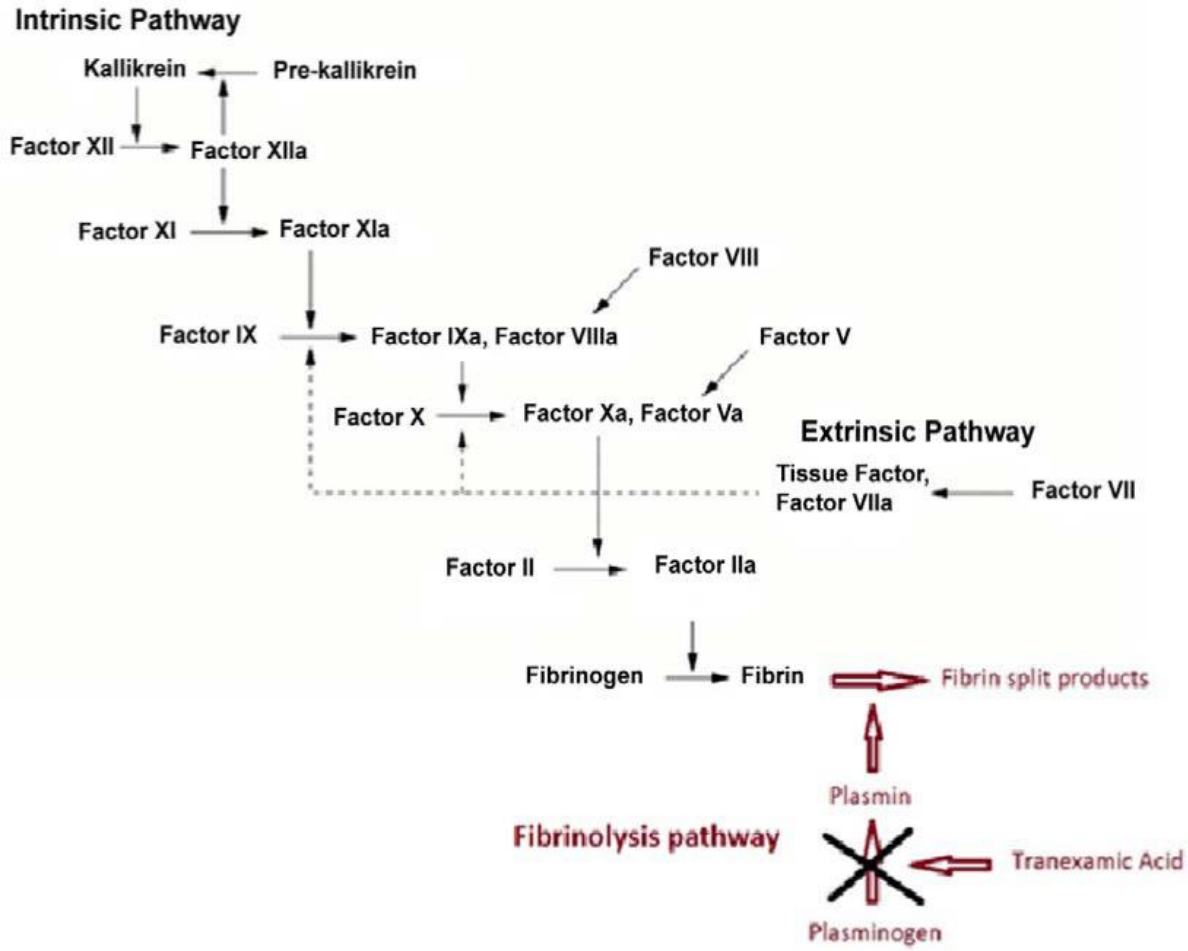

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TXA - Studies

- CRASH – 2
- MATTERS
- MATTERS - II
- PED-TRAX

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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

*CRASH-2 trial collaborators**

- 1gm immediately over 10 min.
- 1gm infusion over 8hrs
- 1st dose given within 8hrs of injury in pts at risk for significant hemorrhage (HR >110, SBP <90)

- RCT: 20,211 trauma pts!
- All-cause mortality reduced: 16 to 14.5%
- Death from hemorrhage reduced: 5.7 to 4.9%

Lancet 2010; 376: 23–32

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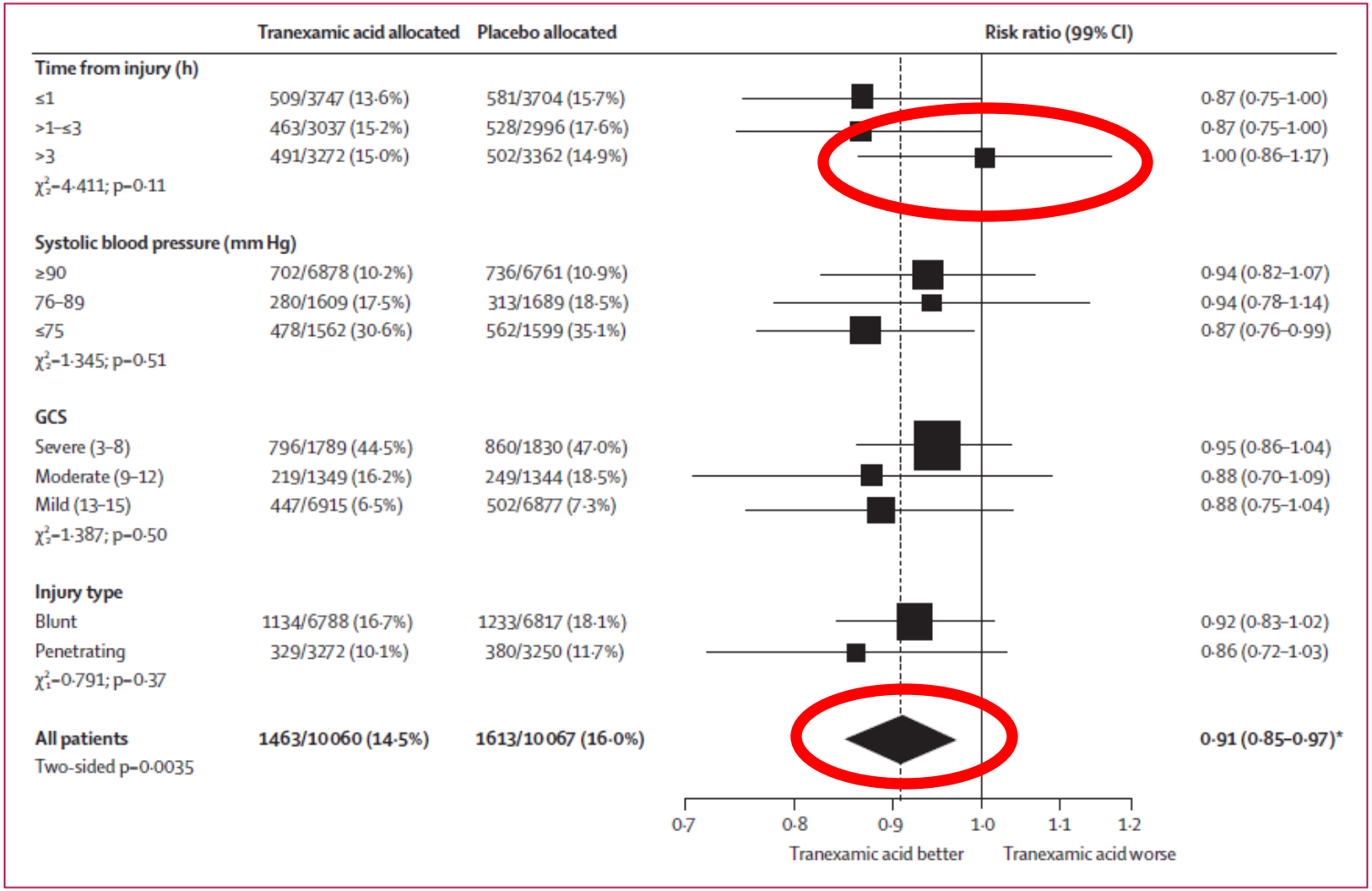

***Figure 3*: All-cause mortality by subgroups**
GCS=Glasgow Coma Score. *95% CI.

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Military Application of Tranexamic Acid in Trauma Emergency Resuscitation (MATTERs) Study

Jonathan J. Morrison, MB ChB, MRCS; Joseph J. Dubose, MD; Todd E. Rasmussen, MD; Mark J. Midwinter, BMedSci, MD, FRCS

- Retrospective observational study, 896 pts
- Combat injuries = mostly all penetrating
- TXA group was more seriously injured, but had lower mortality
  - 17.4 vs. 23.9%
- TXA use associated with reduced coagulopathy, and independently associated with reduced mortality (OR 7.2) in massive transfusion

Arch Surg. 2012;147(2):113-119

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Table 3. Factors Associated With Survival Following Multivariate Analysis of the Overall Group and the Massive Transfusion Group

Cohort	Odds Ratio (95% CI)[a]	*P* Value[b]
Overall		
GCS score ≤8	0.304 (0.108-0.860)	**.02**
Hypotension	0.303 (0.107-0.855)	**.02**
Coagulopathy at admission	0.291 (0.113-0.749)	**.01**
Massive transfusion		
GCS score ≤8	0.027 (0.008-0.085)	**<.001**
ISS >15	0.359 (0.123-1.053)	.06
TXA	7.228 (3.016-17.322)	**<.001**

Abbreviations: GCS, Glasgow Coma Scale; ISS, Injury Severity Score; TXA, tranexamic acid.

