

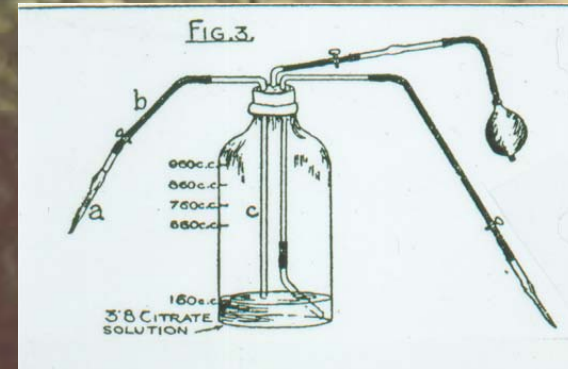
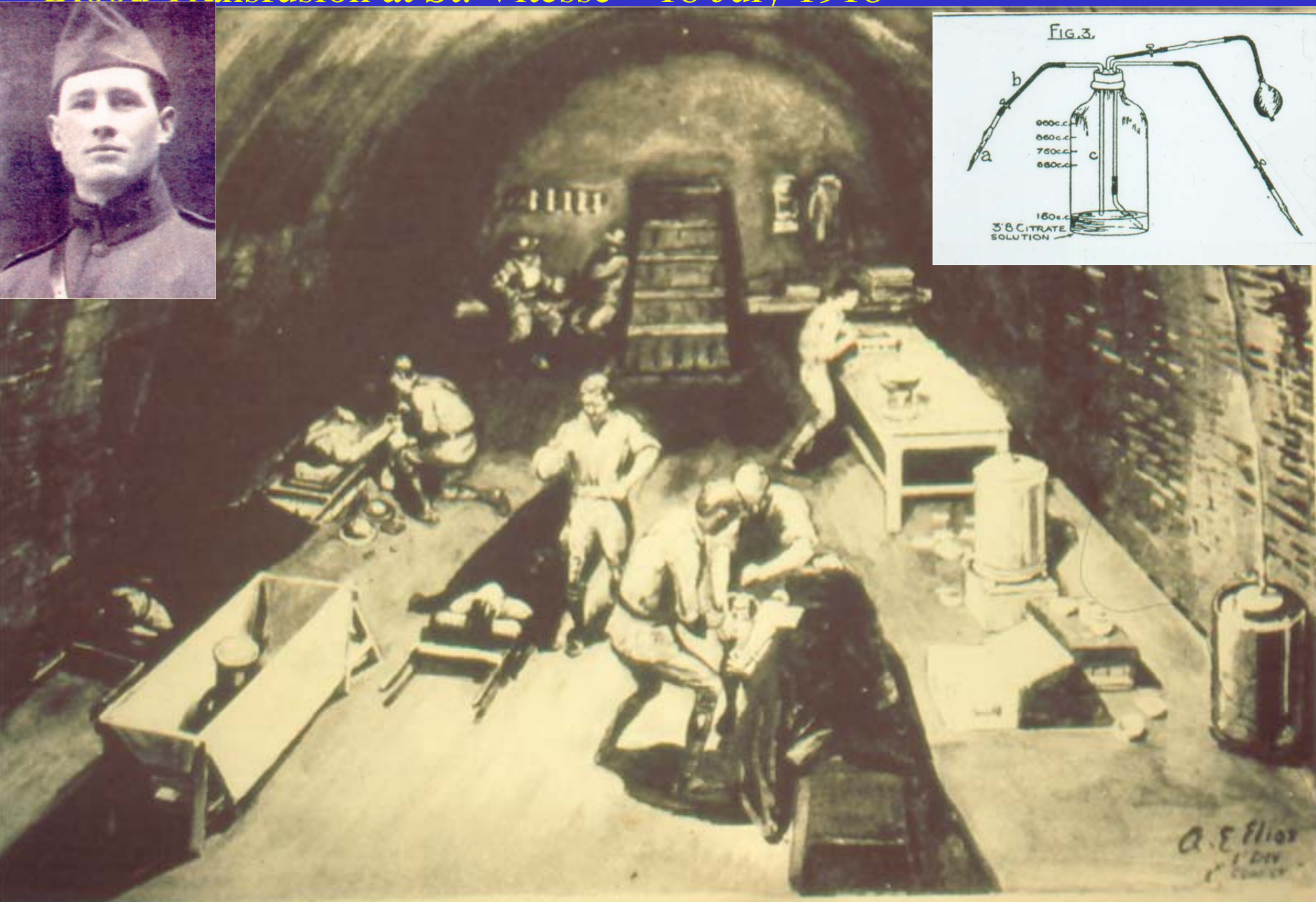
# Blood use in war, disaster and trauma

John R. Hess, MD, MPH, FACP  
U. Maryland, Baltimore





# Blood Transfusion at St. Vitesse – 18 July 1918



Canadian Army Painter – Pvt. Arthur Elias - 1918

# Blood banking in the Spanish Civil War 1936-39

- Canadian Norman Bethune built a blood bank in Madrid that transfused 100 units/day using the Robertson technique.
- Frederic Duran-Jorda built a blood bank and transfusion service in Barcelona that delivered over 45,000 transfusions.

