Outcomes of Traumatic Hemorrhagic Shock and the Epidemiology of Preventable Death from Injury

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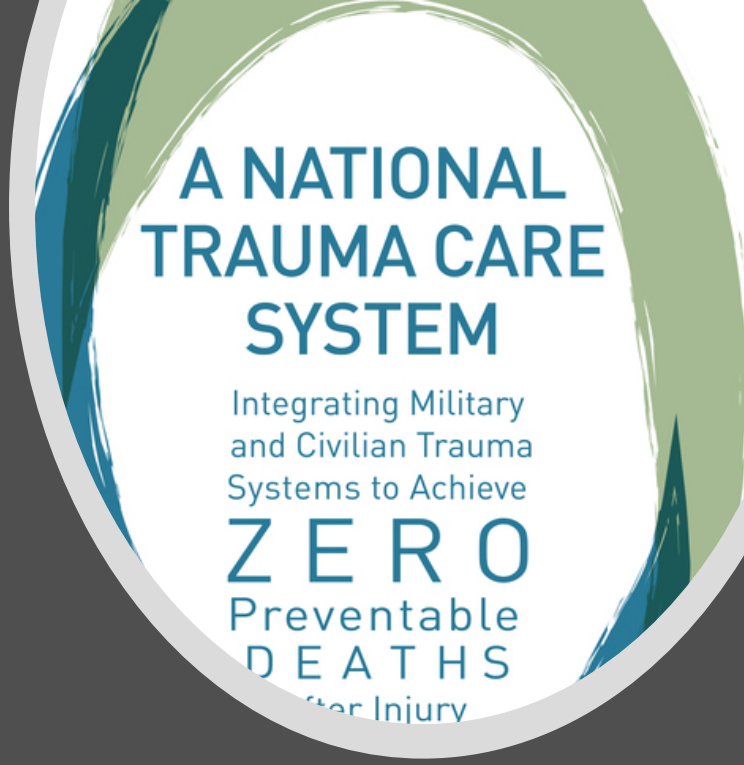
National Trauma System Vision

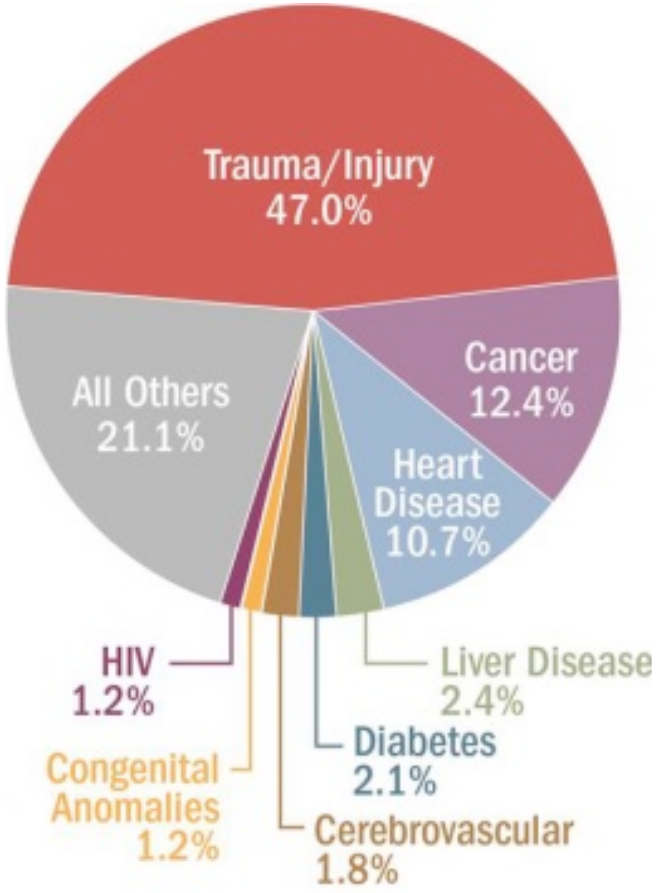
A unified effort is needed to ensure the delivery of optimal trauma care to save the lives of Americans injured within the United States and on the *battlefield.*

*Predicated upon estimates of potentially preventable injury death



Trauma System Scope of the Problem

- Potentially survivable injuries US military operations
  - 1,273 / 4,574 (27.6%)
- Potentially survivable injuries US civilian population 2014
  - 147,790 x 0.276 = 40,790
- Europe and Australia similar rates



PREHOSPITAL INJURY MORTALITY

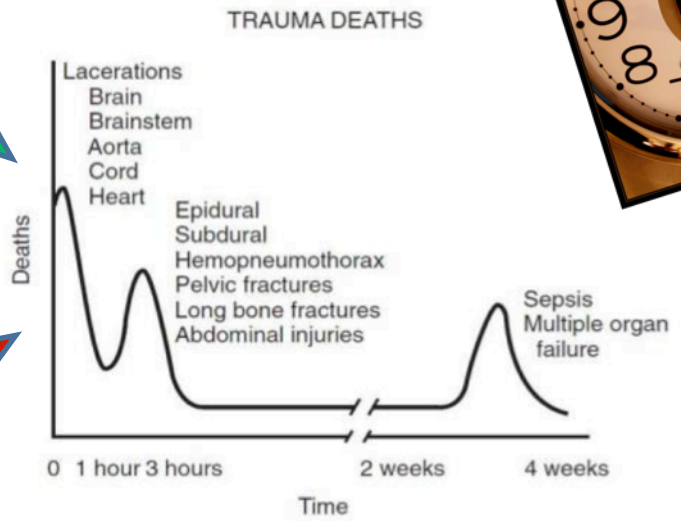
Impact potential for RDCR

Background/Scientific Rationale Pre-Hospital Mortality Civilian

Impact Not Well Quantitated

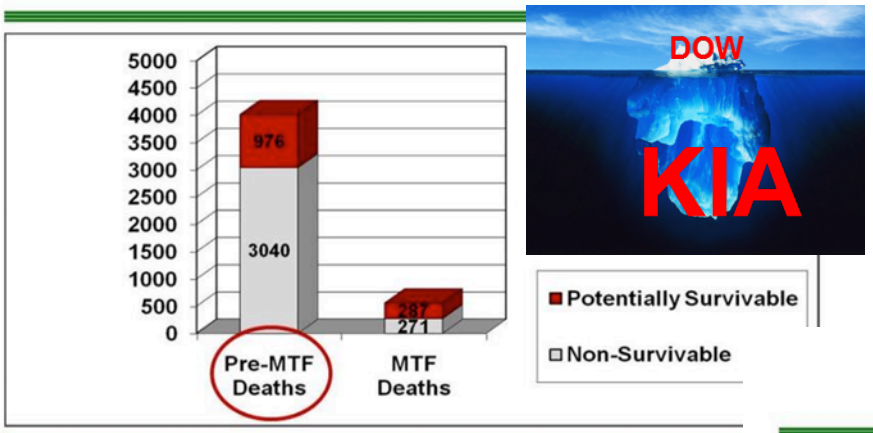
Potential Survivability Poorly Defined

NASEM Report Emphasis



Background/Scientific Rationale PreHospital Mortality Combat

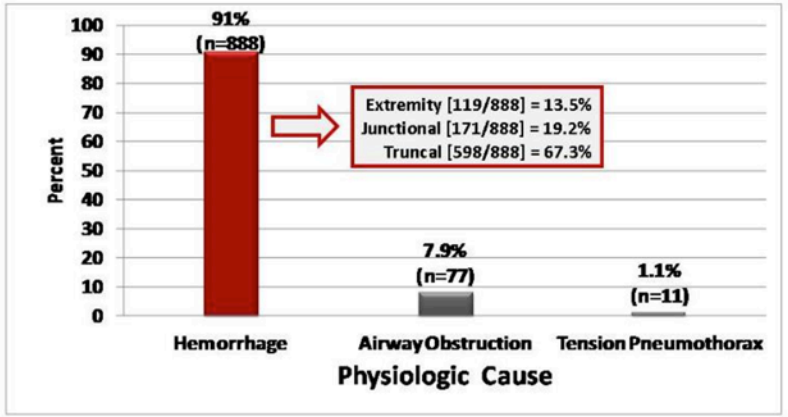
Where Can We Save the Most Lives?



Eastridge BJ, Mabry RL, Seguin PG, et al. Death on the battlefield (2001-2011): implications for the fut combat casualty care. Journal of Trauma 2012, 73(6) Suppl 5: 431-7.

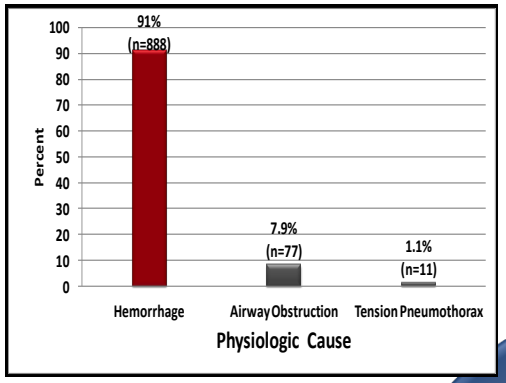
Eastridge BJ, Hardin M, Cantrell J, et al. Died of wounds on the battlefield: causation and implications improving combat casualty care. Journal of Trauma 2011. 71(Suppl 1):4-8.

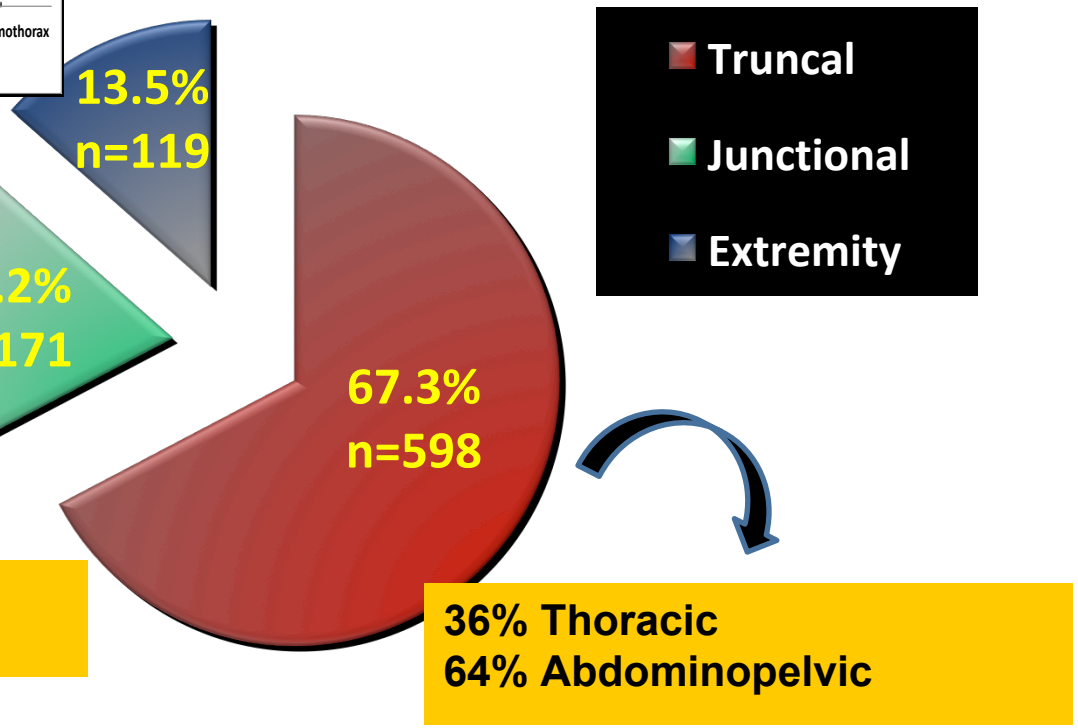
What were the Causes of Preventable Death?



Eastridge BJ, Mabry RL, Seguin PG, et al. Death on the battlefield (2001-2011): implications for the future of combat casualty care. Journal of Trauma 2012, 73(6) Suppl 5: 431-7.

Anatomic / Physiologic Cause of Death





Eastridge BJ, Mabry RL, Seguin PG, et al. Death on the battlefield (2001-2011): implications for the future of combat casualty care. Journal of Trauma, 2012. In press.