[a] Wald 95% CIs for odds ratios are used.

[b] Statistically significant values ($P < .05$) are bold.

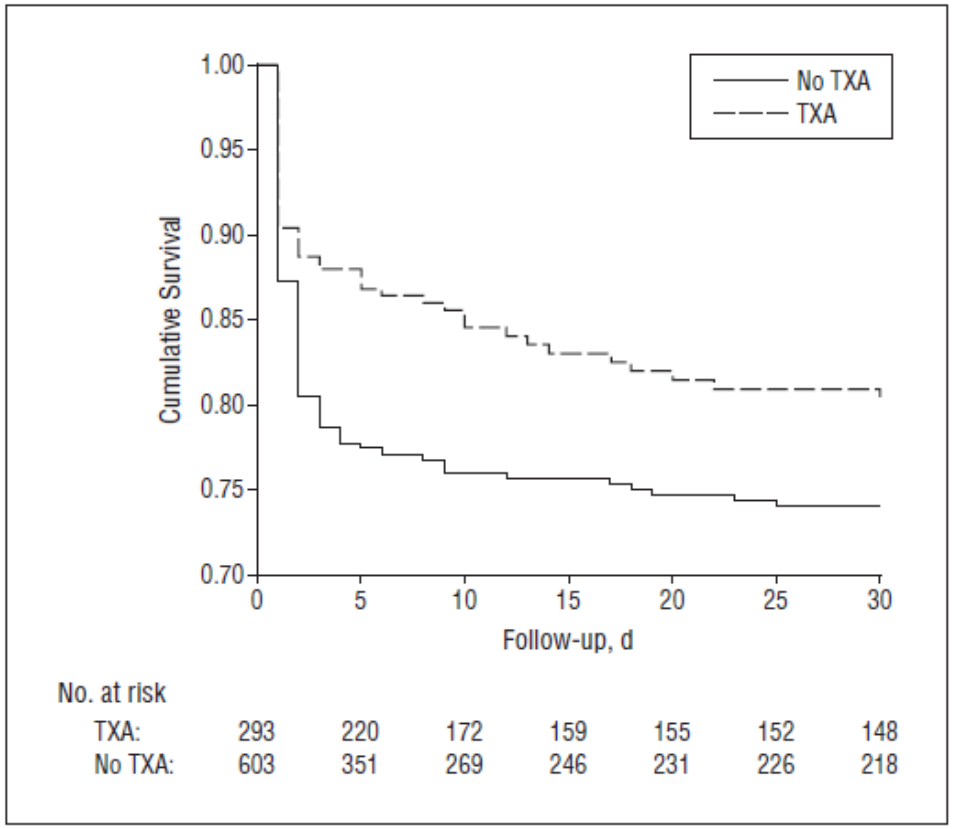

Figure 3. Kaplan-Meier survival curve of the overall cohort, including patients receiving tranexamic acid (TXA) vs no TXA. $P = .006$, Mantel-Cox log-rank test.

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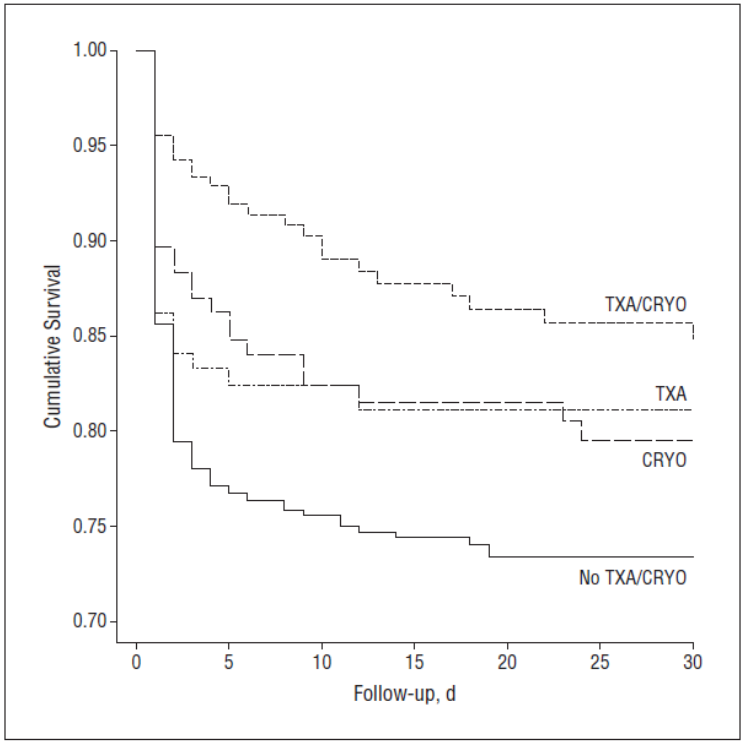
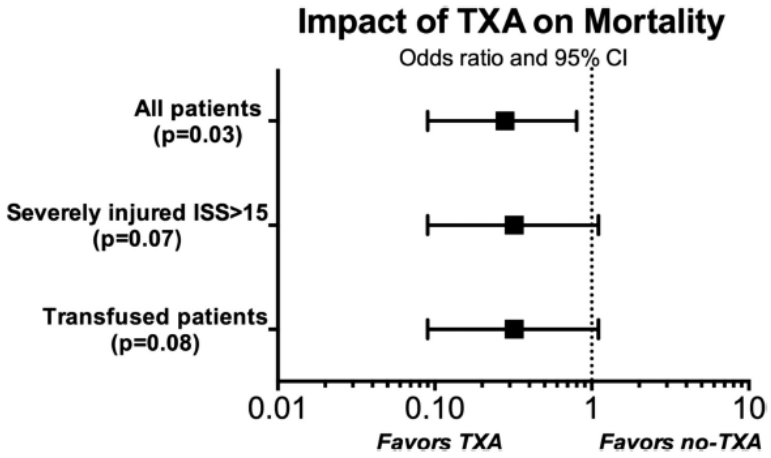
- MATTERS – II
  - Retrospective observational study, combat hospital
  - 4 groups: TXA, cryo, TXA+cryo, none
  - TXA and cryo use were independently associated with increased survival



- PED-TRAX
- Retrospective review, combat hospital, all age <18y/o
- TXA use associated with reduced mortality from trauma (OR 0.3)



JAMA Surg. 2013;148(3):218-225
J Trauma Acute Care Surg. 2014;77: 852–858.

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TXA - Conclusions

- TXA is cheap and effective at reducing trauma mortality from hemorrhagic shock
- TXA is most useful in the sickest patients
- TXA must be given within 3 hrs of injury otherwise no benefit and potentially harmful
- 1gm IV bolus, then 1gm IV infusion over 8hrs

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Hypotensive Resuscitation (still) Works

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Hypotensive Resuscitation

The New England
Journal of Medicine

Volume 331 OCTOBER 27, 1994 Number 17

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.

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Hypotensive Resuscitation

Table 5. Outcome of Patients with Penetrating Torso Injuries, According to Treatment Group.