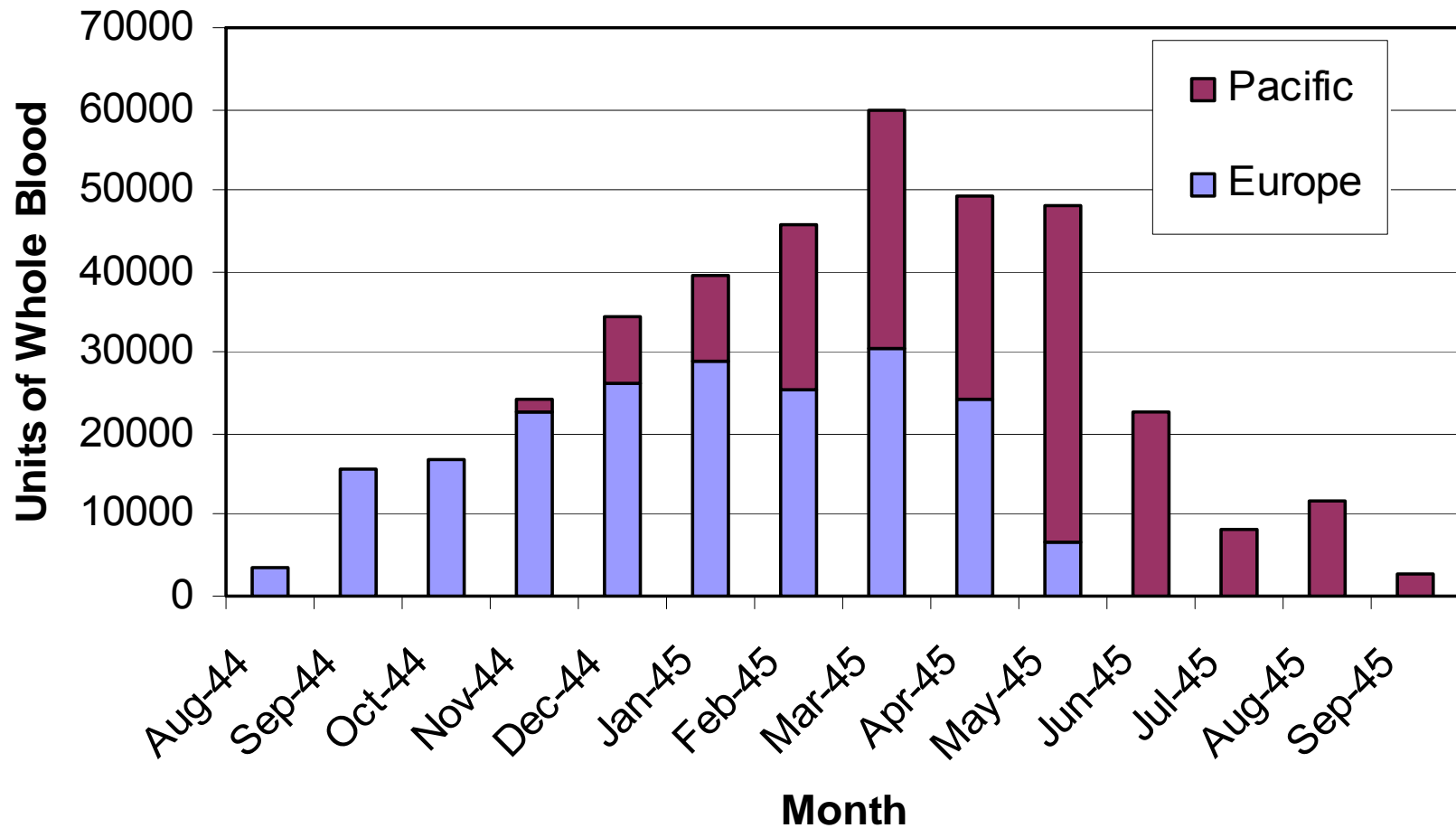
# British Experience in WWII

- London Blood Transfusion Service (f. 1924) collected 548,000 pints during the Blitz (Sep '40 - May '41), third of casualties transfused. Expanded to cover the country.
- British Army planned a full blood transfusion service in 1938, activated it in one day in Sep 1939. Served on 5 continents and taught U.S. military about transfusion.