TRANSITIONAL INJURY MORTALITY FROM FIELD TO HOSPITAL

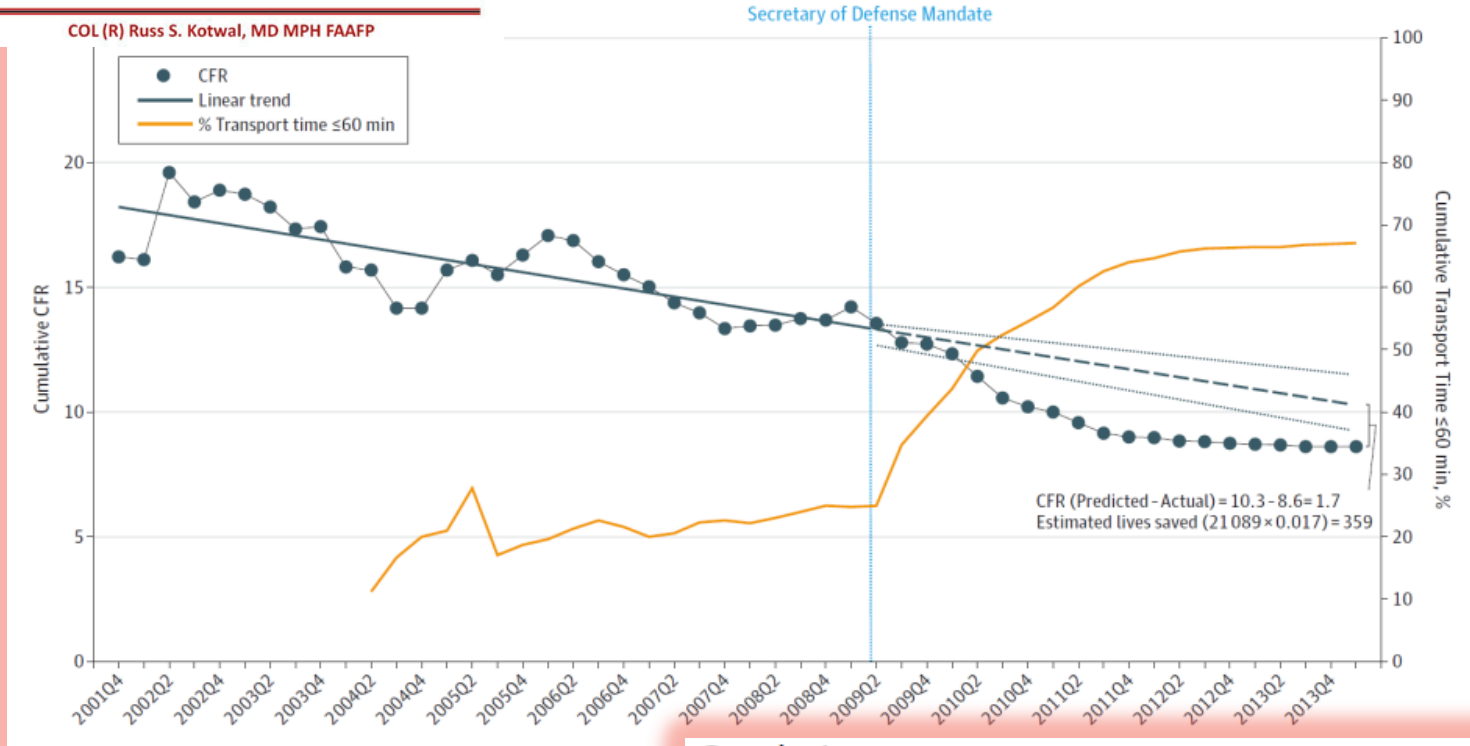
Impact potential for RDCR & continuing DCR

Abstract Presentation for:
Committee on Tactical Combat Casualty Care Meeting
Atlanta, Georgia – February 4, 2015

Saving Lives on the Battlefield:
The Golden Hour and the Gates Effect

COL (R) Russ S. Kotwal, MD MPH FAAFP

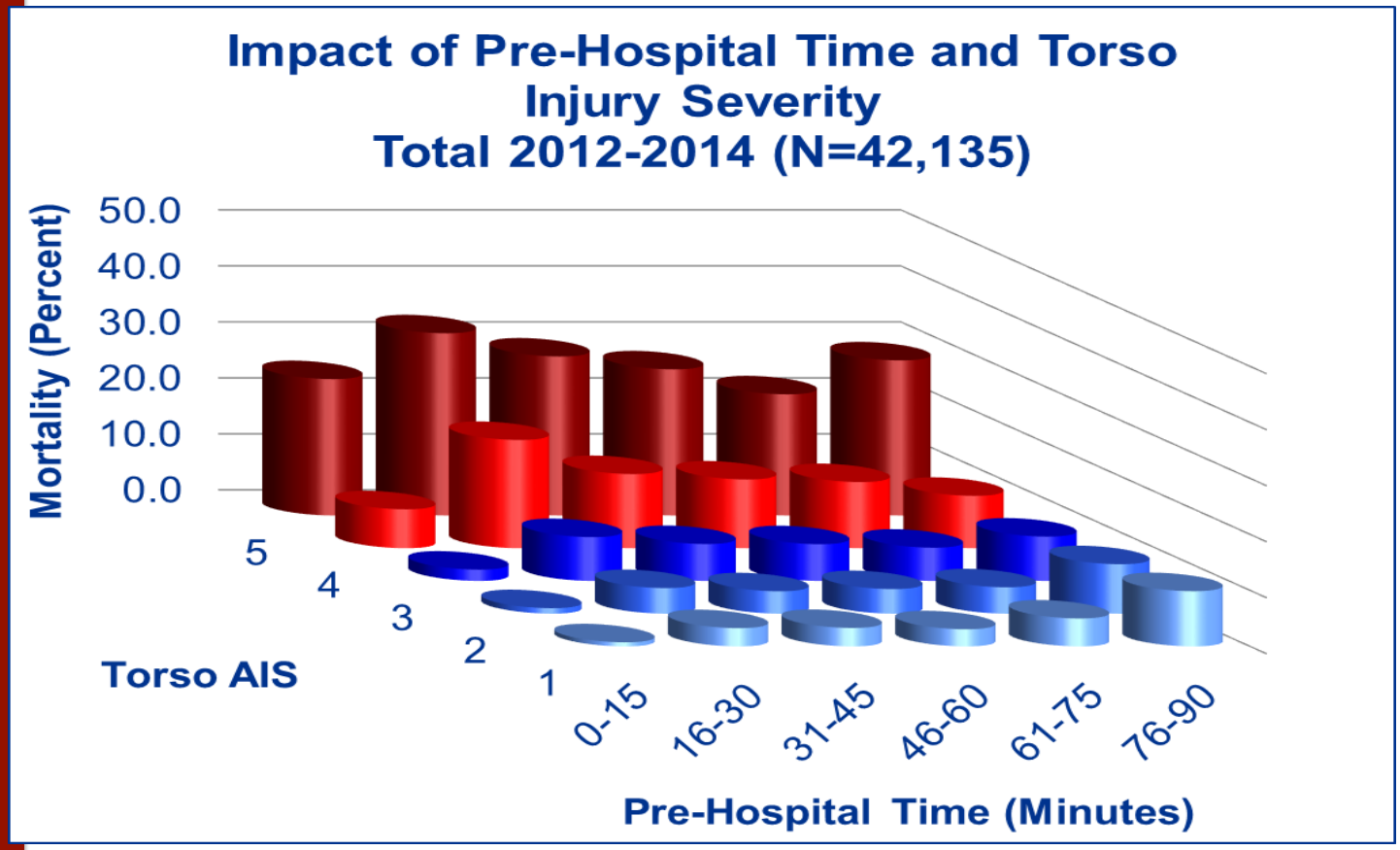
Gates Effect



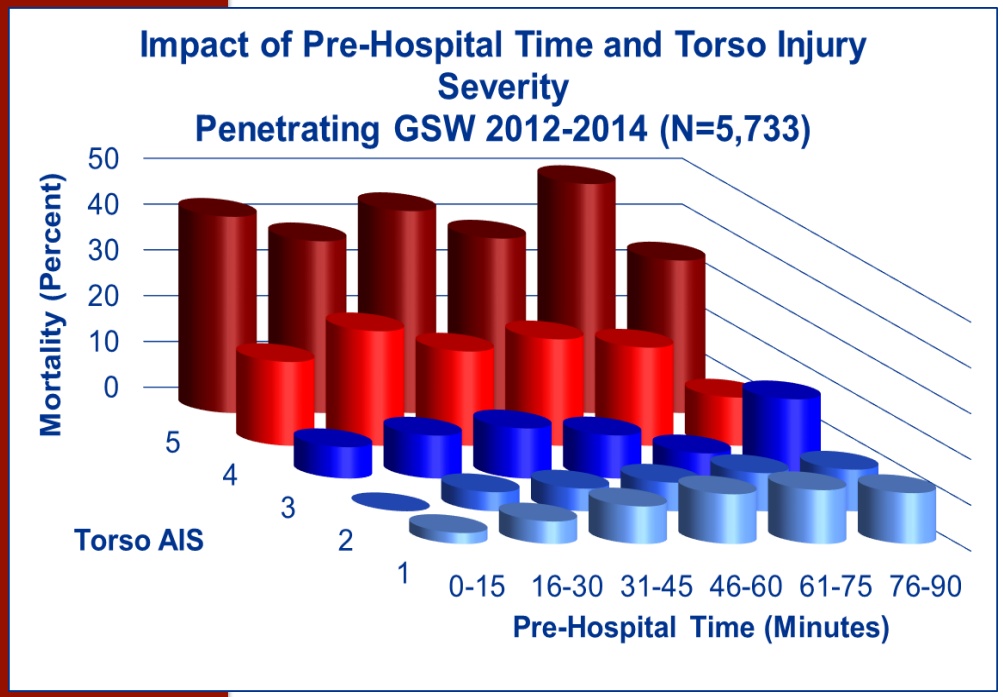
Conclusions

A 2009 mandate by Secretary of Defense Gates reduced the time between critical injury and definitive care for combat casualties in Afghanistan. Despite evidence of increased severity and complexity of wounds from explosive devices, the combination of reduced prehospital transport time and increased treatment capability are likely contributors of casualty survival.

Prehospital Time
Noncompressible Torso Hemorrhage (All)



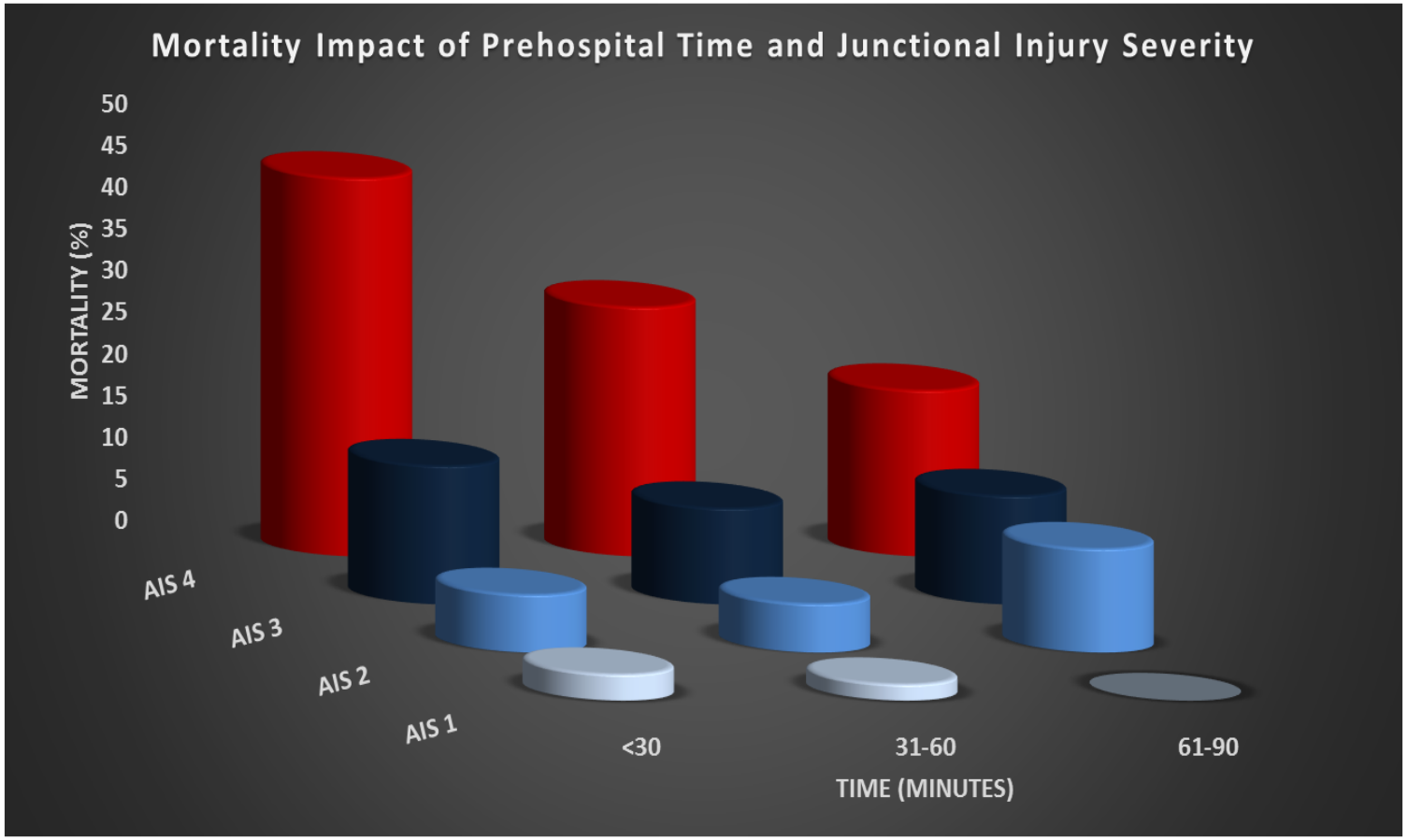
Time is the Enemy
Prehospital Time in Noncompressible Torso Hemorrhage (GSW)