Variable	Immediate Resuscitation	Delayed Resuscitation	P Value
Survival to discharge — no. of patients/total patients (%)	193/309 (62)*	203/289 (70)†	0.04
Estimated intraoperative blood loss — ml‡	3127±4937	2555±3546	0.11
Length of hospital stay — days§	14±24	11±19	0.006
Length of ICU stay — days§	8±16	7±11	0.30

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Hypotensive Resuscitation

- Committee on Tactical Combat Casualty Care (TCCC)
- Clinical Practice Guidelines

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TCCC Guidelines

- If soldier coherent and palpable radial pulse → insert iv, saline lock, hold fluids

- If significant blood loss and loss of radial pulse/AMS → 500 ml Hextend until pulse/MS returns, then hold fluid

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EAST Guidelines

- Penetrating injury, short transport times:
  - Withhold fluids if alert or palpable radial pulse
  - Small boluses until return

Cotton, *et al. J Trauma* 2009

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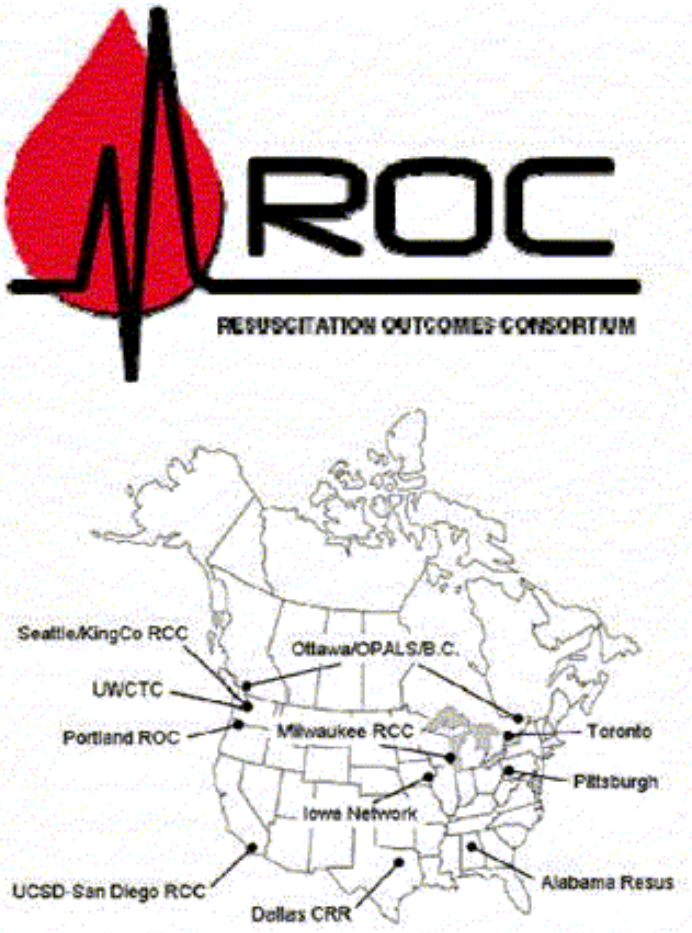
Hypotensive Resuscitation



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Hypotensive Resuscitation

AAST 2014 Plenary Paper

A controlled resuscitation strategy is feasible and safe in hypotensive trauma patients: Results of a prospective randomized pilot trial

Martin A. Schreiber, MD, Eric N. Meier, MS, Samuel A. Tisherman, MD, Jeffrey D. Kerby, MD, PhD, Craig D. Newgard, MD, MPH, Karen Brasel, MD, Debra Egan, MSc, MPH, William Witham, MD, Carolyn Williams, RN, Mohamud Daya, MD, Jeff Beeson, DO, Belinda H. McCully, PhD, Stephen Wheeler, MD, Delores Kannas, RN, MS, MHA, Susanne May, PhD, Barbara McKnight, PhD, David B. Hoyt, MD, *and* **the ROC Investigators,** *Chicago, Illinois*

J Trauma Acute Care Surg
Volume 78, Number 4

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Hypotensive Resuscitation

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- Controlled resuscitation =
  - 250 ml bolus if no radial pulse or if SBP< 70
  - Additional 250 ml to maintain radial pulse or SBP > 70
- Standard resuscitation =
  - All received 2 liters crystalloid and additional fluid to maintain SBP > 110

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- 192 pts randomized (97 CR and 95 SR)
- No difference ICU days, vent days, renal inj
- Blunt trauma 24hr mortality →
  - 3% CR vs. 18% SR
- Strong motivation for Phase III trial

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The Bottom Line on Hypotensive

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The Bottom Line on Hypotensive Resuscitation

- Large volume crystalloid resuscitation is not advantageous
  - May lead to increased bleeding
- In non-TBI patients, a period of hypotension prior to definitive care is reasonably well tolerated

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Hemostatic Resuscitation / 1:1:1

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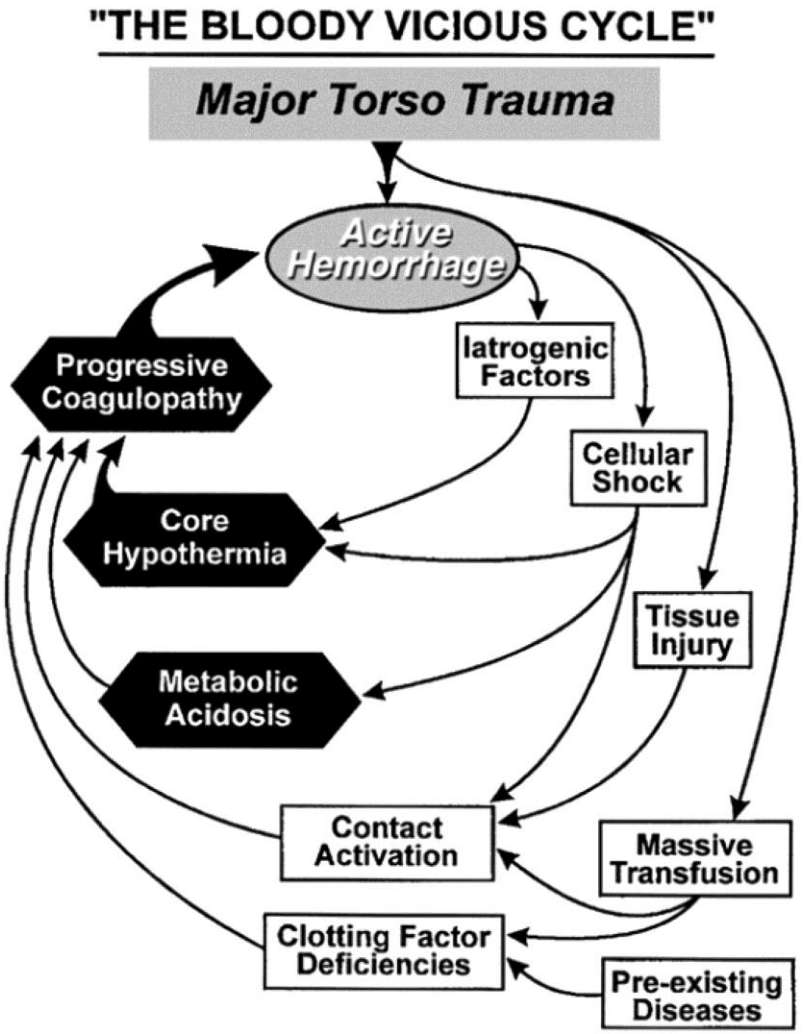

Sihler K C , Napolitano L M Chest 2009;136:1654-1667

CHEST

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•Goals of resuscitation: Prevent the lethal triad

- Definitive hemorrhage control
- Reverse acidosis
- Prevent coagulopathy
- Restore normothermia, and prevent ongoing hypothermia

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Damage Control Resuscitation

- Not really a new idea!
- Collection of old ideas combined together
  - Permissive hypotension
  - Aggressive use of blood and plasma over crystalloid
  - Rapid and early correction of coagulopathy (hemostatic resuscitation)
  - Damage control surgery vital to success

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Damage Control Resuscitation: Directly Addressing the Early Coagulopathy of Trauma

- Hemorrhage is still the leading cause of death in trauma
- Coagulopathy is common - as much as 25-30% of trauma pts
  - Happens early, often prior to hospital arrival
  - Present in >50% pts with ISS >45; 80 - 100% of pts with GCS <6
  - causes: profound pro-inflammatory changes, consumptive coagulopathy
- Development of the lethal triad strongly associated with morbidity and mortality
- Damage Control Resuscitation specifically aimed at combating coagulopathy and lethal triad before they develop
  - early use of FFP, and platelets
  - 1:1:1 ratio of PRBC : FFP : Plt
  - Damage control surgery

J Trauma. 2007;62:307–310.