# Freeze-dried human plasma – World War II

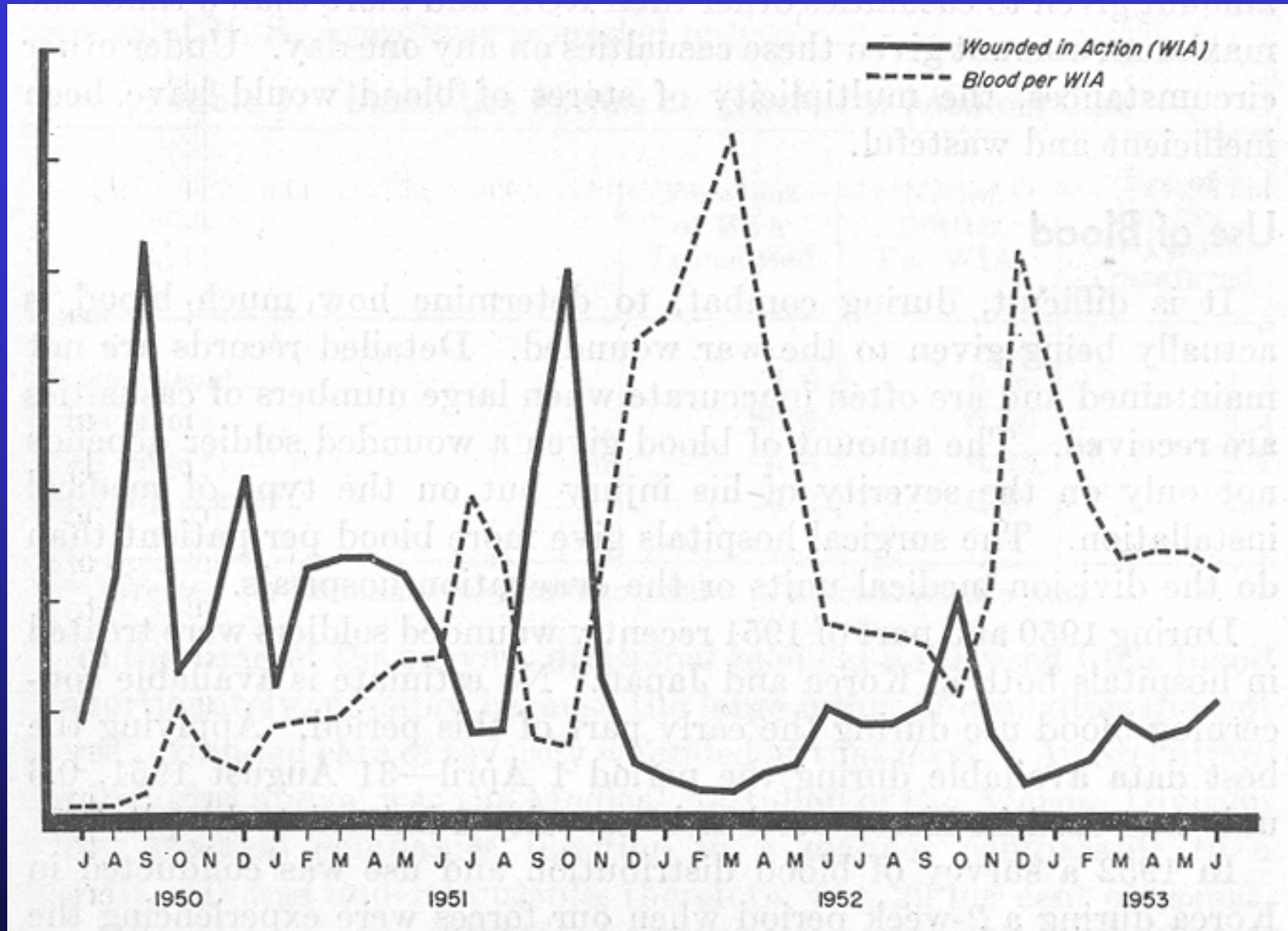


## U.S. Blood Shipments in World War II



Kendrick DB, Blood Program in World War II, 1964, p 753

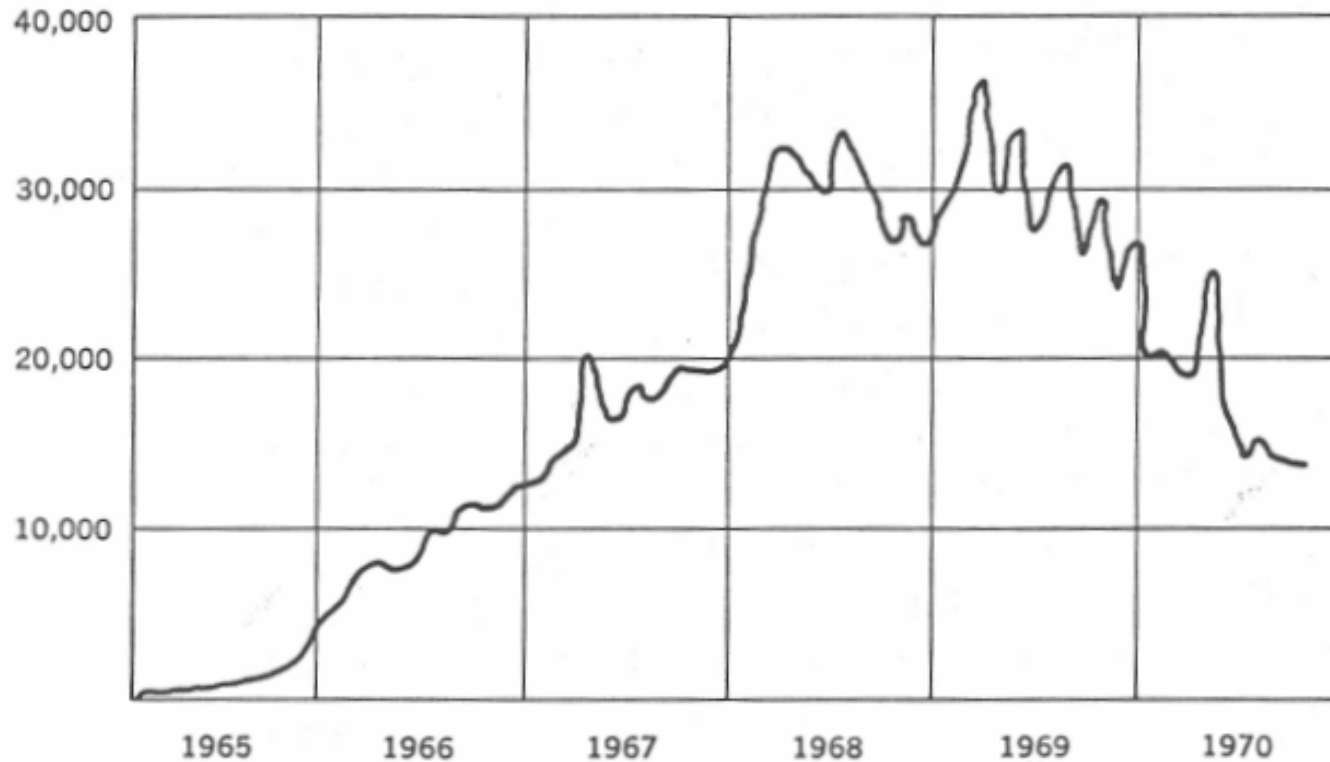




Steer A, Hullinghorst RL, Mason RP. The Blood Program in the Korea War, Chapter 2 in Crosby WH Ed, Battle Casualties in Korea, Vol II: Tools for Resuscitation, 1955, p 159

# Blood Program in the Vietnam War

CHART 12—UNITS OF BLOOD AVAILABLE IN SOUTH VIETNAM, BY MONTH, JANUARY 1965–DECEMBER 1970<sup>1</sup>



<sup>1</sup>Includes shipments from the continental United States, the Pacific Command, and blood collected in South Vietnam.

Neel, Medical Support of the U.S. Army in Vietnam '65-70, Washington, DC, Department of the Army, 1973, p 155



# Britain - Falklands War, 1982

- Drew 4000 U of 3-week CPD blood from troops on QEII at Portsmouth and burned them at St. Helena while waiting for last minute supplies. 5-week storage systems were available.
- Used 250 U mostly for Scots Guards burned in ship bombing.
- No blood used at Goose Green
- 40 U used at Port Stanley by 2 FSTs operating for 70 hours.



# Blood use in the Gulf War

- 80,000-120,000 U requested based on 20,000-30,000 estimated casualties
- About 82,000 U sent, 3 U platelets were drawn in country
- About 1000 U were used, 250 U treating U.S. casualties and 750 U in Iraqis
- Full frozen blood capability on hospital ship Comfort was activated but not used
- Of 250 U given to U.S. soldiers, 52 U went to a single individual

# Blood use in Somalia

## 46th CSH, 30 Sep - 4 Oct 1993

- 30 Sep - shark attack victim,  
> 50 U PRBCs & FFP, > 20 U WB
- 2 Oct - Jeep hit mine, 4 injured,  
> 20 U WB, type O Neg, used for female
- 3-4 Oct - Ranger unit decimated,  
> 70 U WB used, type O





**U.S./U.N. soldier  
with RPG injury,  
given 46 U fresh  
whole blood**



# ***SFOR Blood Usage***

***(as of 8 September 2000)***

- **5792 shipped**
  - **5263 PRBC**
  - **289 FRCZ**
  - **196 FFP**
  - **44 Plts**
- **111 transfusions (1.7%)**
  - **79 PRBC**
  - **0 FRCZ**
  - **13 FFP**
  - **5 Plts**
  - **14 emergency WB**

**14 whole blood transfusions = 12.6% of total**

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# ***KFOR Blood Usage***

***(as of 8 September 2000)***

- **1630 shipped**
  - **1521 PRBC**
  - **109 FFP**
  - **32 UK FFP**
- **308 transfusions (16.7%)**
  - **225 PRBC**
  - **38 FFP**
  - **9 UK FFP**
  - **36 emergency WB**