Alarhayem, Eastridge, et al: Mortality in Trauma Patients with Hemorrhage from Torso Injury Occurs Long Before the "Golden Hour" Am J Surg 2016

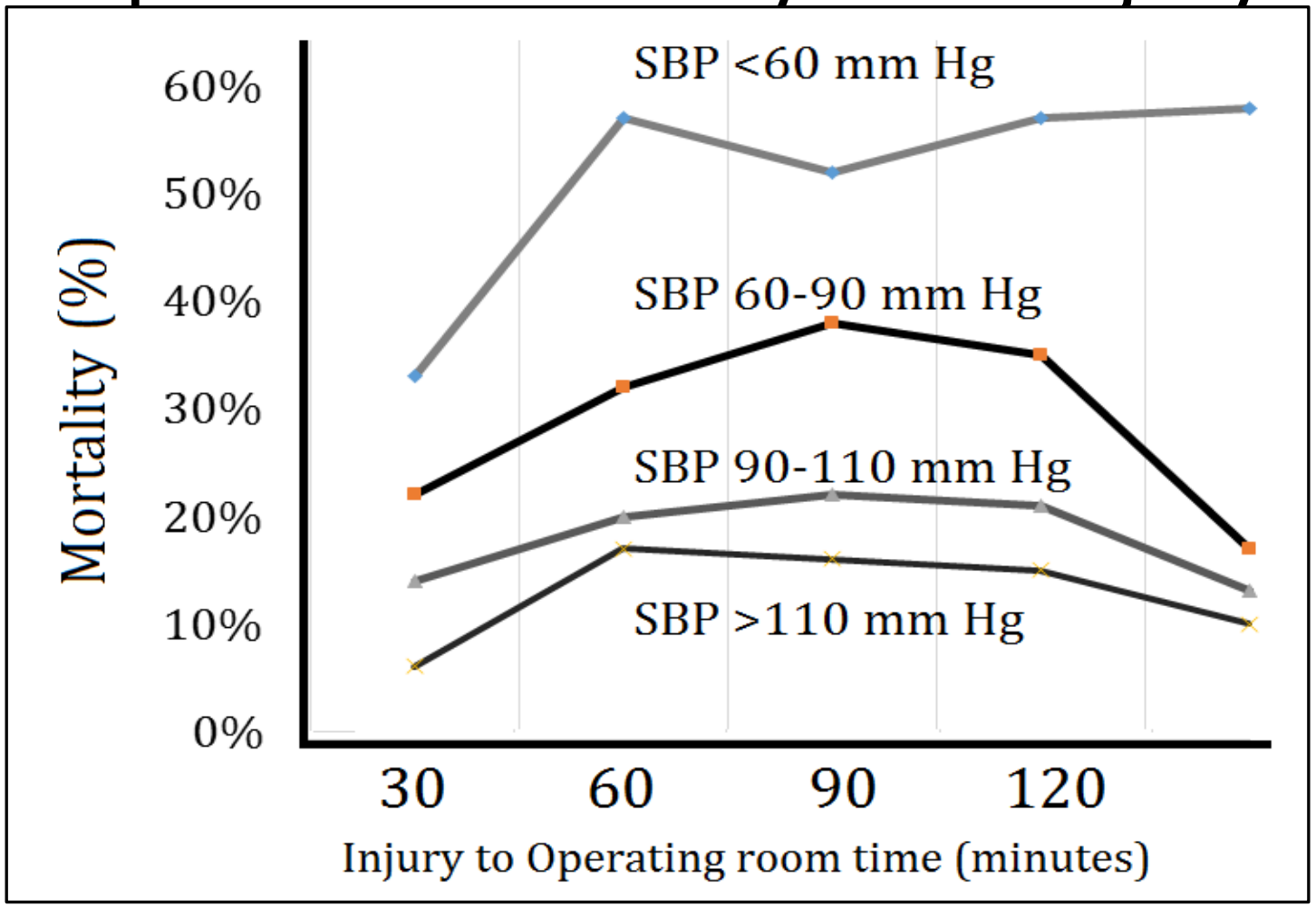
- High grade torso injury, AIS grades ≥ 4, associated with significant hemorrhage.
- Rise in patient mortality was exhibited in high grade injury demonstrated at prehospital times < 30 minutes
- Highlights critical nature of prehospital time in patients with non-compressible torso hemorrhage.
- Evacuation times < 30 minutes not realistic, particularly in rural or austere environments,
- Future efforts should be directed toward the development of therapies to increase the window of survival in the prehospital environment.

Junctional Hemorrhage and Prehospital Time Impact on Injury Mortality



Alarhayem, Eastridge: Highlighting the Need for Novel Strategies to Control Complex Sources of Hemorrhage and Temporize Survival to Definitive Care. Presented MHSRS 2016

SBP and Time to OR
Impact on Mortality after Injury

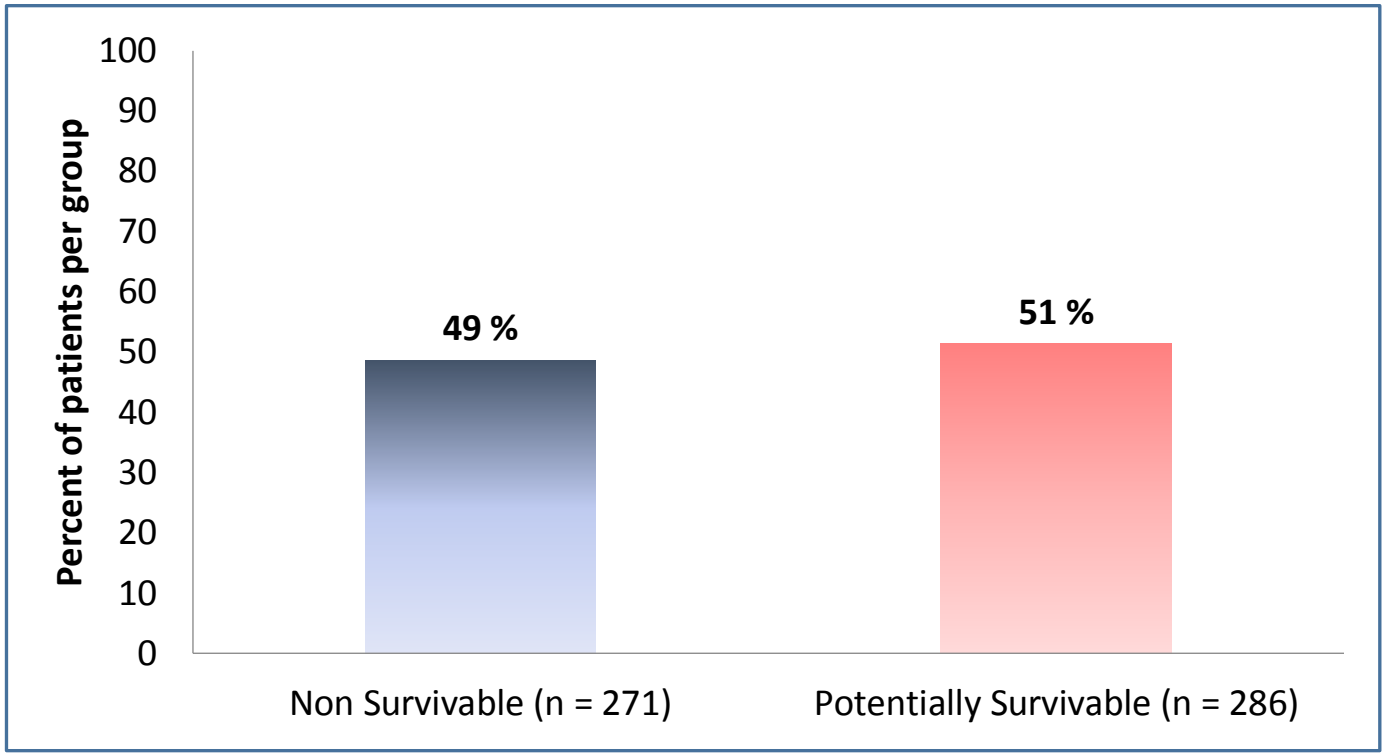


Alarhayem, Eastridge: No Time to Bleed. Presented at Southwestern Surgical Congress 2017