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Nothing new!

Minimizing Dilutional Coagulopathy in Exsanguinating Hemorrhage: A Computer Simulation

Asher Hirshberg, MD, Mark Dugas, DO, Eugenio I. Banez, MD, Bradford G. Scott, MD, Matthew J. Wall, Jr., MD, and Kenneth L. Mattox, MD

- Computer simulation model of hemodilution and hemorrhagic shock from 44pts
- Calculated changes in coagulation parameters over time
- Optimal transfusion ratios:
  - 3:2 PRBC : FFP
  - 5:4 PRBC : Platelets
- FFP Replacement after 3 or more units of PRBCs will not prevent coagulopathy

J Trauma. 2003;54:454–463.

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Impending Hemorrhagic Shock

- **Risk factors for Massive Transfusion**
  - **SBP < 110**
  - **HR > 105**
  - **HCT < 32**
  - **pH < 7.25**

85% chance of MT

Table 1 Suggested nonweighted, nonlaboratory scoring system to predict the need for massive transfusion

Assessment of Blood Consumption (ABC) score
ED systolic blood pressure ≤90 mmHg (0 = no, 1 = yes)
ED heart rate ≥120 b.p.m. (0 = no, 1 = yes)
Penetrating mechanism (0 = no, 1 = yes)
Positive fluid on abdominal ultrasound (0 = no, 1 = yes)
Score of 2 predicts 38% need for massive transfusion
Score of 3 predicts 45% need for massive transfusion
Score of 4 predicts 100% need for massive transfusion

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TABLE 1. Demographic Characteristics for MT Patients

Characteristic	Total
N	466
Overall survival	59%
Age (yr)	39 ± 18
Men (%)	76
Blunt injury, (%)	65
Admission SBP (mm Hg)	107 ± 33
Heart rate (bpm)	114 ± 28
Admission base deficit	−11.7 ± 7.7
pH	7.2 ± 0.2
INR	1.6 ± 0.9
Admission temperature (°C)	36 ± 1.3
Admission GCS	9 ± 5
Injury severity score	32 ± 16

SBP indicates systolic blood pressure; INR, international normalized ratio; GCS, glasgow coma score.

Holcomb et al. *J Trauma* 2008;248:445-458

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Acute Traumatic Coagulopathy

Karim Brohi, BSc, FRCS, FRCA, Jasmin Singh, MB, BS, BSc, Mischa Heron, MRCP, FFAEM, and Timothy Coats, MD, FRCS, FFAEM

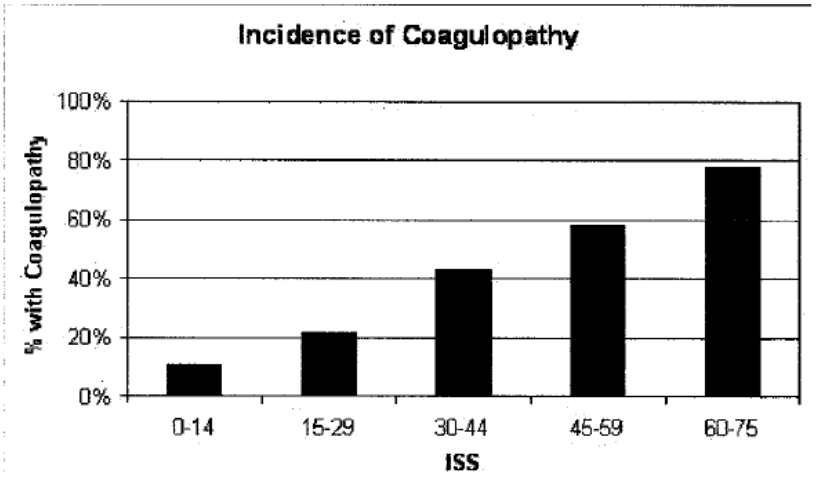

Fig. 1. *Incidence of coagulopathy. ISS, Injury Severity Score.*

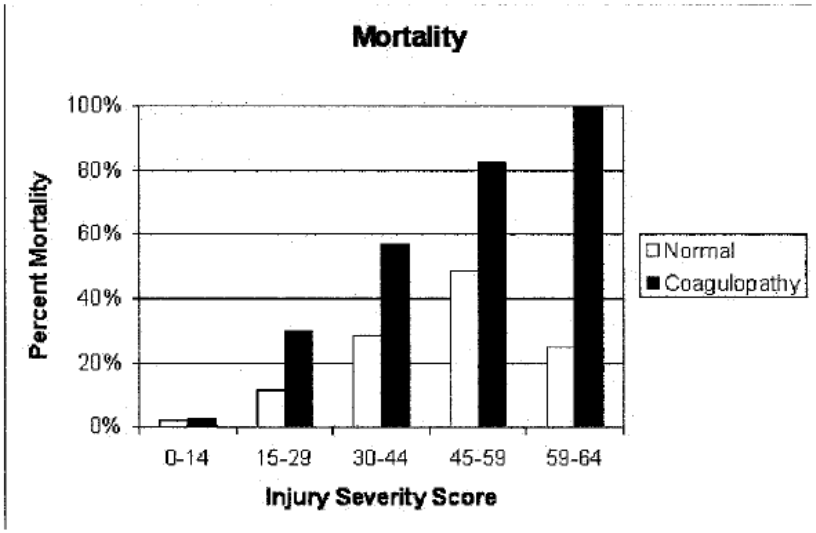

Fig. 2. *Mortality.*

- Coagulopathy is highly lethal (46 vs.. 10% mortality)
- Acute coagulopathy directly related to injury and not fluid administered

J Trauma. 2003;54:1127–1130.