**36 whole blood transfusions = 11.7% of total**

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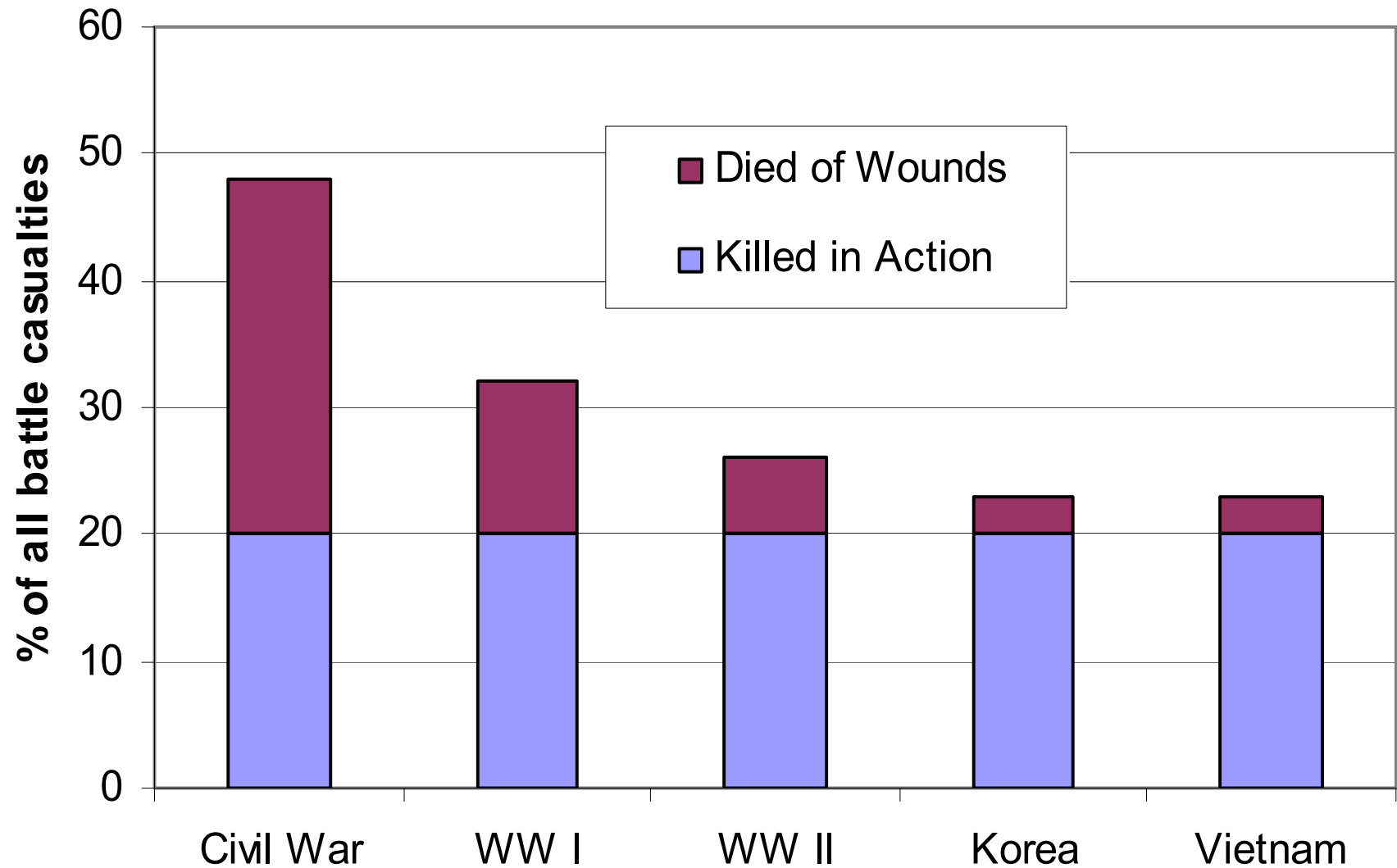
# Blood use in Afghanistan and Iraq 2001-2004

- 143,000 units sent by March 2004 with 46,000 units sent to Afghanistan and 97,000 sent to Iraq
- Units used to support military and military civic action.
- No intention to supply all blood used by civilian populations of over 25 million in each country
- 8% of all blood given as fresh whole blood.

# **Blood demand exceeded supply**

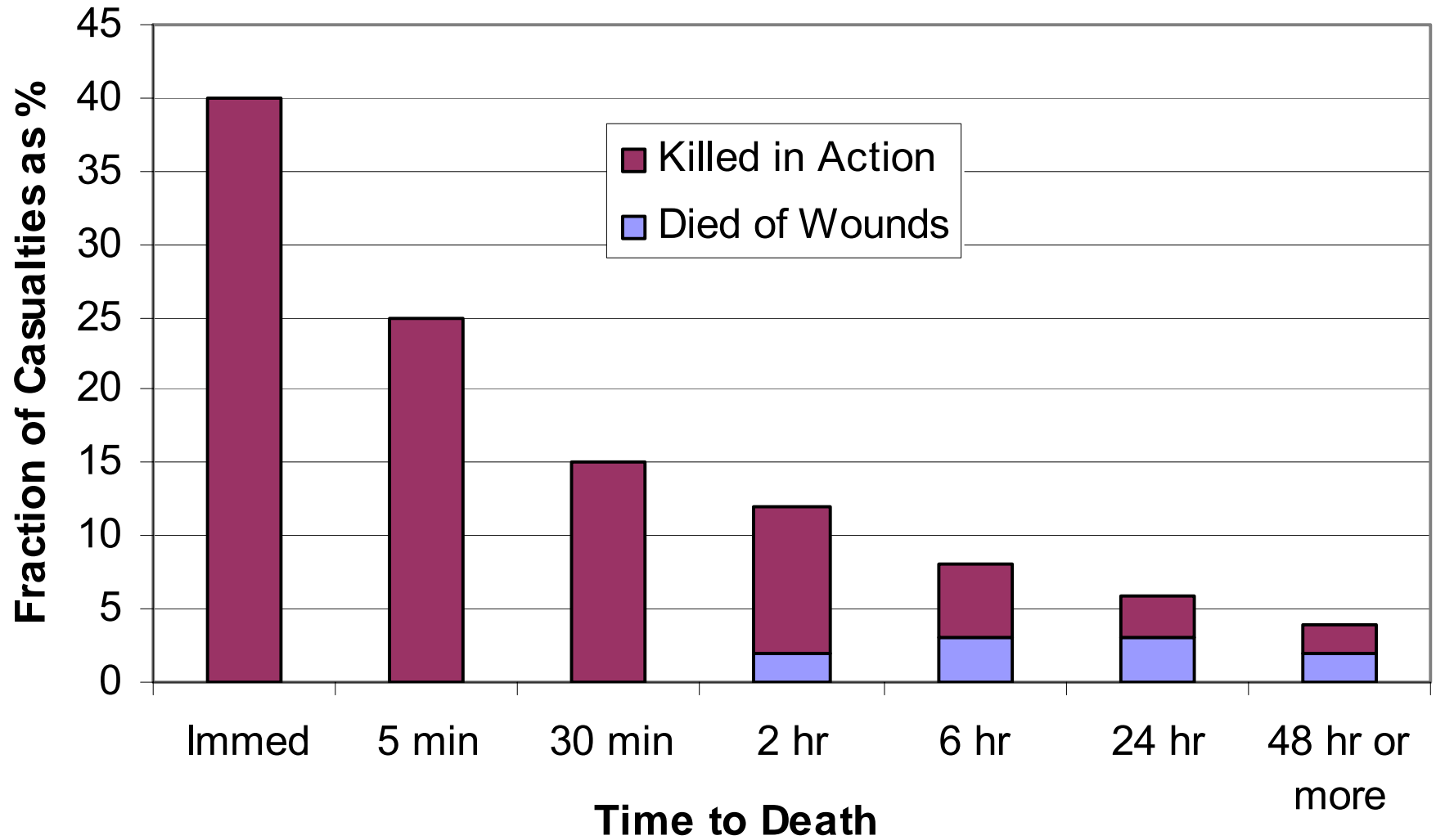
- **System failures**
  - at the Battle of the Bulge
  - at the start of the Korean War
- **Remote incidents**
  - in Vietnam, Feb '65
  - in Mogadishu, Oct '93
- **Local supply worked each time**