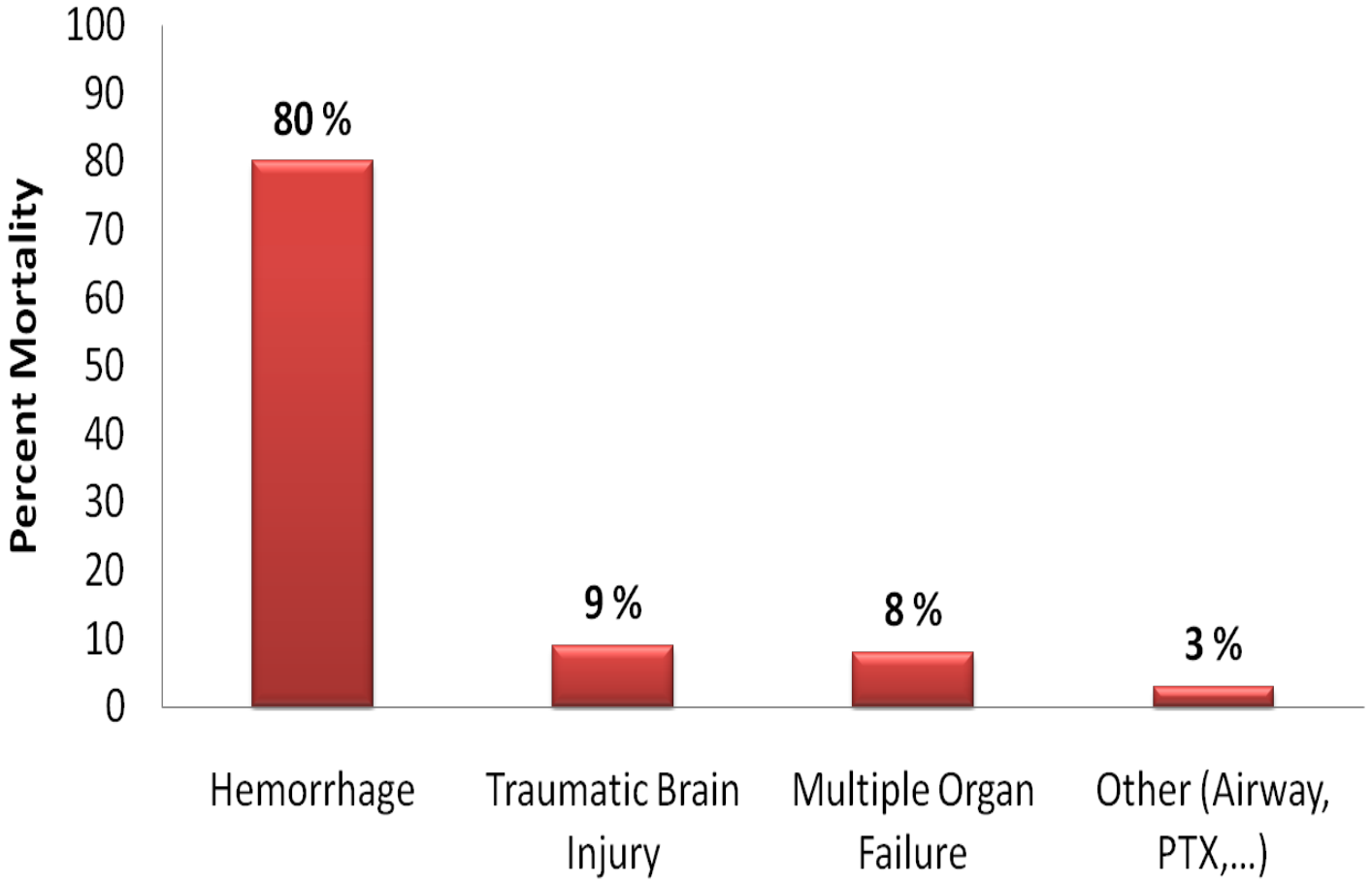
HOSPITAL INJURY MORTALITY

Impact potential for DCR

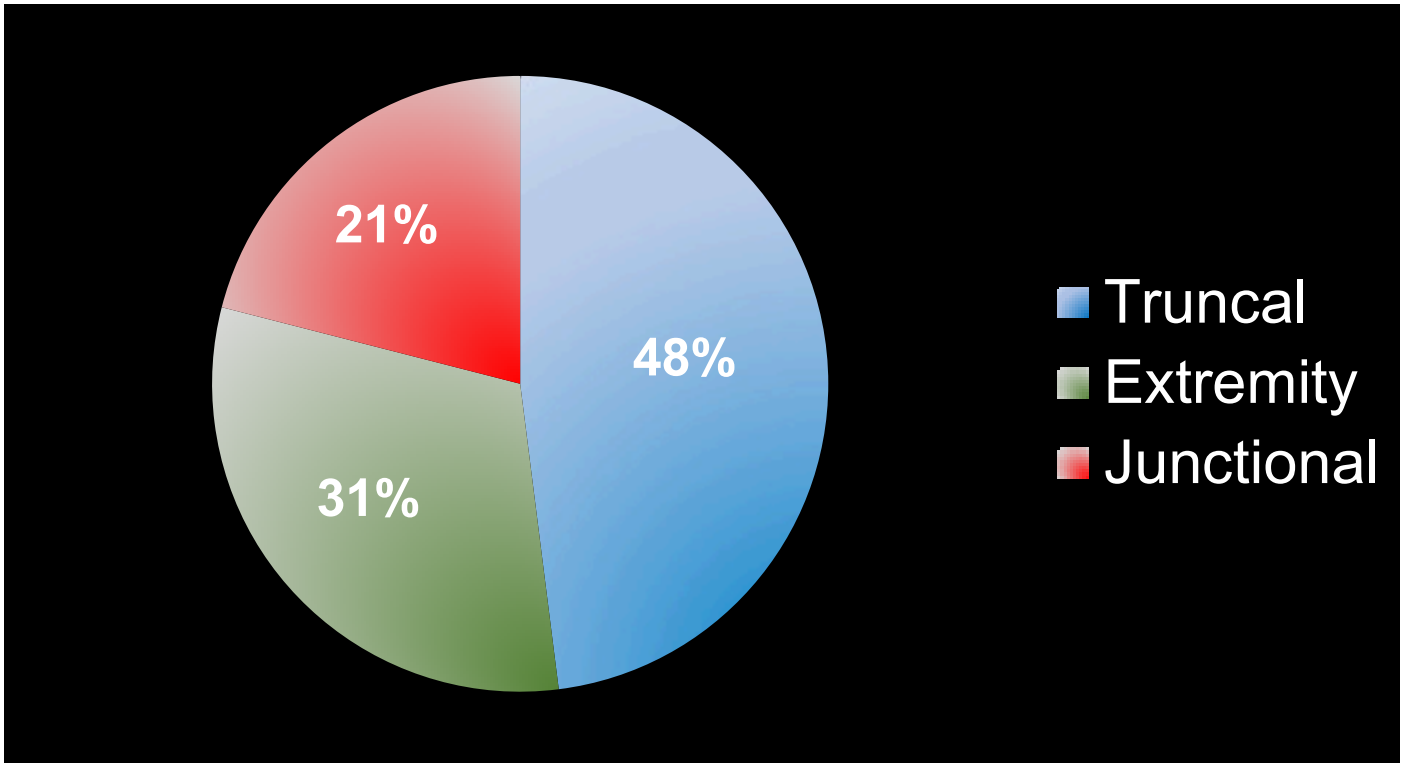
Classification
Potentially Preventable DOW