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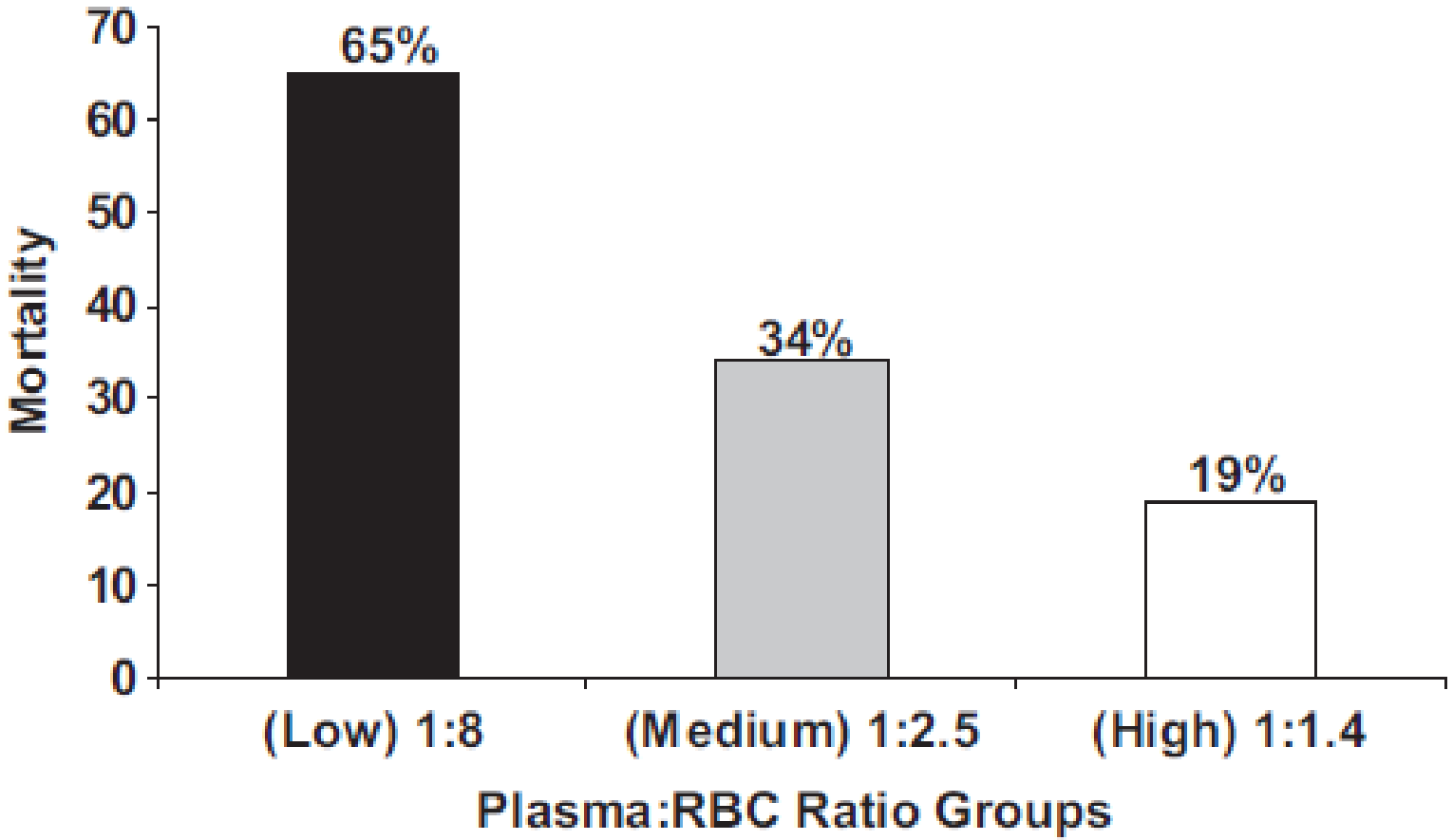
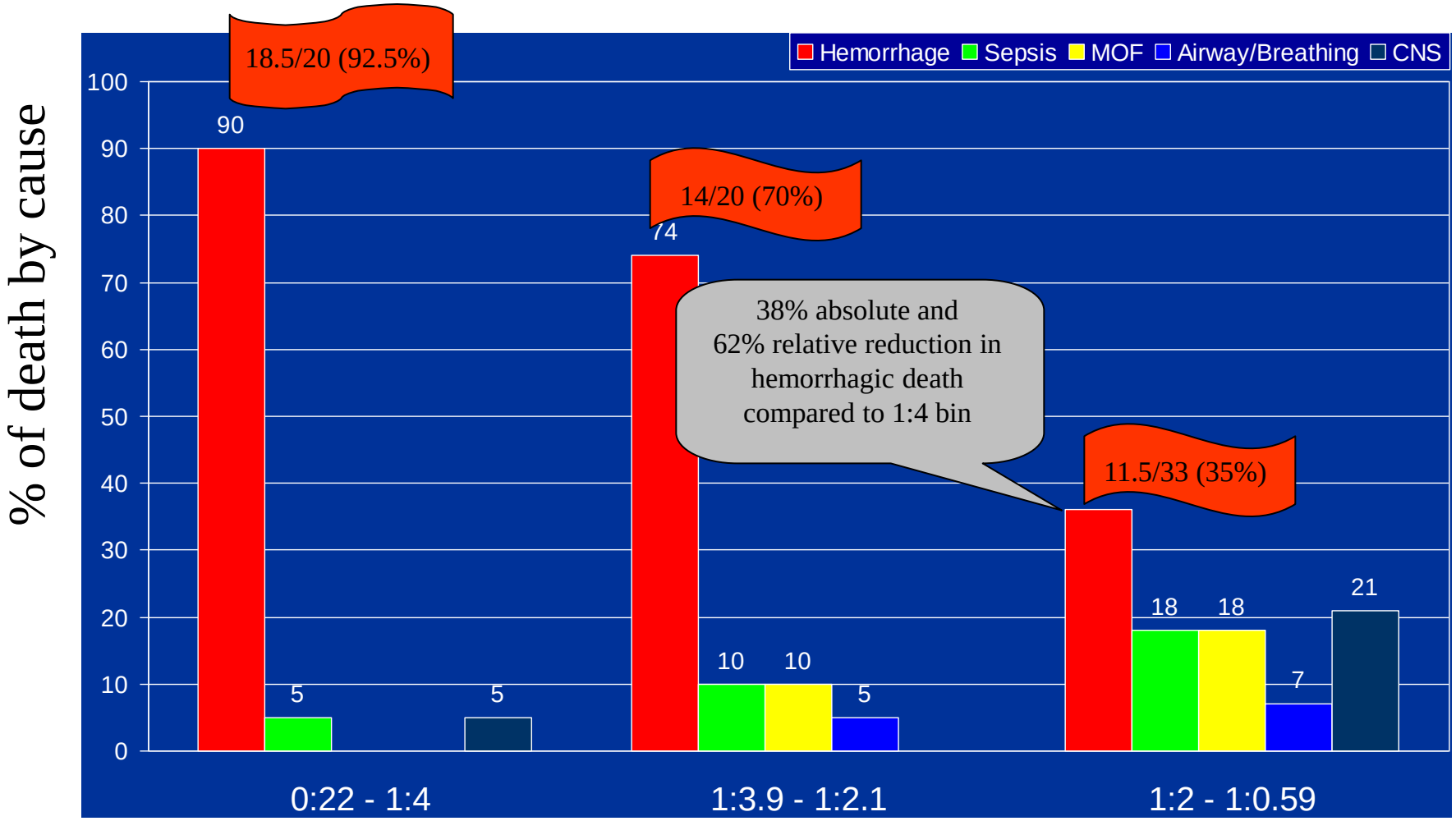
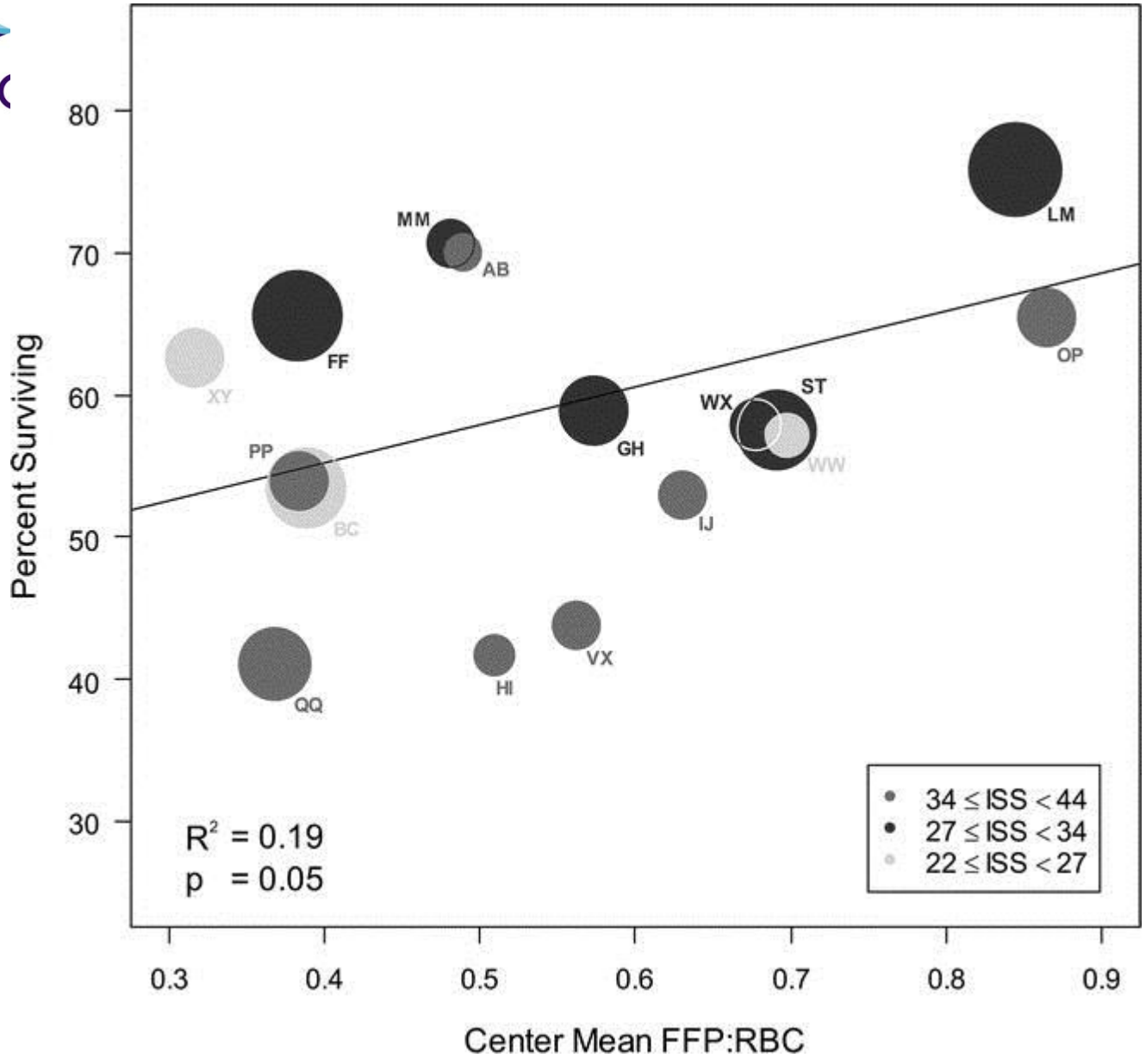
Effect of FFP:RBC Ratio on Overall Mortality



Borgman et al. *J Trauma*. 2007;63:805-813.