# Declining Battle Mortality





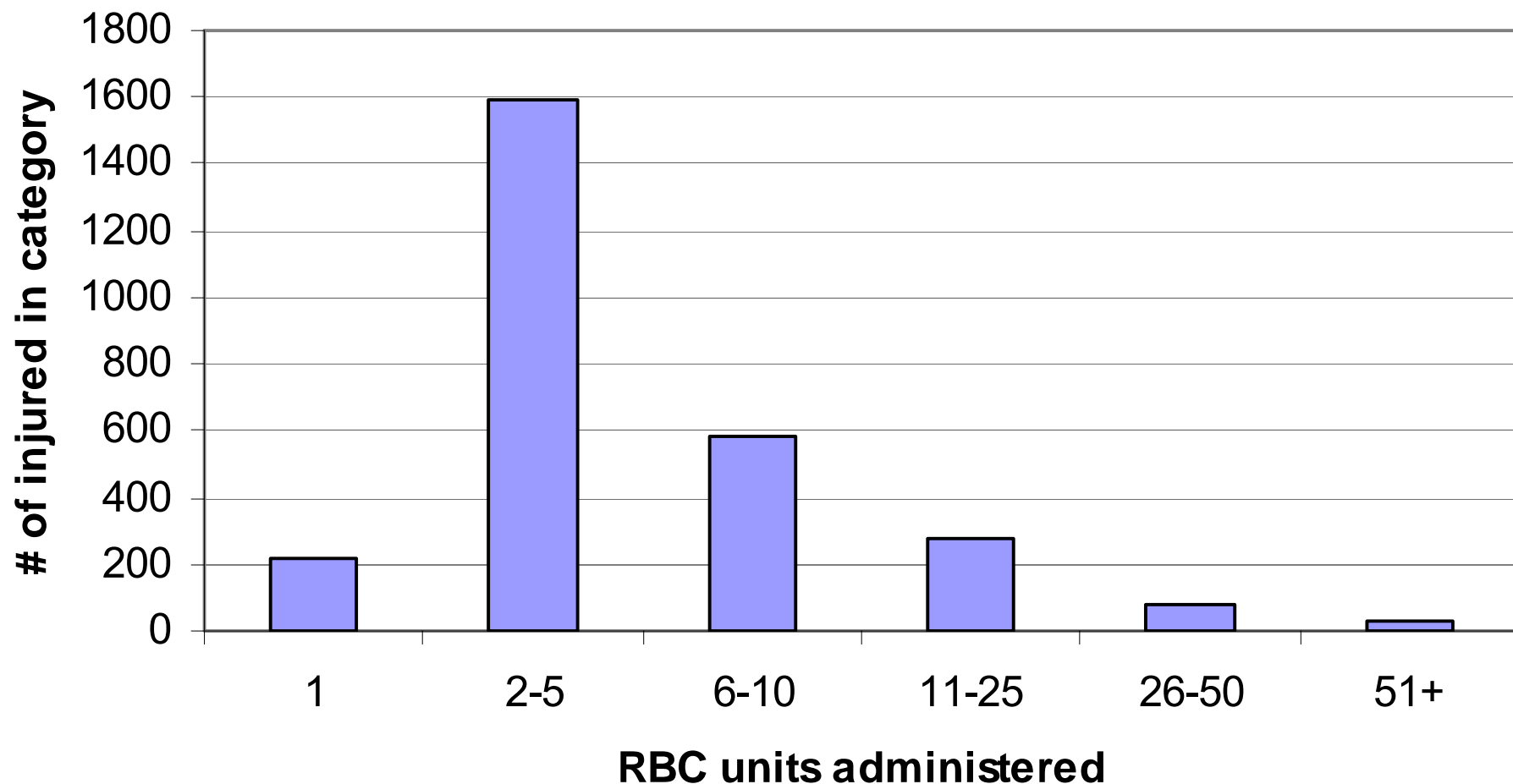
# Time to Death of Vietnam Casualties



# Published blood use in combat

Author	Percent Transfused	Units per Transfused	Units per Casualty
Camp	43%	4.3 U	1.8 U
Mendelson	16%	7.1 U	1.2 U
Moss	36%	7.5 U	2.6 U
Cary	24%	6.5 U	1.6 U
Allam	50%	6.0 U	3.0 U
Eshaya-Chauvin	16%	2.9 U	0.5 U

## RBC use among 2,774 Vietnam casualties receiving 19,721 units





# Universal Donor Blood

- More than 100,000 U of Group “O” RBC were given as universal donor blood in Vietnam without a single hemolytic transfusion reaction. Recipients were mostly young, healthy males.
- All 9 fatal hemolytic transfusion reactions in Vietnam occurred as a result of crossmatching errors, usually in multi-casualty situations.
- Use universal donor blood in mass casualty situations!

# Limits on RBC use

- Casualty needs -  
 $100,000 \text{ casualties/day} \times 4 \text{ U/C} = 400,000 \text{ U/day}$
- Blood system through-put  
 $2 \text{ ASWBPL} \times 7,200 \text{ U/A/day} = 14,400 \text{ U/day}$
- Historic maximum - 2,000 U/day
- Use rate  
(surgeons use  $<1 \text{ U/hr}$  taking care of casualties) 5 surgeons in Korea = 120 U/day



James Garfield  
transfusing the  
vigorous blood  
of Chester  
Arthur into frail  
Democracy.