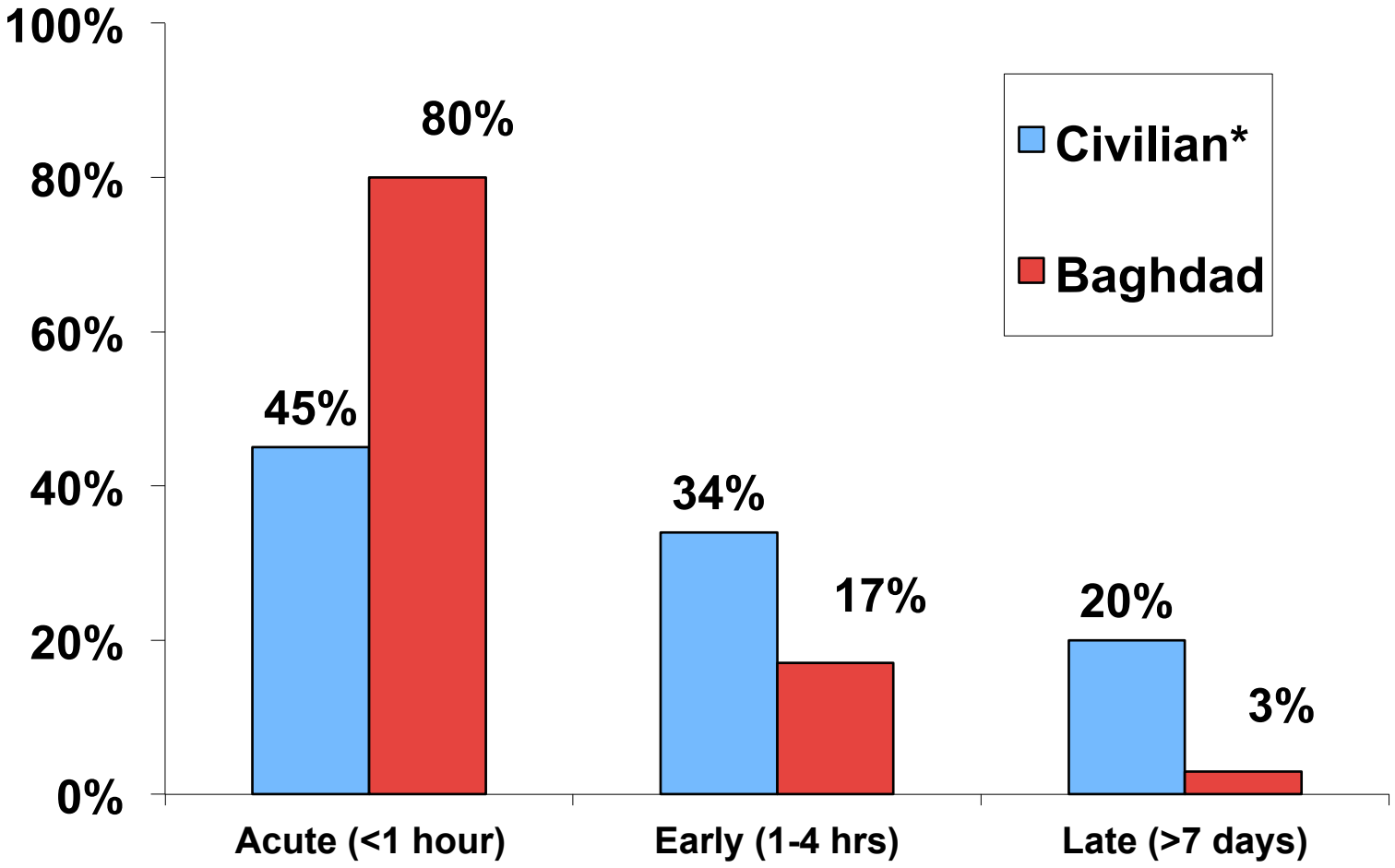
Potentially Survivable Death Causality



Potentially Preventable Hemorrhage Mortality Causality by Anatomic Region

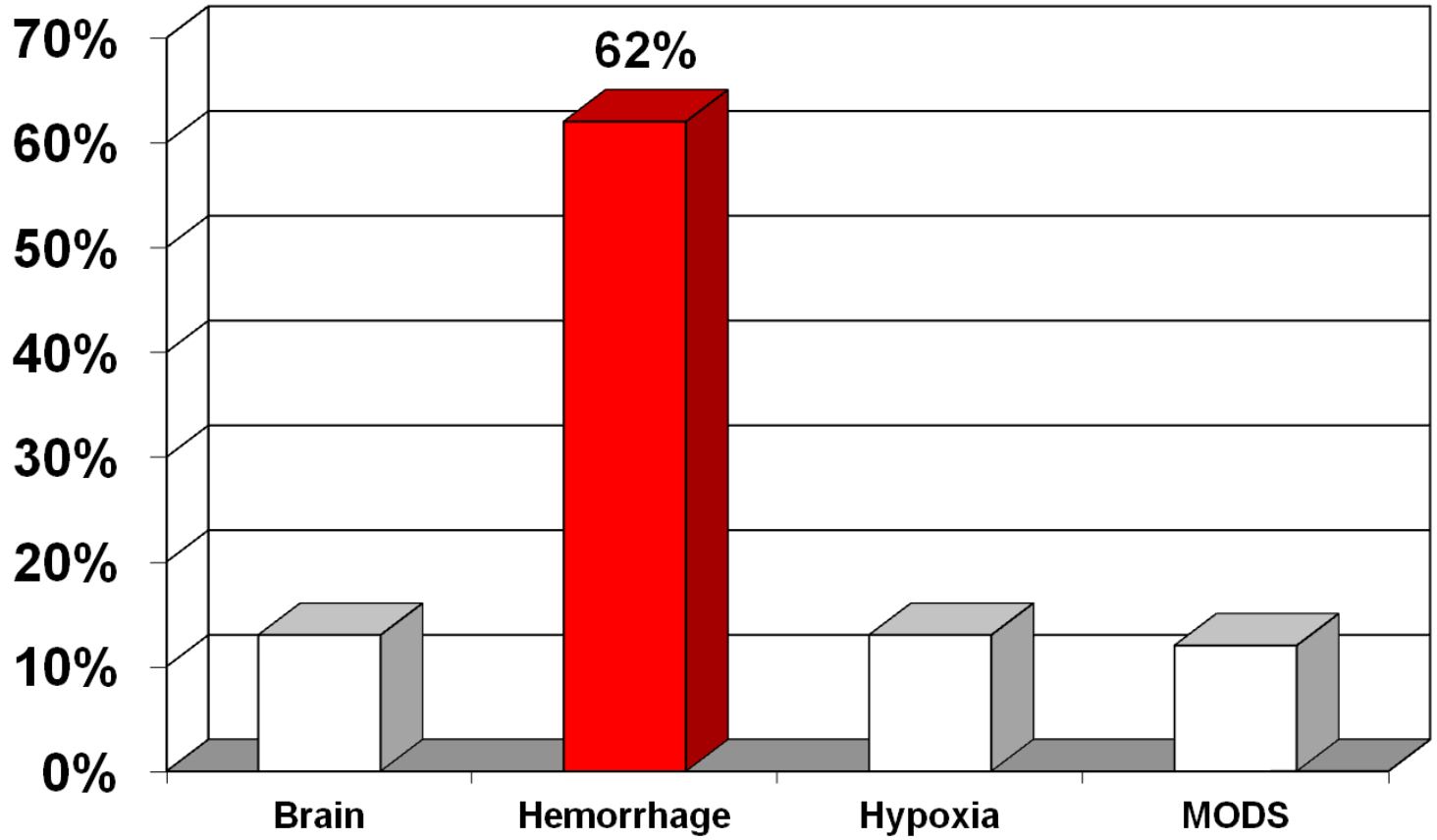


Timing of Trauma Death



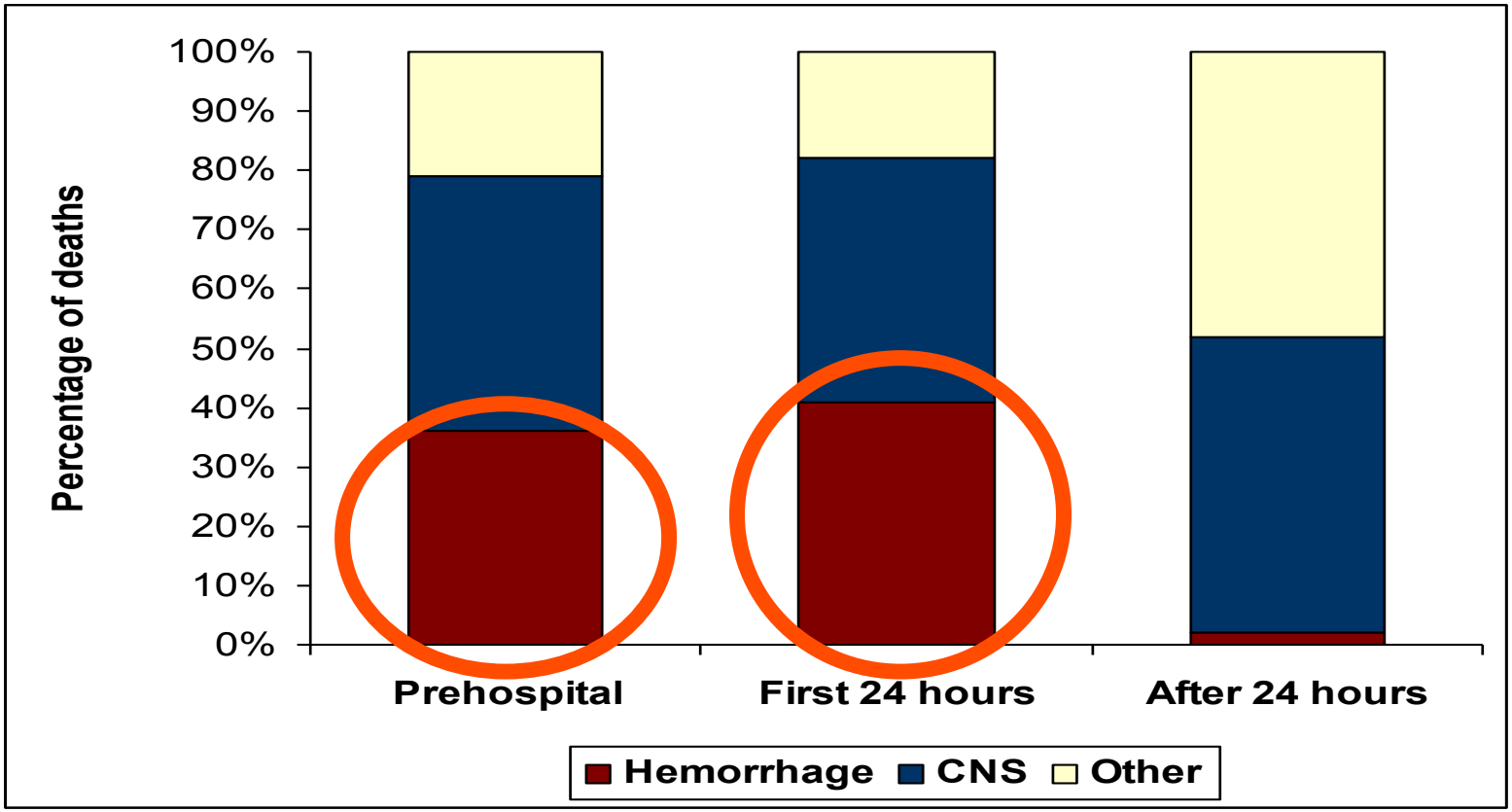
Martin et al., J Trauma 2009

Combat Hospital Death



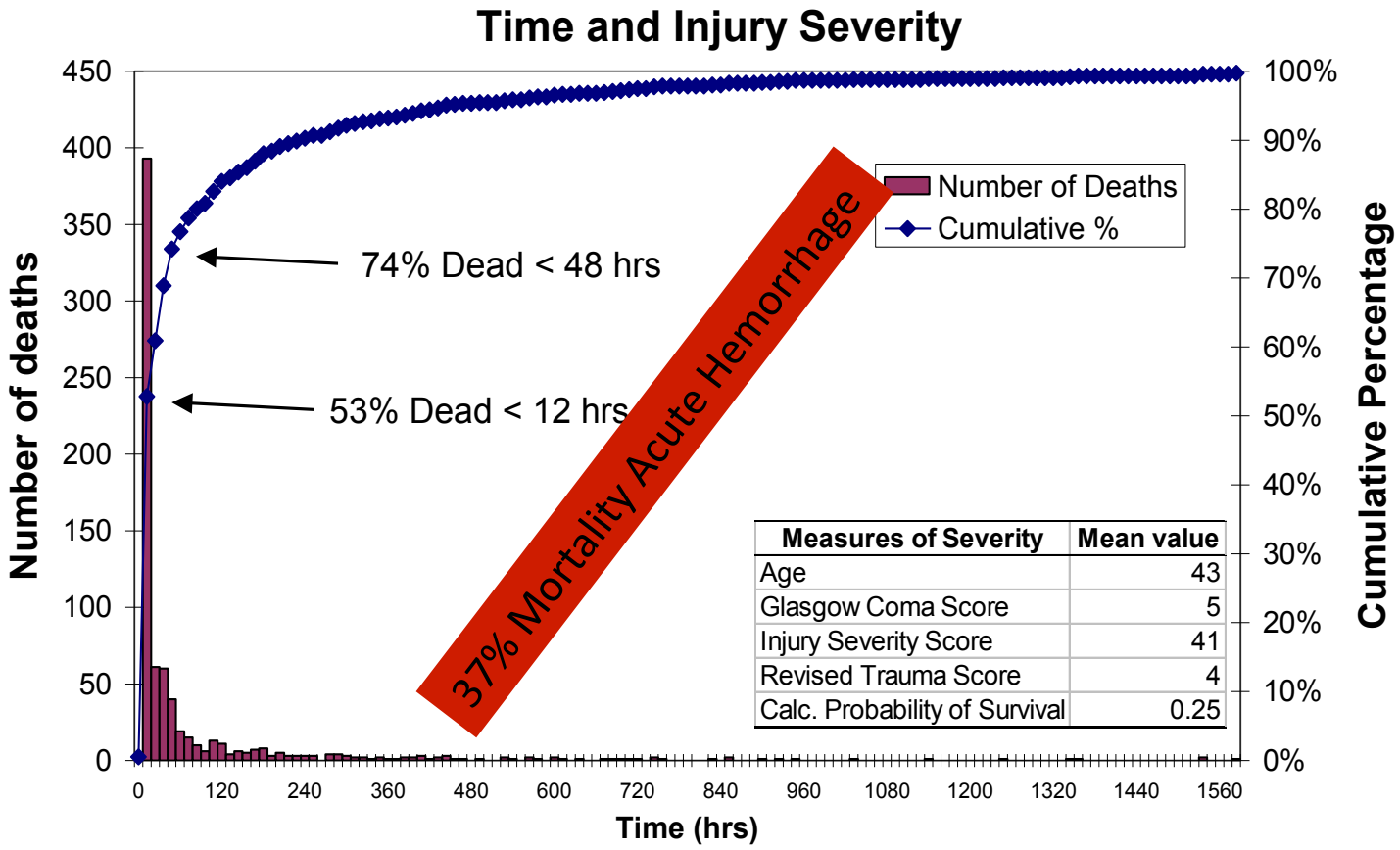
Martin et al., J Trauma 2009

Civilian Injury Hemorrhage Mortality



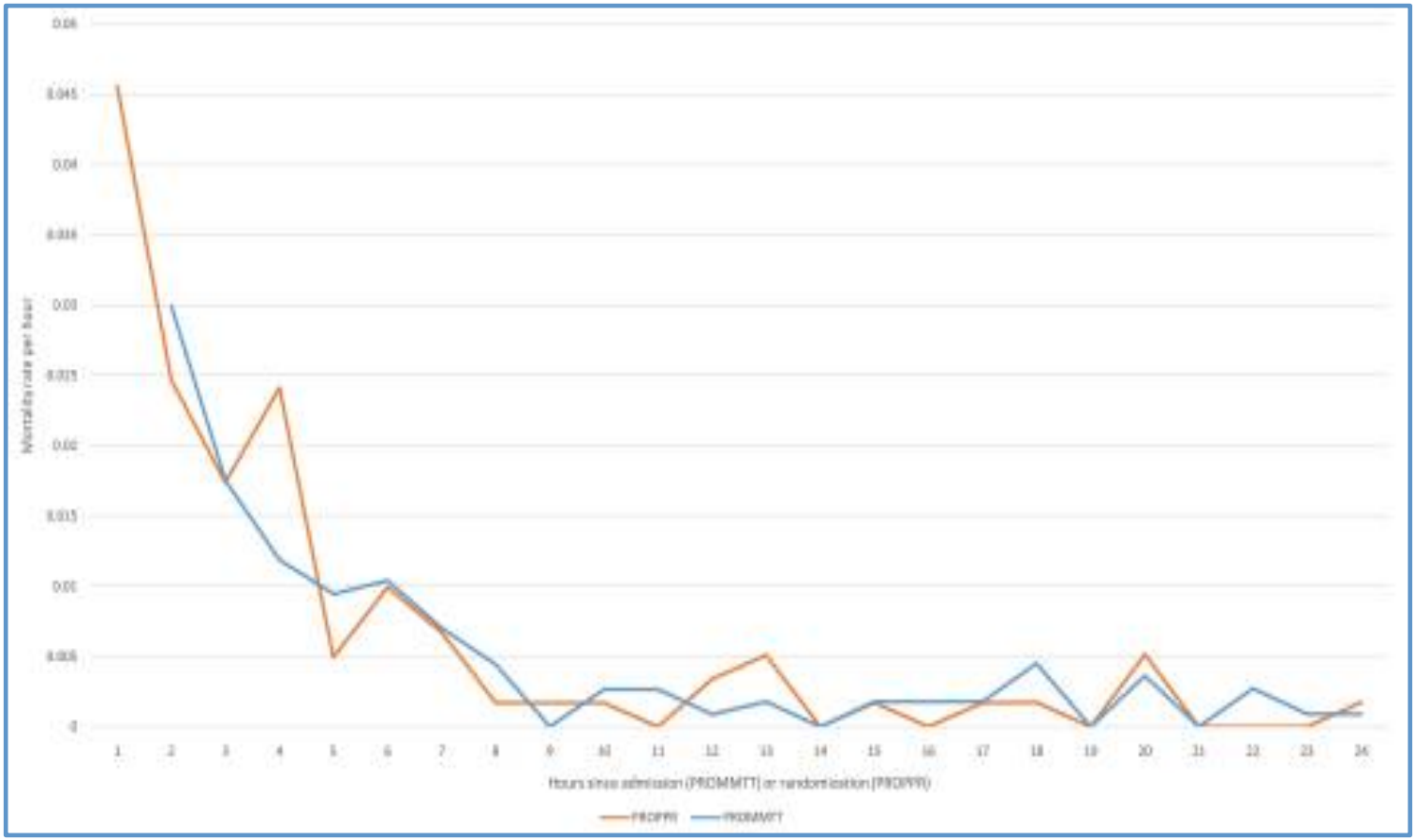
Data adapted from: Acosta, et al. *J Am Coll Surg* 1998 & Sauaia, et al. *J Trauma* 1995

Trauma Center Mortality



Stewart: Analysis of 753 deaths in a Level I Trauma Center. J Trauma 2003.

Civilian Trauma Centers Mortality Rates from PROMMTT and PROPPR



Earlier Endpoints Are Required for Hemorrhagic Shock Trials among Severely Injured Patients

Study	N	Year	Time to hemorrhagic death (h)	All-cause mortality at 24 h	All-cause mortality at 30 days
rFVIIa (7)	573	2010	NA	NA	11.6%
HSD shock (5)	852	2011	2*	NA	26.9%†
PolyHeme (6)	714	2011	2	NA	11.5%
PROMMTT (8)	1245	2013	2.6	11.9%‡	20.9%‡
PROPPR (9)	680	2015	2.4	14.9%	24.1%

*Time to all-cause death in shock cohort only.
†All-cause mortality at 28 days.
‡In-hospital mortality.