1:1 Ratio Decreases Death from Hemorrhage





Holcomb et al. *J Trauma* 2008;248:445-458

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Damage Control Resuscitation Is Associated With a Reduction in Resuscitation Volumes and Improvement in Survival in 390 Damage Control Laparotomy Patients

Bryan A. Cotton, MD, MPH,† Neeti Reddy, BS,† Quinton M. Hatch, MD,† Eric LeFebvre, BS,† Charles E. Wade, PhD,† Rosemary A. Kozar, MD, PhD,* Brijesh S. Gill, MD,* Rondel Albarado, MD,* Michelle K. McNutt, MD,* and John B. Holcomb, MD*†*

- Retrospective study of outcomes before and after implementation of DCR policy
- DCR patients did better:
  - less IVF (5 vs.. 14L)
  - fewer blood products used (PRBC, FFP, and Plts)
  - Less lethal triad on ICU admission (46 vs.. 80%)
  - Higher 24hr (97 vs. 88%) and 30d survival (86 vs.. 76%)

Ann Surg 2011;254:598–605

Crystalloid to packed red blood cell transfusion ratio in the massively transfused patient: When a little goes a long way

Matthew D. Neal, MD, Marcus K. Hoffman, MD, Joseph Cuschieri, MD, Joseph P. Minei, MD, Ronald V. Maier, MD, Brian G. Harbrecht, MD, Timothy R. Billiar, MD, Andrew B. Peitzman, MD, Ernest E. Moore, MD, Mitchell J. Cohen, MD, *and* Jason L. Sperry, MD, MPH, *Pittsburgh, Pennsylvania*

- Multicenter cohort study
- Blunt trauma pts with hemorrhagic shock
- Analyzed ratio of IVF (liters): PRBCs (units) in 1st 24hrs
- Ratio >1.5:1
  - 2x risk of multiple organ failure
  - 3x risk of ARDS
  - 4x risk of abdominal compartment syndrome
  - No effect on mortality

J Trauma. 2012;72: 892–898

Predefined Massive Transfusion Protocols are Associated With a Reduction in Organ Failure and Postinjury Complications

Bryan A. Cotton, MD, Brigham K. Au, BS, Timothy C. Nunez, MD, Oliver L. Gunter, MD, Amy M. Robertson, MD, and Pampee P. Young, MD, PhD

- Pre- and post- DCR protocol assessment
- All pt required MT
- DCR protocol - 3:2 PRBC:FFP, and 5:1 PRBC:Plts
- DCR pts: more plasma and platelets in OR, but overall less in 1st 24hrs
- No difference 24hr mortality; dramatic improvement 30d mortality (57 vs.. 37%)
- fewer ventilator days
- reduction in sepsis and MOF with DCR
- Less abd compartment syndrome and better able to close abdomen in DCR pts

Developing Multiple Organ Failure

	Odds Ratio	95% CI	*p*
Received TEP	**0.20**	**0.106–0.395**	**<0.001**
Age	1.00	0.986–1.020	0.732
Gender	1.00	0.795–1.267	0.971
ISS	0.997	0.979–1.017	0.831
w-RTS	0.999	0.891–1.120	0.996
Total 24-h blood products (units)	1.01	1.000–1.024	0.045

TEP, trauma exsanguination protocol; ISS, Injury severity score; w-RTS, weighted revised trauma score.

Table 6 Multivariate Regression Model for the Odds of Achieving Primary Abdominal Fascial Closure by Day 7

	Odds Ratio	95% CI	*p*
Received TEP	**5.61**	**2.476–12.723**	**<0.001**
Age	1.00	0.981–1.019	0.992
Male	0.99	0.725–1.355	0.959
ISS	1.00	0.986–1.032	0.414
w-RTS	0.88	0.773–1.002	0.056
Total 24-h blood products (units)	0.98	0.957–1.039	0.208

TEP, trauma exsanguination protocol; ISS, Injury Severity Score; w-RTS, weighted revised trauma score.

Is DCR really that great?

The Relationship of Blood Product Ratio to Mortality: Survival Benefit or Survival Bias?

Christopher W. Snyder, MD, Jordan A. Weinberg, MD, Gerald McGwin, Jr., MS, PhD, Sherry M. Melton, MD, Richard L. George, MD, Donald A. Reiff, MD, James M. Cross, MD, Jennifer Hubbard-Brown, BS, Loring W. Rue, III, MD, and Jeffrey D. Kerby, MD, PhD

- Looked at effect of time and PRBC:FFP ratio
- Odds of death lower at 24hrs if ratio 1:1
- At 6hrs, no benefit existed!
- Takes some time to thaw FFP; typical MT given large volumes of PRBCs 1st, with only modest FFP given initially as it thaws
- Survival bias: only pts who survive live long enough for ratio to catch up to 1:1 by 24hrs
- Study done prior to newer protocols with pre-thawed FFP in ER

Debunking the survival bias myth: Characterization of mortality during the initial 24 hours for patients requiring massive transfusion

Joshua B. Brown, MD, Mitchell J. Cohen, MD, Joseph P. Minei, MD, Ronald V. Maier, MD, Micheal A. West, MD, Timothy R. Billiar, MD, Andrew B. Peitzman, MD, Ernest E. Moore, MD, Joseph Cushieri, MD, Jason L. Sperry, MD, MPH, *and* **The Inflammation and the Host Response to Injury Investigators,** *Pittsburgh, Pennsylvania*

- multi-center cohort study, blunt trauma with hemorrhagic shock; 604 pts
- Compared ratios (high vs.. low) of PRBC : FFP at 6, 12, 24hrs to mortality
- mortality reduced by 50% at 6, 12, 24 hrs if ratio of PRBC : FFP was > 1:1.5
- dose response relationship seen (1:1 was better than 1:1.5, etc...)

J Trauma Acute Care Surg. 2012;73: 358–364.

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6 Hour Ratio Study

Table 3 Mortality differences and respiratory outcome based on the ratio of blood products

Product	Transfusion ratio in first 6 h			*P*
Ratio				<.001
Measure	<1:4	1:4-1:1	≥1:1	
6-h mortality %	37.3*	15.2*	2.0*	
FFP:PRBC				
In-hospital mortality %	54.9*	41.1*	25.5*	<.04
Ventilator free days†	9	7.9	6.3	.35
6 h mortality %	22.8	19.0	3.2*	<.002
PLT:PRBC				
In-hospital mortality %	43.7	46.8	27.4*	<.03
Ventilator-free days‡	6*	9.9†	9.1†	<.004

*Significant difference from other 2 ratios.

†P = nonsignificant (.79).

‡Massive transfusion patients who survived >30 days (n = 277), Fisher exact test.