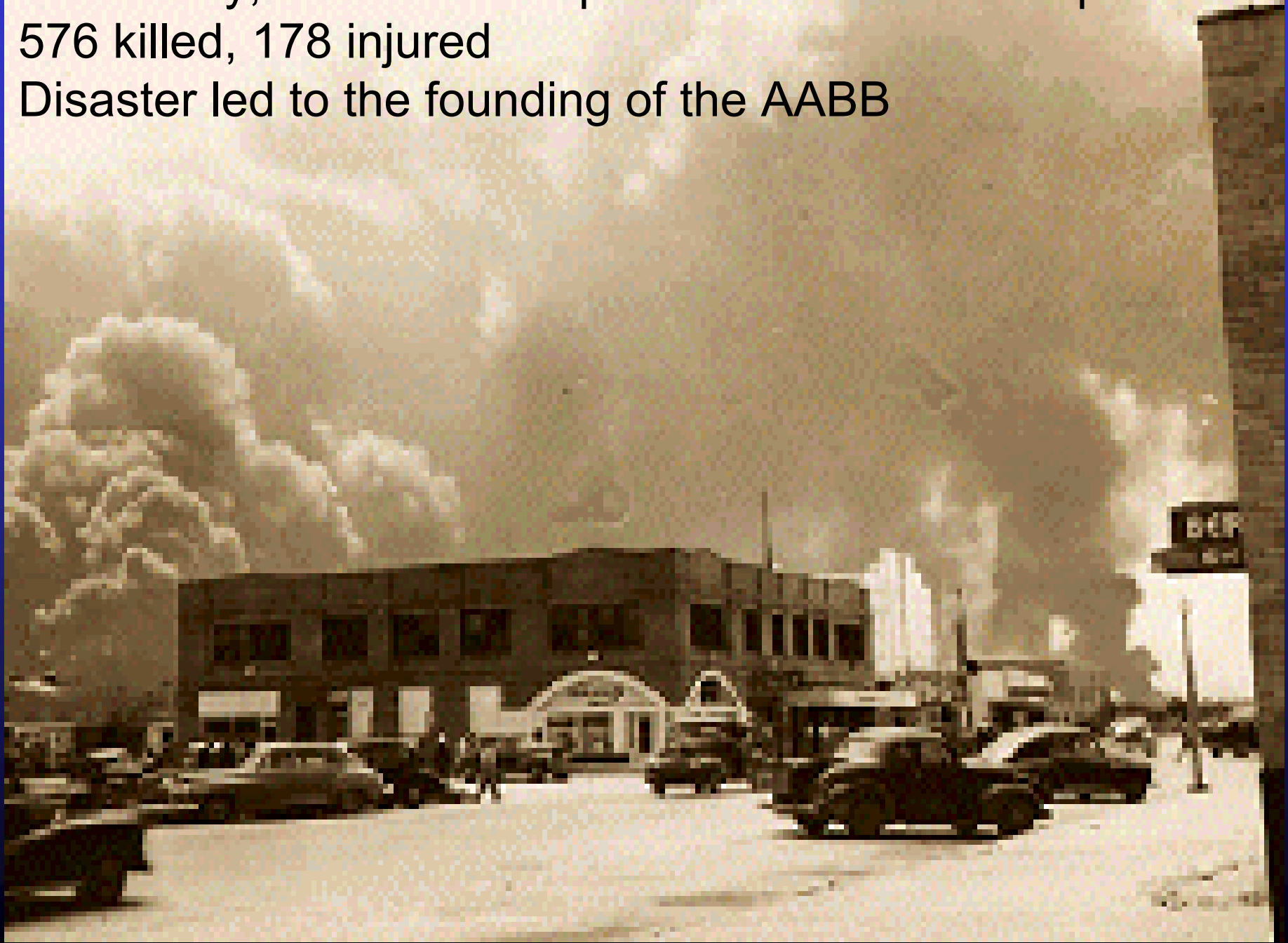
Harper's  
Weekly

2 October 1880

Texas City, TX - 16-17 April 1947  
Two shiploads of ammonium nitrate  
exploded



Texas City, TX - 16-17 April 1947 - Chemical explosion  
576 killed, 178 injured  
Disaster led to the founding of the AABB





**TABLE 1. U.S. DISASTERS IN THE PAST 25 YEARS IN WHICH MORE THAN 100 UNITS OF BLOOD WERE USED.**

CITY AND YEAR	VICTIMS		BLOOD*		
	KILLED	HOSPI-	ON	COLLECTED	TRANS-
		TALIZED			
	no.			units†	
Kansas City, Mo., 1981	114	188	2500	1500	126
Sioux City, Iowa, 1989	111	185	713	602	119
Oklahoma City, 1995	167	83	NA	>9000	131
Denver, 1999	15	30	1924	1700	105

\*Data for Kansas City are from Schmidt and Bayer,<sup>1</sup> data for Sioux City are from Schmidt,<sup>2</sup> data for Oklahoma City are from Belcher and Gilcher,<sup>3</sup> and data for Denver are from the Bonfils Blood Center (Dickey WC: personal communication). NA denotes not available.

†Values are units of red cells. Other blood components are not listed.

**TABLE 2. BLOOD USE AFTER SEPTEMBER 11, 2001.**

CITY	VICTIMS		BLOOD		
	KILLED	HOSPI-TALIZED	ON HAND	COLLECTED NATIONWIDE	TRANS-FUSED
	no.			units*	
New York City	Approximately 3000	139	NA		224†
Washington, D.C.	189	61	12,000		34‡
Total				>475,000	258

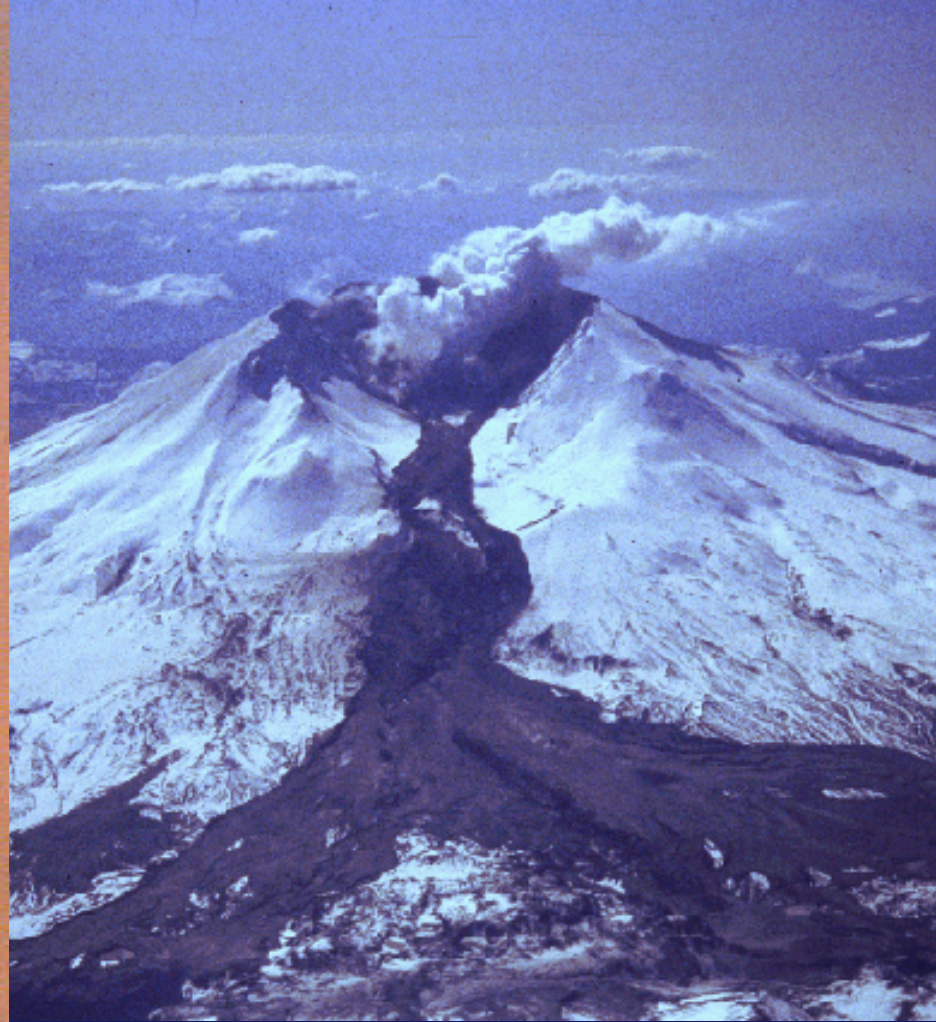
\*Values are units of red cells. Other blood components are not listed. NA denotes not available.