Earlier Endpoints Are Required for Hemorrhagic Shock Trials among Severely Injured Patients. Shock 2017

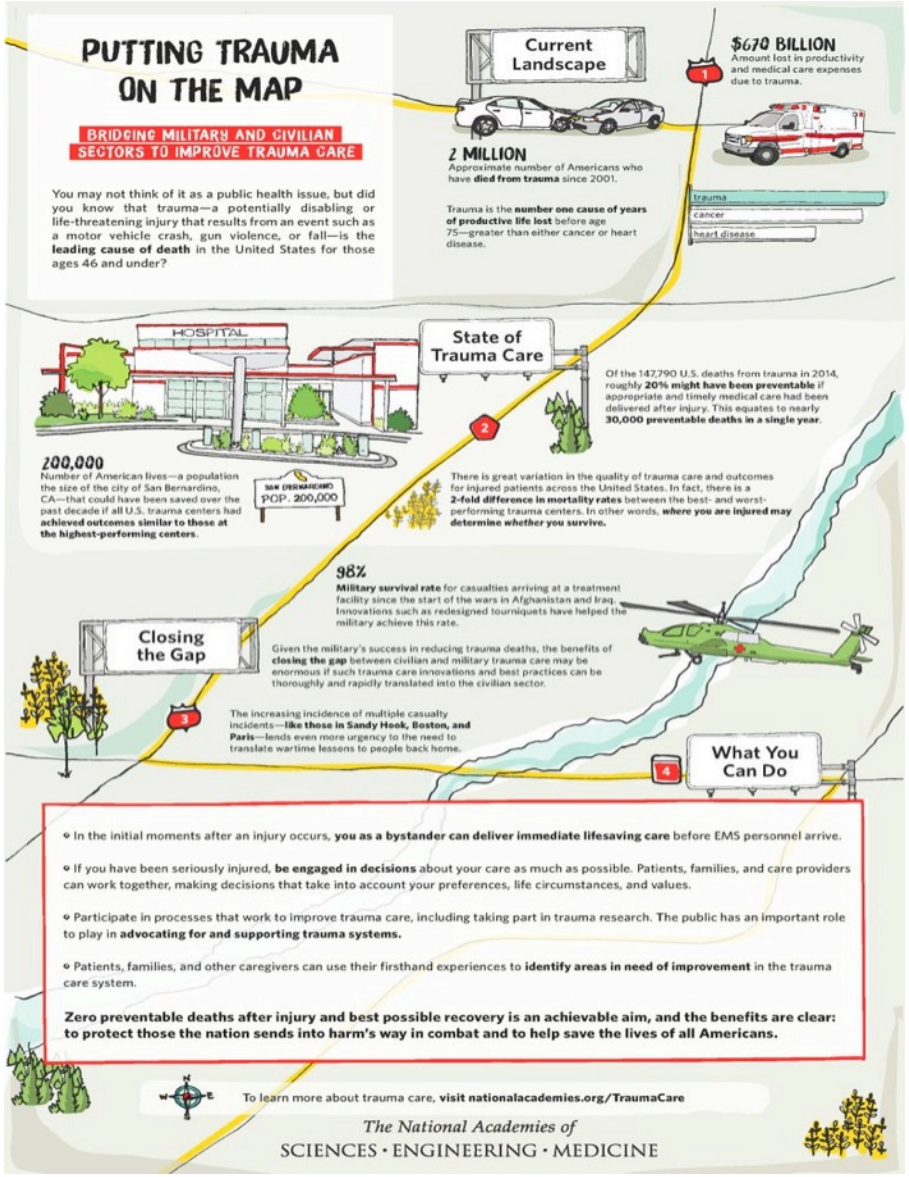
Who May Benefit From DCR?

Injury Death	Military (%)	Civilian (%)
Potentially preventable injury deaths (pre and in-hospital)	27.5	20
Deaths that occur prehospital (injury)	90	
Prehospital potentially preventable deaths after traumatic injury	25	29
Prehospital potentially preventable deaths after traumatic injury (hemorrhage associated)	90	64
Deaths that occur in hospital (injury)	10	4.1
In-hospital potentially preventable deaths after traumatic injury	50	
In-hospital potentially preventable deaths after traumatic injury (hemorrhage associated)	80	

Spinella, Cap: Prehospital hemostatic resuscitation to achieve zero preventable deaths after traumatic injury. Current Opin Hemat 2017

Getting Beyond Estimates

Objectively establishing the impact of Damage Control Resuscitation



NASEM Zero Preventable Death

Specific Recommendations for ME system Integration

Gap:

Linkages are incomplete or entirely missing among prehospital care; hospital-based acute care; rehabilitation; and medical examiner data.

"A critical but often neglected source of data—particularly in civilian systems—is autopsy reports on trauma deaths, which could be used to determine the preventability of fatalities based on a common, accepted lexicon."

Recommendation 5:

The Secretary of Health and Human Services and the Secretary of Defense, together with their governmental, private, and academic partners, should work jointly to ensure that military and civilian trauma systems collect and share common data spanning the entire continuum of care

Multiinstitutional Multidisciplinary Injury Mortality Investigation in Civilian PreHospital Environment

PIs:Eastridge, Nolte, MacKenzie
Funded by USAMRMC
(Department of Defense)

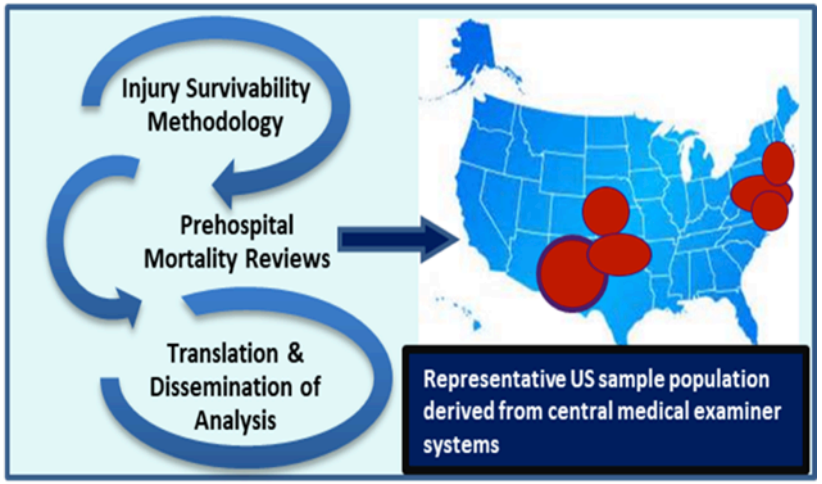
Purpose of this proposal is to develop a coordinated, multidisciplinary, multi-institutional effort within the civilian clinical sector to identify and characterize the causes of pre-mortality from trauma

Identify potential high yield areas for research and development in pre-hospital medical care, injury prevention, and trauma systems.

Multi-Disciplinary Multi-Institutional Mortality Investigation in the Civilian Prehospital Environment (MIMIC)

Methodology

- Develop a framework for evaluating the causes and pathophysiology of pre-hospital deaths
- Network of experts identify the causes of 3,000 pre-hospital deaths due to trauma and estimate potential for survivability.
  - Trauma surgery
  - Neurosurgery
  - Orthopedic surgery
  - Forensic pathology
  - Emergency medicine
  - Emergency medical services



Study Hypotheses/Aims Purpose

- Advances in care in both trauma centers and trauma systems have substantially reduced death and disability associated with injury
- Substantial opportunity to further reduce deaths in pre-hospital setting.
  - Potential liabilities in civilian and military pre-hospital care must be identified and remediated in order to reduce the number of potentially preventable deaths on the battlefield and in the civilian environment.

Goal and Strategy

Develop a framework and methodology for evaluating the causes and pathophysiologic mechanisms of pre-hospital deaths

Describe the epidemiology of all pre-hospital injury deaths for defined populations

- Age: 0-14; 15-24; 25-54; 55-74; 75 and older
- Type: Blunt vs. Penetrating vs. Other Sharp Forces
- Geography: Urban/Suburban; Rural/Wilderness
- Major focus of pathophysiology associated with death

Develop blueprint for a sustained effort at public health injury mitigation strategies in the pre-hospital environment

Identifying high priority areas for injury prevention, trauma systems performance improvement and research and development.

Survivability
Optimal & Context

Non-Survivable

Head / Neck

- Decapitation
- Brain evisceration
- Head crush with skull fragmentation and extensive parenchymal brain destruction
- Transection spinal cord C3 and above

Torso

- Torso dismemberment
- Torso crush with extensive injury / loss of investing soft tissue associated with massive internal organ injury / avulsion
- Cardiac avulsion
- Aortic injury, uncointained by mediastinum
- Liver avulsion
- Massive open pelvis with major vascular injury / hemi-pelvectomy

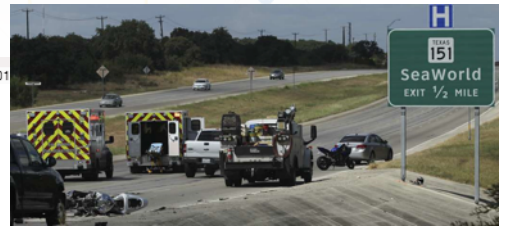
Importance of Context
Where You Live Should Not Determine *Whether* You Live

Del Rio to University Hospital = 152mi

Ground Transport ≈ 2hr 33min | Air Transport ≈ 54min

Del Rio to SAMMC = 160mi

Ground Transport ≈ 2hr 40min | Air Transport ≈ 57min



Study Setting
Six Regions in the Country

(all have a centralized ME system and use an electronic case management system to collect uniform data on all deaths)

1. **State of Connecticut**. Serves a population of 3.6 million. They perform approximately 2,200 autopsy examinations at a single, centralized facility annually.
2. **Johnson County, Iowa.** Serves a population of 142,000. In 2014 JCME accepted jurisdiction of 380 deaths and performed 118 autopsies.
3. **State of Maryland.** Serves a population of approximately 6.0 million residents . They perform 4,220 autopsies at the single, centralized facility annually.
4. **State of New Mexico.** Serves a population of 2.0 million. They perform approximately 2,100 full autopsy examinations annually
5. **State of Oklahoma.** Serves a population of 3.8 million and conducts investigation of roughly 4,000 deaths annually.
6. **The District of Columbia.** Serves a population of 659,000. They perform approximately 1,110 examinations annually.

Methods

Steering Committee (Military and Civilian) to define definitions and process

Expert review panels (~ 50 Military and Civilian reviewers) (3-5 individuals each) will be identified and trained (Trauma Surgery, Emergency Medicine, Neurosurgery, Orthopedic Surgery, Forensic Pathology, EMS, Trauma Systems)

Panels will each review a certain number of cases using the PROFILER and assign a determination of survivability to each case – members of the panels will review cases independently (on-line without discussion with other panels members)

Discrepancies in determination of survivability will be identified by Coordinating Center and the panel will discuss these cases (either in person or via webex) and a second vote taken – ideally to reach consensus for each case

Methods

Collaborate with selected centralized OCME sites to identify 3,000 cases that meet criteria

Research Coordinators at each OCME will abstract defined set of data on each case and enter these data into REDCap

Data will then be used for following:

- Assign AIS injury codes (centrally by expert) and compute ISS, NISS … Abstractors will be trained on best way to describe each injury in detail
- ICD 10 injury codes and external causes of injury codes
- Geospatial mapping
- NEMSIS cross-referencing

Specific data from CRFs will be used to populate an on-line 'Case PROFILER' that will summarize the pertinent information about each case and provide electronic access to specific documents (e.g. ME summary, EMS run sheet) for electronic case review

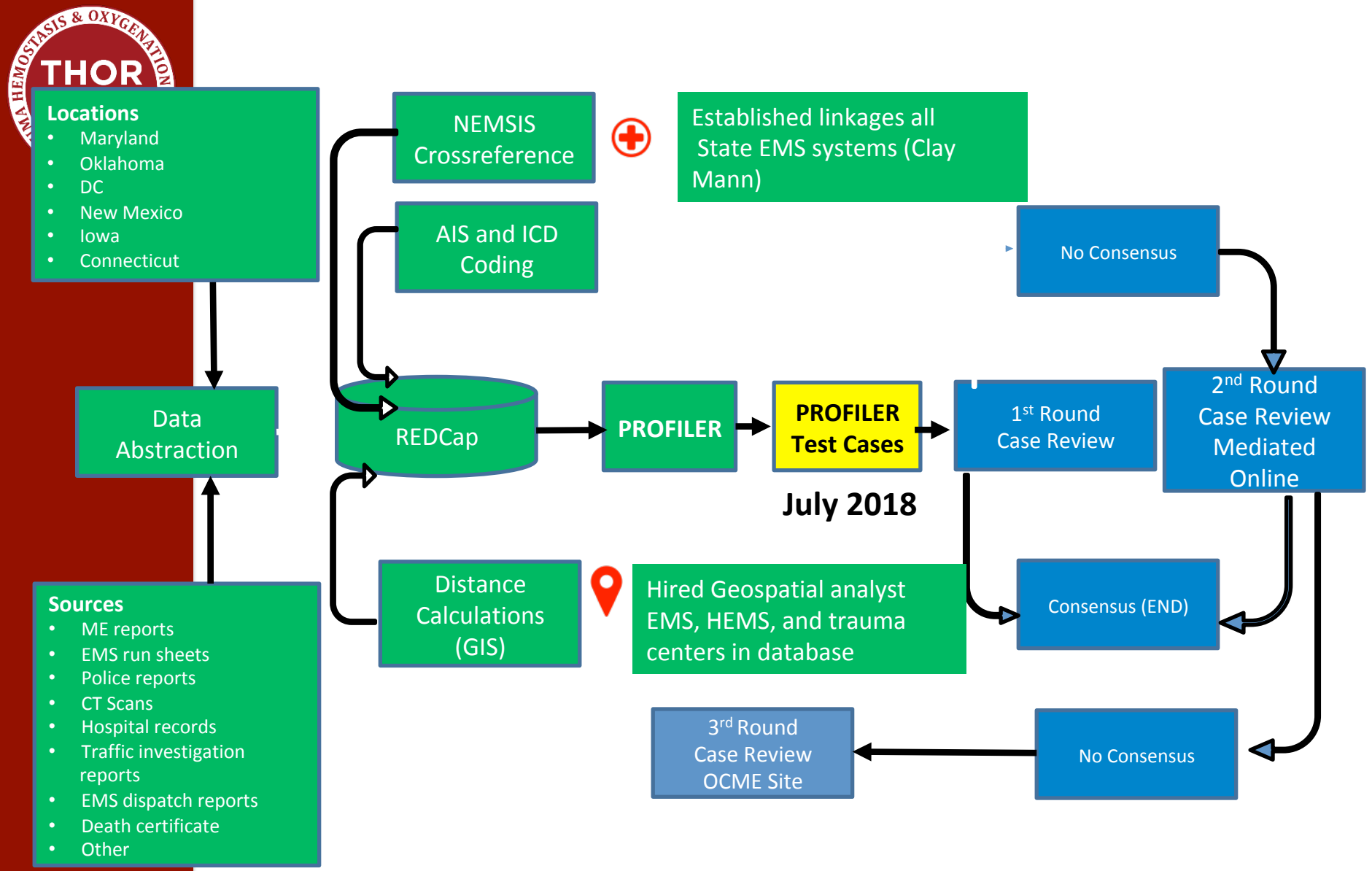
Study Population

Inclusion Criteria:

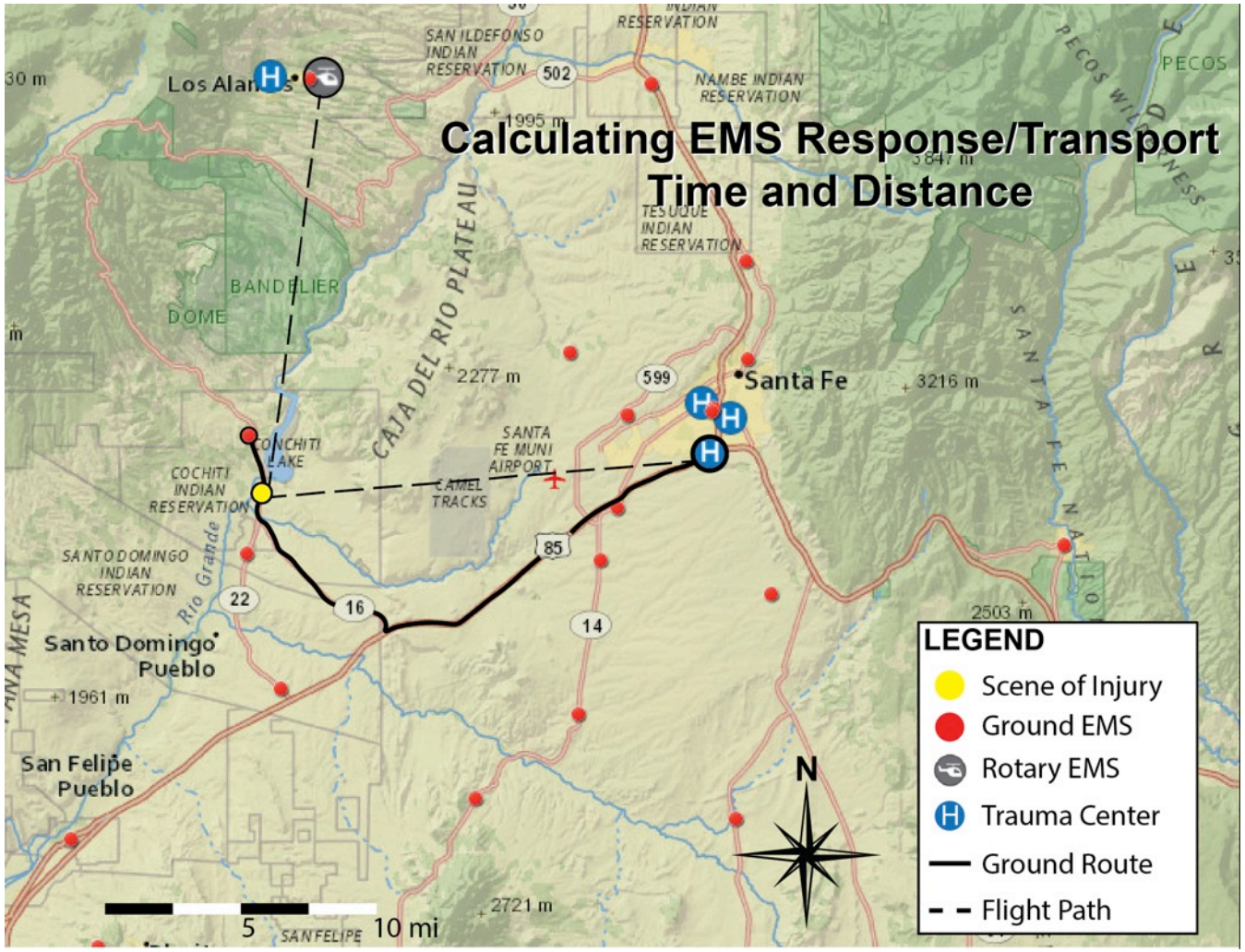
1. Pre-hospital deaths (at scene, en route to hospital or DOA – defined as no vitals upon arrival at hospital)
2. Due to a blunt, penetrating or other sharp force
3. Adequate forensic record

Exclusion Criteria:

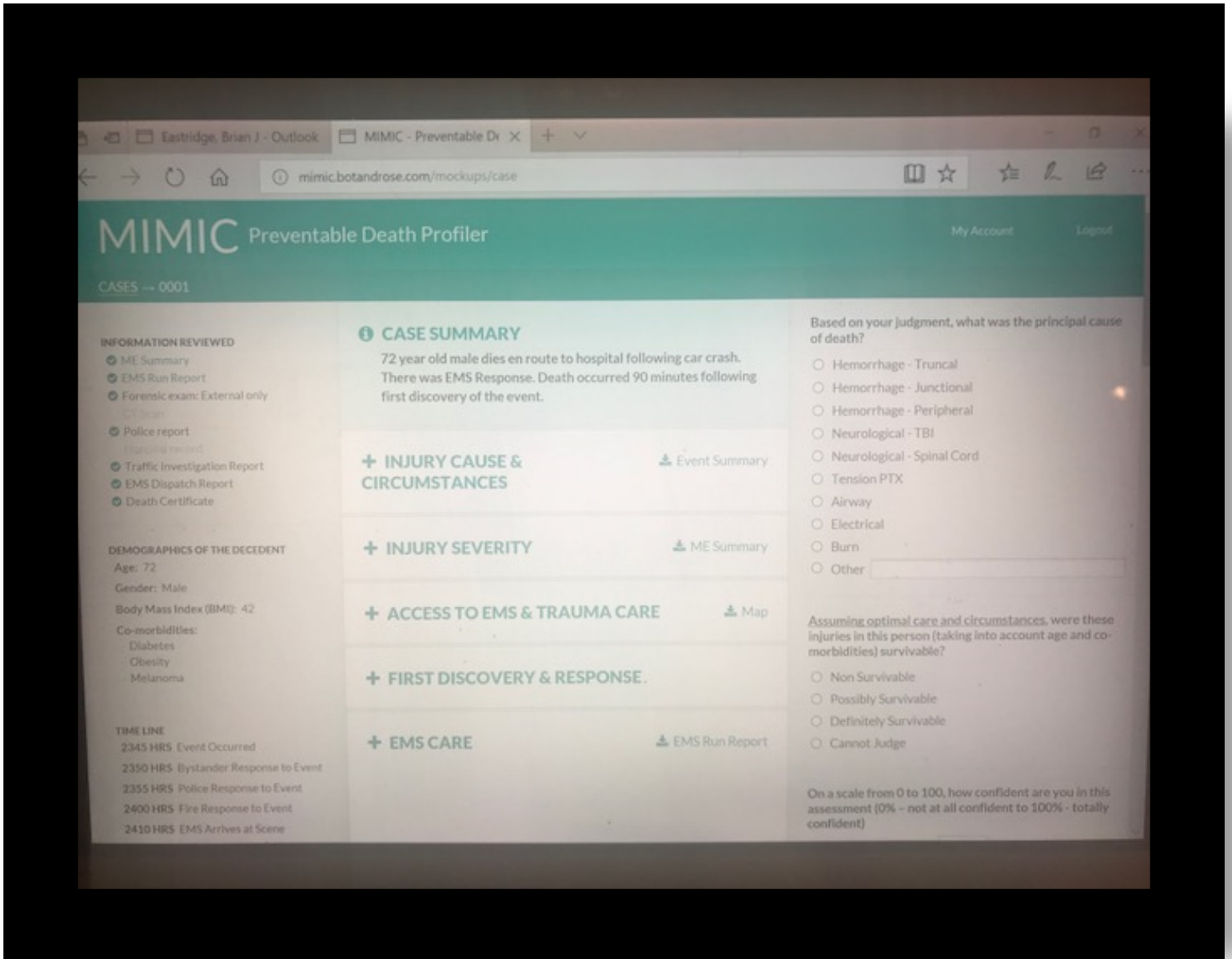
1. Non-mechanical causes: poisoning, incl. drug overdoses, asphyxia, drowning,
2. Decomposed remains only (not fully fleshed with distinguishable organs)


THOR
TRAUMA HEMOSTASIS & OXYGENATION
Locations
Maryland
Oklahoma
DC
New Mexico
Iowa
Connecticut
NEMSIS Crossreference
Established linkages all State EMS systems (Clay Mann)
AIS and ICD Coding
No Consensus
Data Abstraction
REDCap
PROFILER
PROFILER Test Cases
July 2018
1st Round Case Review
2nd Round Case Review Mediated Online
Sources
ME reports
EMS run sheets
Police reports
CT Scans
Hospital records
Traffic investigation reports
EMS dispatch reports
Death certificate
Other
Distance Calculations (GIS)
Hired Geospatial analyst EMS, HEMS, and trauma centers in database
Consensus (END)
3rd Round Case Review OCME Site
No Consensus

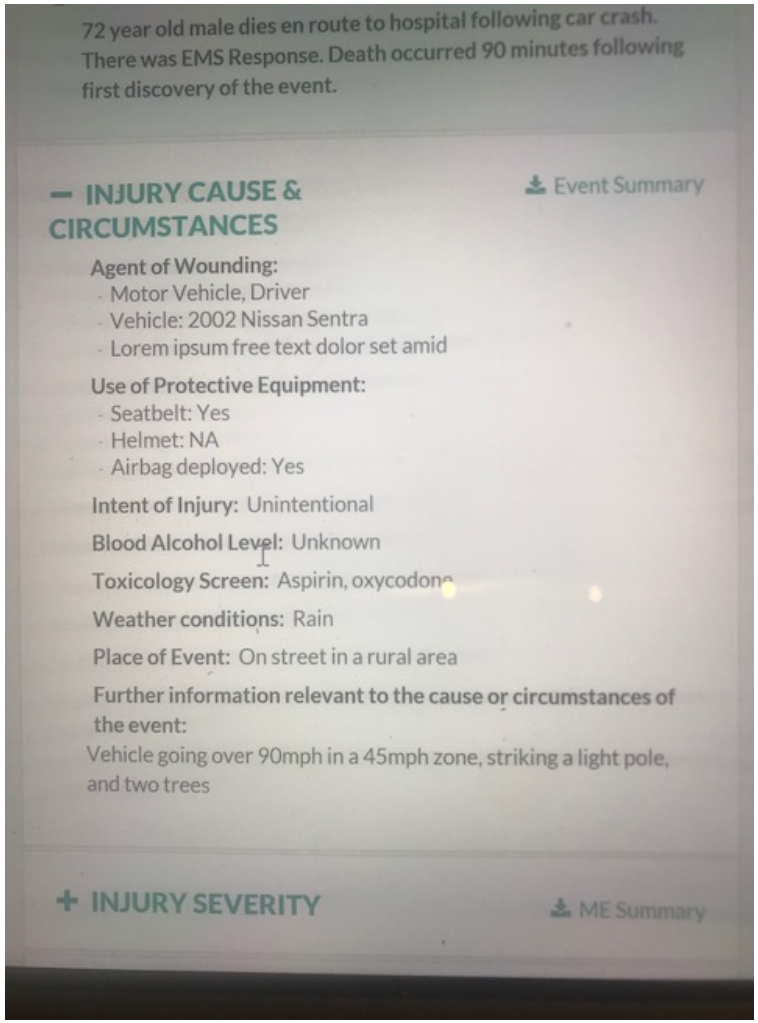
Integrating Geospatial Modeling For EMS



MIMIC Profiler



MIMIC Profiler



72 year old male dies en route to hospital following car crash. There was EMS Response. Death occurred 90 minutes following first discovery of the event.