Zink et al *Am J Surg* 2009;197:565-570

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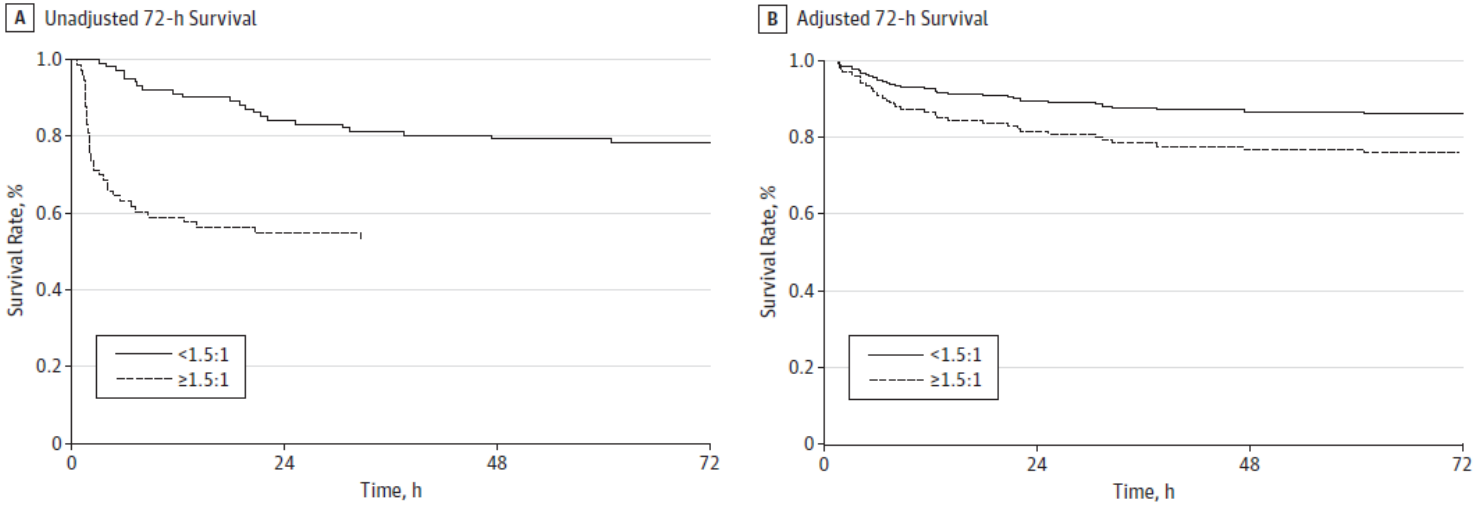
A Paradigm Shift in Trauma Resuscitation
Evaluation of Evolving Massive Transfusion Practices

Matthew E. Kutcher, MD; Lucy Z. Kornblith, MD; Raja Narayan, BA; Vivian Curd, RN; Aaron T. Daley, MA; Brittney J. Redick, BA; Mary F. Nelson, RN, MPA; Eberhard W. Fiebig, MD; Mitchell J. Cohen, MD

Figure 2. Unadjusted and Adjusted Survival Plots



Kaplan-Meier 72-hour survival plots based on the red blood cell (RBC) to fresh frozen plasma (FFP) ratio transfused within 24 hours of admission are shown for unadjusted survival ($P < .001$ determined by log-rank test) (A) and adjusted for age, Injury Severity Score, Glasgow Coma Scale score, and base deficit at admission using Cox proportional hazards regression (B). The Harrell C index was 0.808 for the adjustment model. By convention, the solid line indicates a plasma-based ratio (RBC:FFP ratio < 1.5:1), and the dashed line indicates an erythrocyte-based ratio (RBC:FFP ratio ≥ 1.5:1).

- Each decrease in PRBC:FFP ratio by 0.1, reduced mortality by 5.6%

JAMA Surg. 2013;148(9):834-840. doi:10.1001/jamasurg.2013.2911
Published online July 17, 2013.

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Ten-year analysis of transfusion in Operation Iraqi Freedom and Operation Enduring Freedom: Increased plasma and platelet use correlates with improved survival

Heather F. Pidcoke, MD, James K. Aden, PhD, Alejandra G. Mora, Matthew A. Borgman, MD, Philip C. Spinella, MD, Michael A. Dubick, PhD, Lorne H. Blackbourne, MD, Andrew P. Cap, MD, PhD

- All soldiers who received at least 1u blood product(s)
- 33% had INR >1.5 on presentation
  - 5x increased risk of mortality
  - Association with need for Massive Transfusion
- Higher ratios of PRBCs to FFP and platelets saved more lives
- No effect on decreasing blood product utilization

(*J Trauma Acute Care Surg*. 2012;73: S445–S452.

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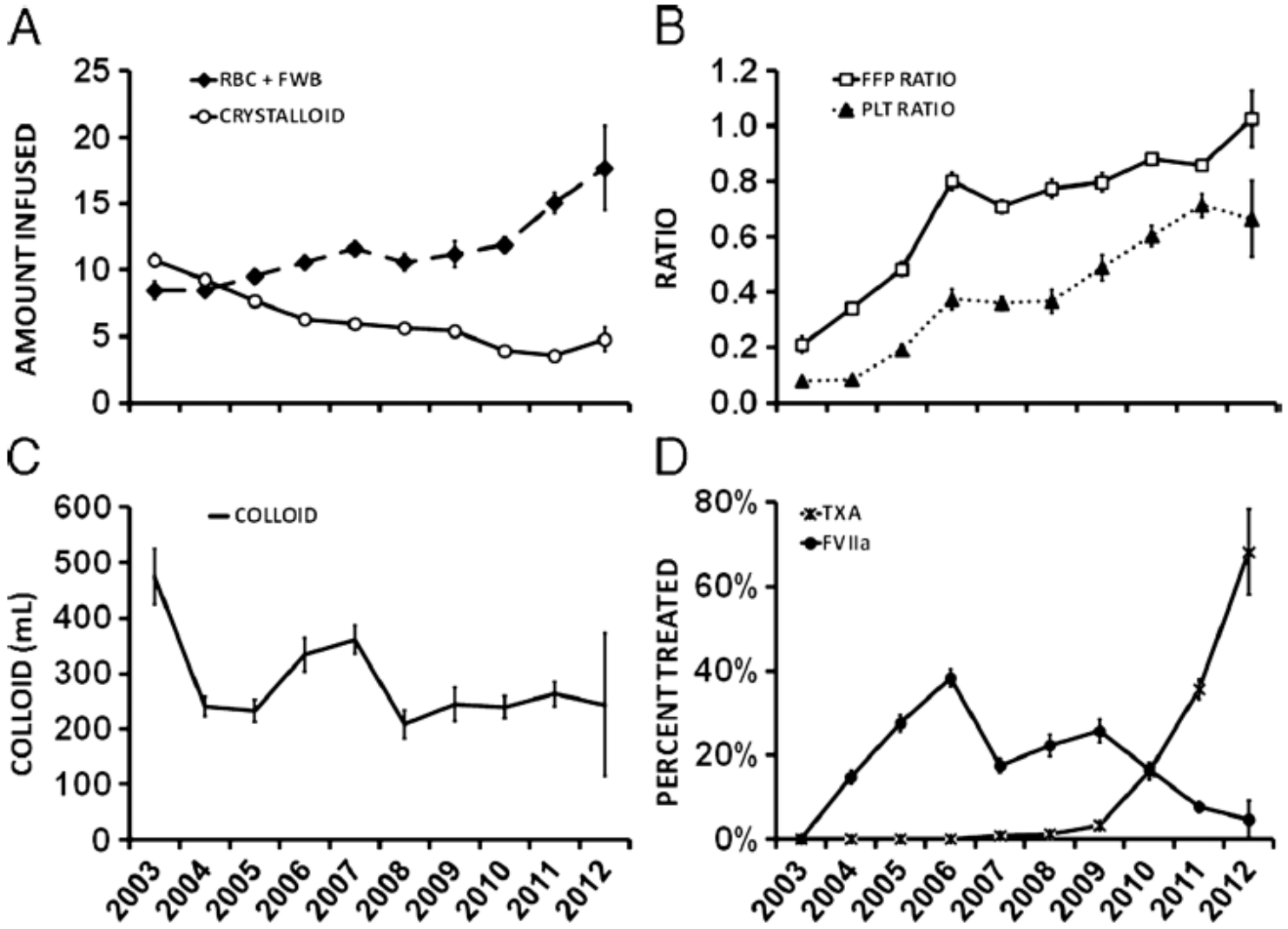