†The number was provided by the New York State Department of Health (Linden JV: personal communication).

‡The number was provided by the American Red Cross, Greater Chesapeake and Potomac Region (Gibble JW: personal communication).

# Seward, Alaska, 1964 - Earthquake and Tsunami





Mt . Saint Helens, 1980  
62 dead



# San Francisco, CA 17 Oct 1989 - Earthquake, Mag 7.1





**Hurricane Andrew - 24 Aug 1992**  
**15 direct deaths, 25 indirect in Dade County**  
**Quarter of a million homeless**





# Civil Disasters in Britain 1975-2000

- Airplane crash on a motorway
- Oil platform fire
- Three-train surface accident
- Two-train underground accident
- Underground station fire
- Terrorist bombing
- Crowd stampede at soccer stadium

# Troubles in Northern Ireland

- A quarter of a century of terrorism and communal strife in Northern Ireland killed 3,100 and injured 36,500 out of a population of 2 million.
- Twice in 25 years the local blood center released an additional 200 units when bombings lead to more than 100 casualties (blood used to replace stocks).
- Blood used to treat casualties was 3-6% of total blood use.

# Terrorism in Israel

- 1148 incidents between September 2000 and September 2002.
- 5354 casualties
- 6934 units of blood used.
- Israel has 6 million population
- Israel collects 280,000 units of blood yearly.
  - from Dr. Eilat Shinar, MDA Israel

# Disaster Planning

- “The two primary lessons learned from the Sept. 11 disaster include the need to control collections in excess of medical need and the need to ensure that facilities maintain adequate inventories to prepare for disasters at all times in all locations.”
  - Don Doddridge, Chair, AABB  
Intraorganizational Task Force on  
Domestic Disasters and Acts of Terrorism

# Disaster Planning

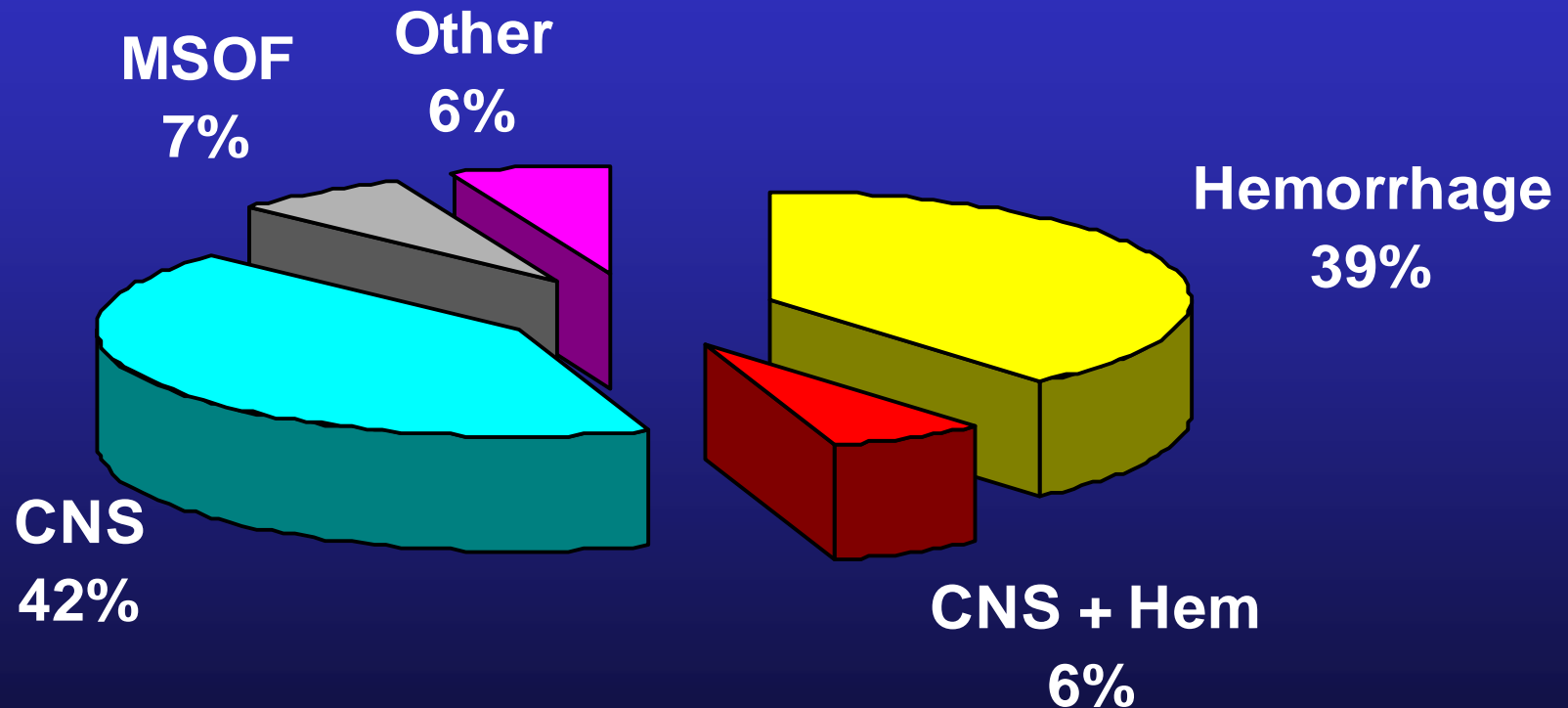
- “there are no currently identified scenarios in which the need for blood and/or blood components would be beyond the capabilities of the blood community to provide. It is the consensus of the task force that the single greatest risk of natural disasters and acts of terrorism is not lack of supply, but disruption of the blood system”
  - Don Doddridge, Chair, AABB Intraorganizational Task Force on Domestic Disasters and Acts of Terrorism



# Injury and Blood Use: National Numbers

- 36 million Americans are injured each year
- 27 million seek emergency medical care
- 1.2 million are hospitalized
- 200,000 receive blood
- 1.2 million U of RBC are used to treat injury
- 93,000 die

# Mortality After Civilian Trauma



# R Adams Cowley Shock Trauma Center at the University of Maryland



“There is a  
Golden Hour”