– INJURY CAUSE & CIRCUMSTANCES Event Summary

Agent of Wounding:
- Motor Vehicle, Driver
- Vehicle: 2002 Nissan Sentra
- Lorem ipsum free text dolor set amid

Use of Protective Equipment:
- Seatbelt: Yes
- Helmet: NA
- Airbag deployed: Yes

Intent of Injury: Unintentional

Blood Alcohol Level: Unknown

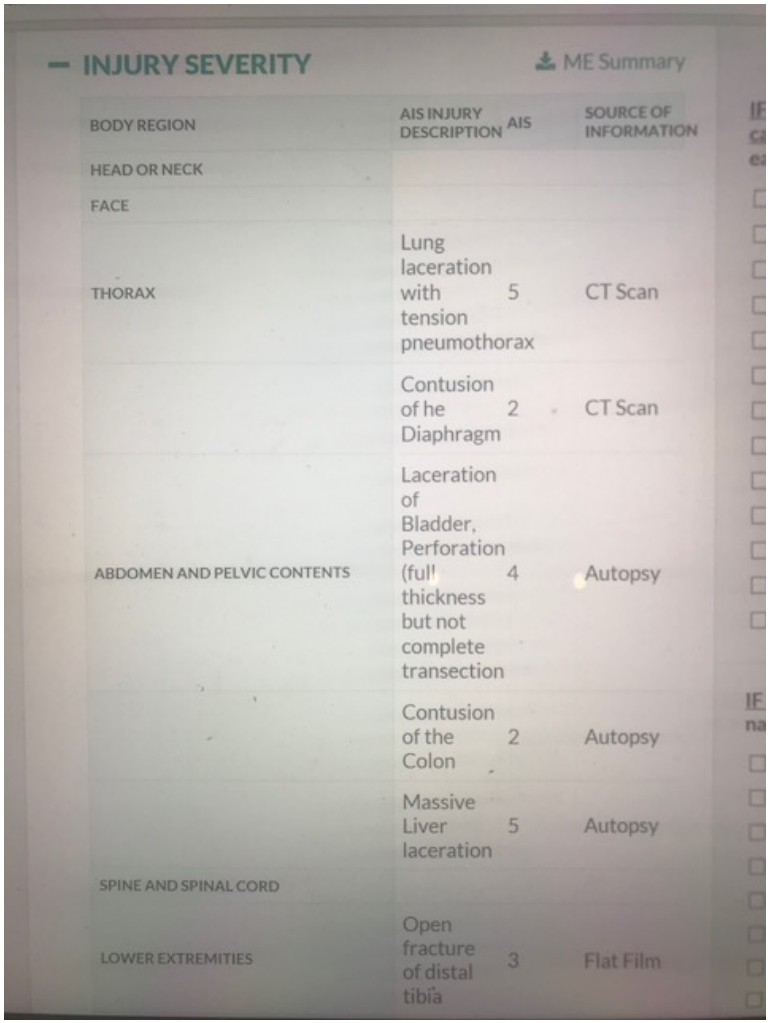
Toxicology Screen: Aspirin, oxycodone

Weather conditions: Rain

Place of Event: On street in a rural area

Further information relevant to the cause or circumstances of the event:
Vehicle going over 90mph in a 45mph zone, striking a light pole, and two trees

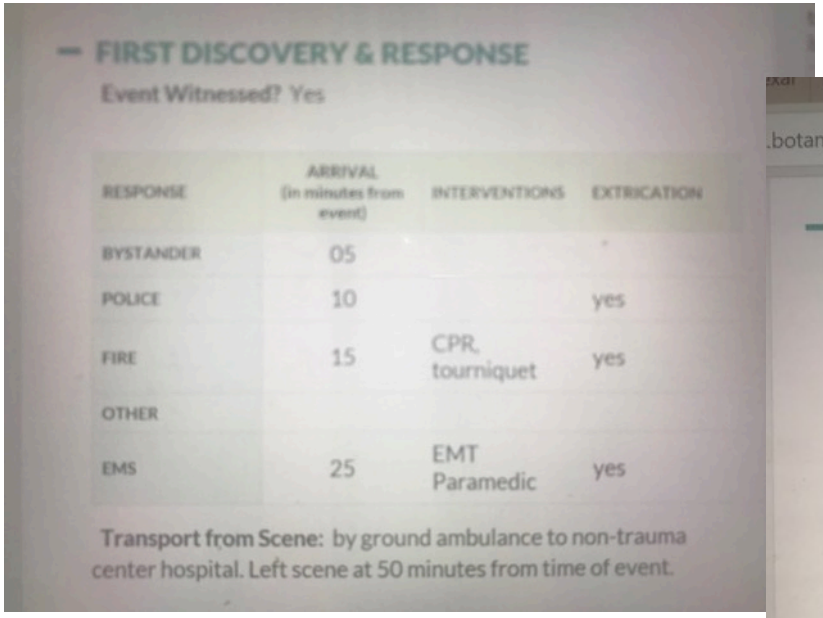
+ INJURY SEVERITY ME Summary



– INJURY SEVERITY ME Summary

BODY REGION	AIS INJURY DESCRIPTION	AIS	SOURCE OF INFORMATION
HEAD OR NECK			
FACE			
THORAX	Lung laceration with tension pneumothorax	5	CT Scan
	Contusion of he Diaphragm	2	CT Scan
ABDOMEN AND PELVIC CONTENTS	Laceration of Bladder, Perforation (full thickness but not complete transection	4	Autopsy
	Contusion of the Colon	2	Autopsy
	Massive Liver laceration	5	Autopsy
SPINE AND SPINAL CORD			
LOWER EXTREMITIES	Open fracture of distal tibia	3	Flat Film

MIMIC Profiler

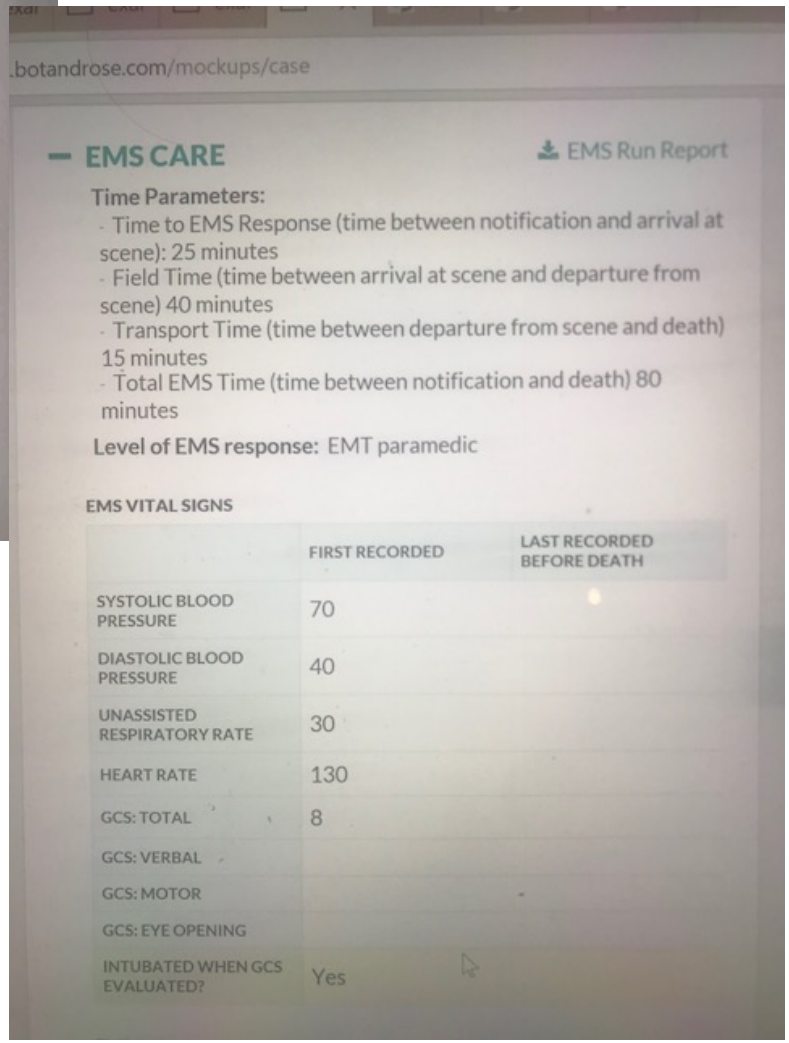


FIRST DISCOVERY & RESPONSE

Event Witnessed? Yes

RESPONSE	ARRIVAL (in minutes from event)	INTERVENTIONS	EXTRICATION
BYSTANDER	05		
POLICE	10		yes
FIRE	15	CPR, tourniquet	yes
OTHER			
EMS	25	EMT Paramedic	yes

Transport from Scene: by ground ambulance to non-trauma center hospital. Left scene at 50 minutes from time of event.



.botandrose.com/mockups/case

EMS CARE

EMS Run Report

Time Parameters:

- Time to EMS Response (time between notification and arrival at scene): 25 minutes
- Field Time (time between arrival at scene and departure from scene) 40 minutes
- Transport Time (time between departure from scene and death) 15 minutes
- Total EMS Time (time between notification and death) 80 minutes

Level of EMS response: EMT paramedic

EMS VITAL SIGNS

	FIRST RECORDED	LAST RECORDED BEFORE DEATH
SYSTOLIC BLOOD PRESSURE	70	
DIASTOLIC BLOOD PRESSURE	40	
UNASSISTED RESPIRATORY RATE	30	
HEART RATE	130	
GCS: TOTAL	8	
GCS: VERBAL		
GCS: MOTOR		
GCS: EYE OPENING		
INTUBATED WHEN GCS EVALUATED?	Yes	

Trauma System Potential Benefits

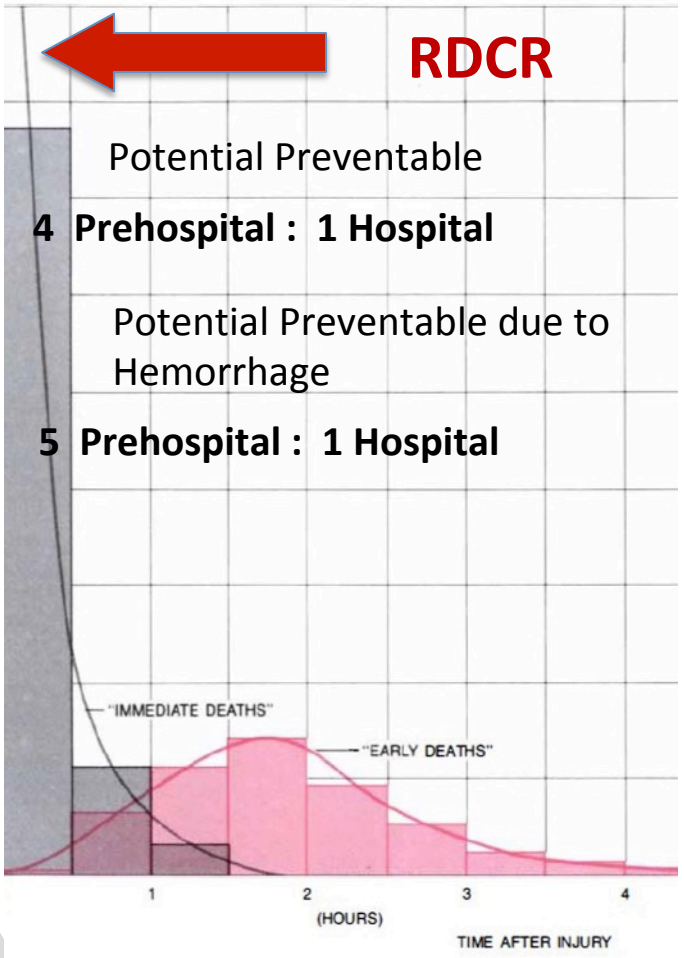
Trauma

- Military / civilian trauma system evolution
- Performance improvement
  - Engineering
  - Medical devices / procedures
  - EMS value validation
  - Injury Prevention
- Integration of ME and injury data sources
- Collaboration between trauma and ME communities

Medical Examiner

- Support for enhanced ME systems / resources
- Funding for radiological imaging / advanced technology
- Bridge the gap between ME and trauma care providers

RDCR
Shifting the Curve to the Left



Bridging the Chasm

Injury
Potentially
preventable
Death Data

DCR &
RDCR
Outcomes
Analysis