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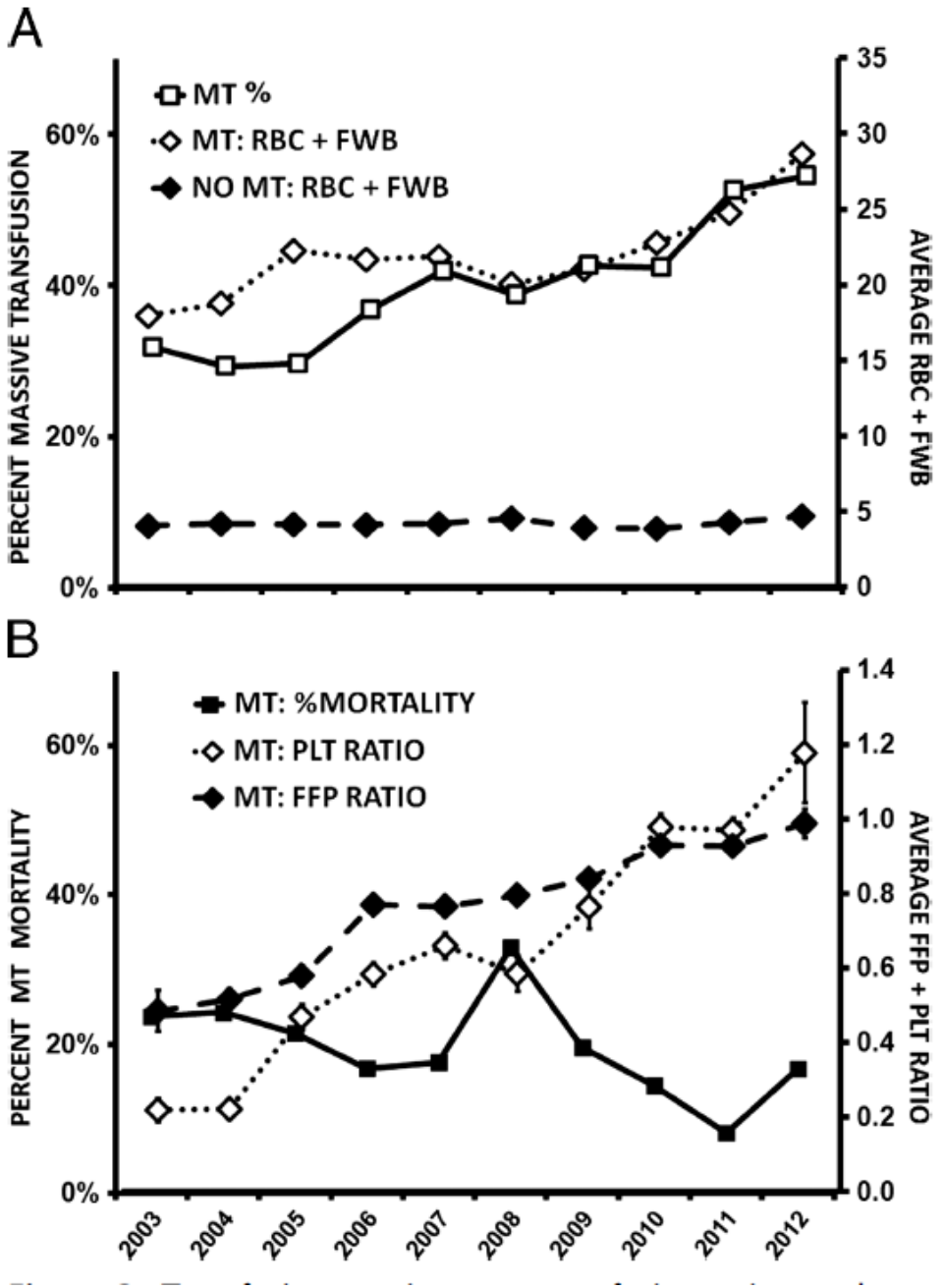

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Transfusion of Plasma, Platelets, and Red Blood Cells in a 1:1:1 vs a 1:1:2 Ratio and Mortality in Patients With Severe Trauma

The PROPPR Randomized Clinical Trial

- Is 1:1:1 really important or does 1:1:2 work just as well?
  - Plt : FFP : PRBCs
- PROMMTT study demonstrated that ratios <1:2 in first 6hrs were associated with 3-4x mortality compared to 1:1
- RCT, 680 pts at12 Level I trauma centers
- No mortality difference at 24hrs or 30d
- 1:1:1 group had better hemostasis, and fewer deaths from exsanguination at 24hrs
- No difference in complications (ARDS, MOF, CHF, PNA, etc…)
- 1:1:1 is safe, and reduces exsanguination with no effect on mortality

JAMA. 2015;313(5):471-482
JAMA Surg. 2013;148(2):127-136.

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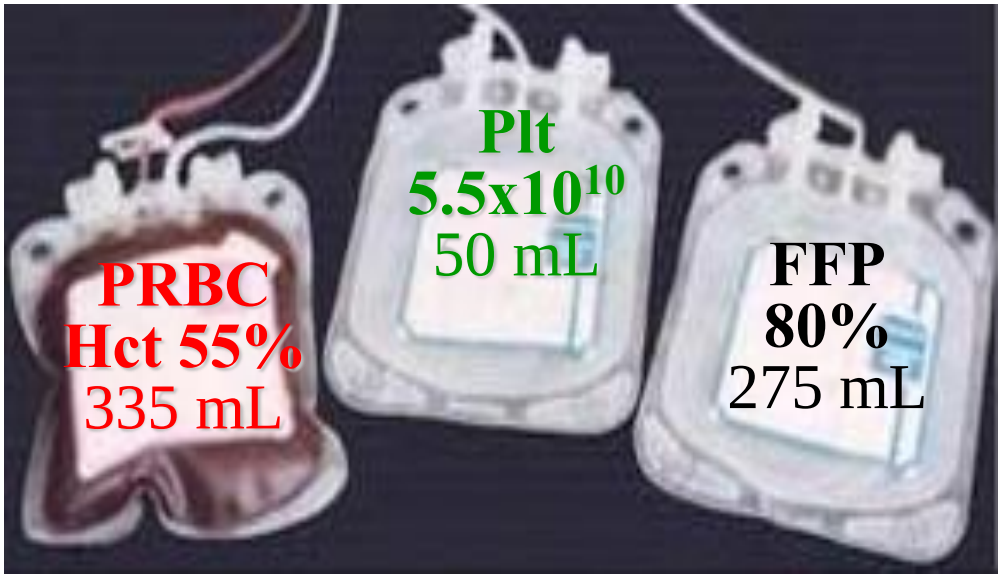
High Ratios of Plasma and Platelets to Packed Red Blood Cells Do Not Affect Mortality in Nonmassively Transfused Patients

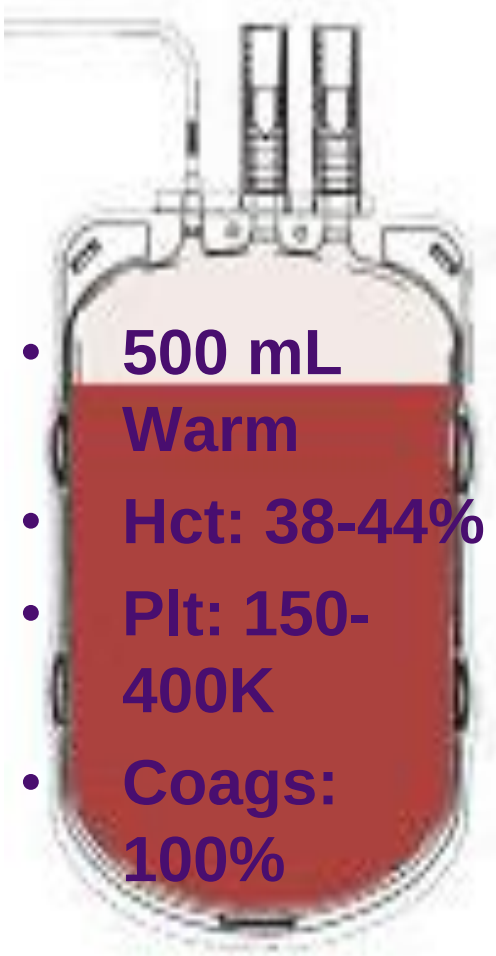
Chitra N. Sambasivan, MD, Nicholas R. Kunio, MD, Prakash V. Nair, MS, Karen A. Zink, MD, Joel E. Michalek, PhD, John B. Holcomb, MD, Martin A. Schreiber, MD, and the Trauma Outcomes Group

- 1788 trauma pts without MT, retrospective review
- No difference in mortality at variety of ratios
- trend towards more ventilator days, and longer ICU stay with 1:1 ratio
- DCR and 1:1 ratio should be quickly stopped when it is clear that a pt does not require MT

J Trauma. 2011;71: S329–S336

Component Therapy vs. Whole Blood





- 500 mL
- Warm
- Hct: 38-44%
- Plt: 150-400K
- Coags: 100%

So Component Therapy Gives You

1U PRBC + 6U PLT + 1U FFP + 10 pk Cryo

- ***Hct 29%***
- ***Plt 87K***
- ***Coag activity 65%***
- ***750 mg fibrinogen***

Armand & Hess, Transfusion Med. Rev., 2003

1500 mg Fibrinogen

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Questions?

- Michael Englehart, MD
- MEnglehart@billingsclinic.org
- 406-238-2321
- Gordon Riha, MD
- GRiha@billingsclinic.org
- 406-238-5361