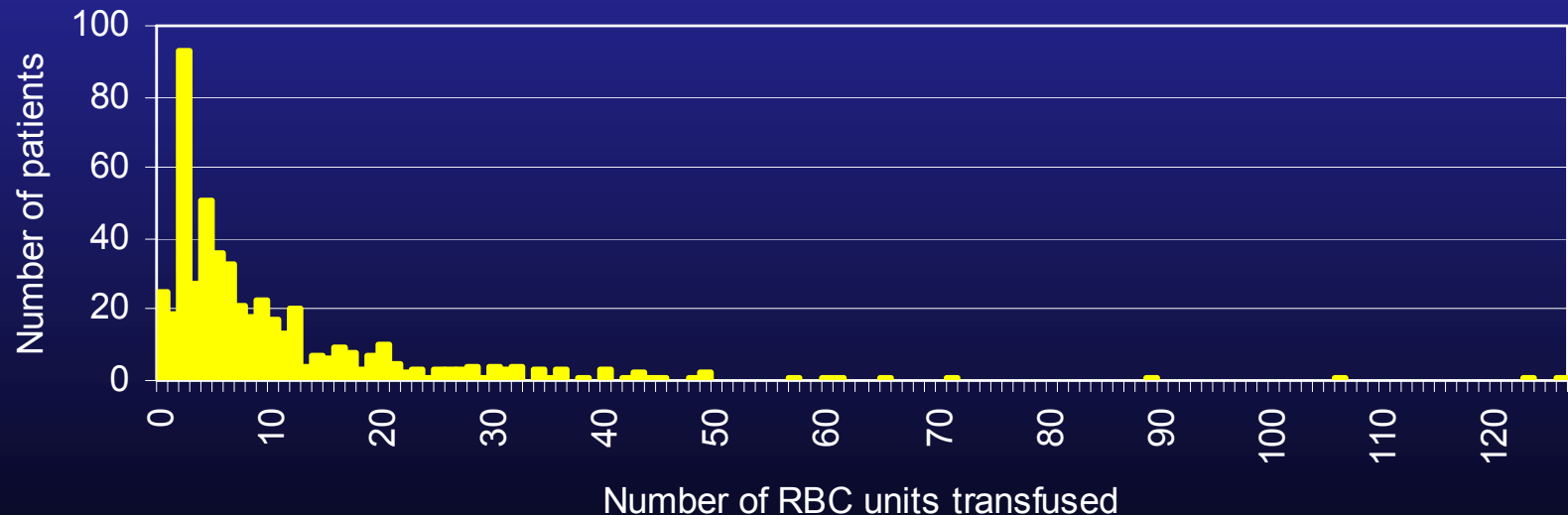


# Blood Use at STC in 2000

- About 7200 patients admitted
- 5645 admitted directly from scene of injury
- 514/5645 received blood products
- 490 received RBC
- Remainder received plasma (elderly receiving warfarin with intracranial bleeding, etc)

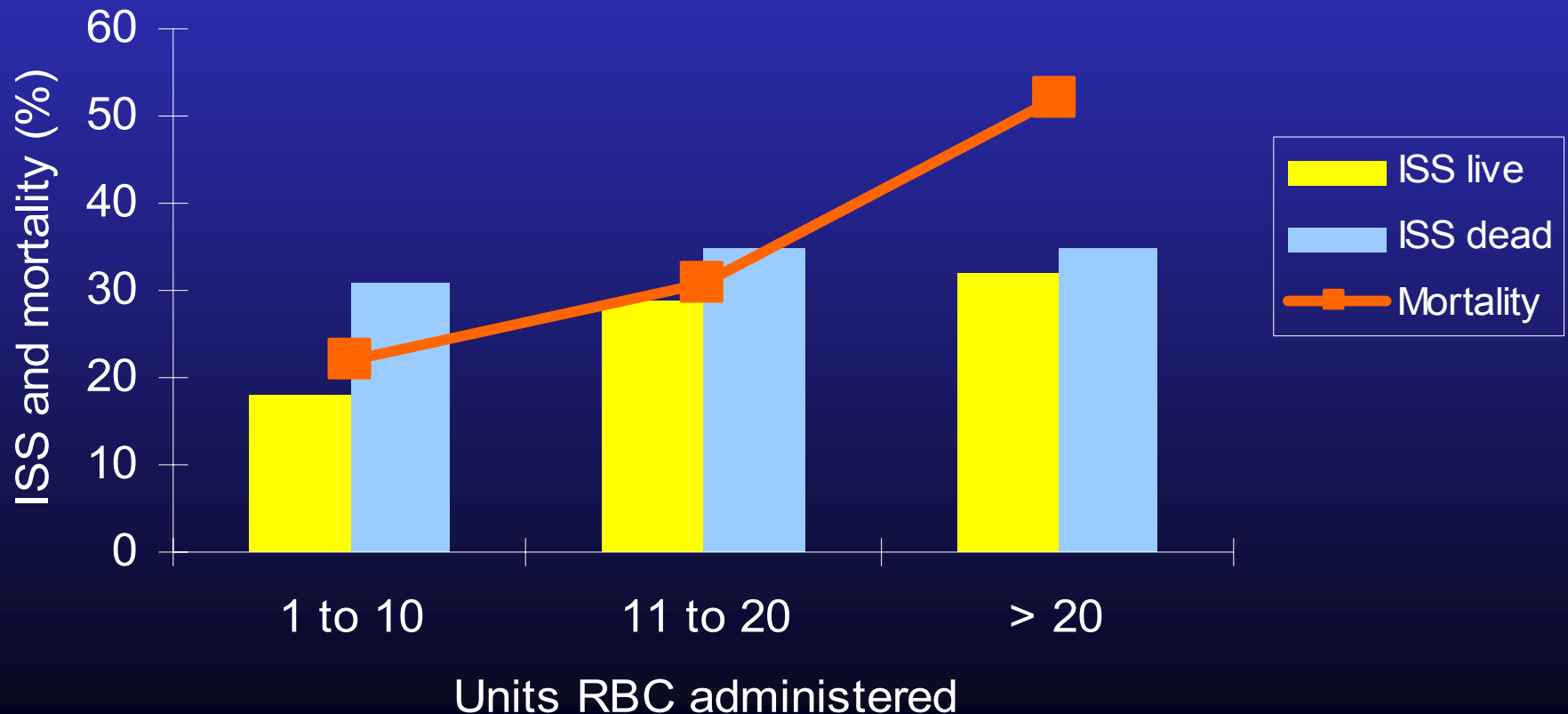
# RBC Units Used at STC in 2000

- 5645 patients admitted directly from the scene of injury
- 514 patients required transfusion
- 5219 RBC units were given to 490 of the patients requiring transfusion



# Relationship Between Injury Severity, Blood Use, and Mortality

ISS and Mortality by  
Number of RBC Units Administered

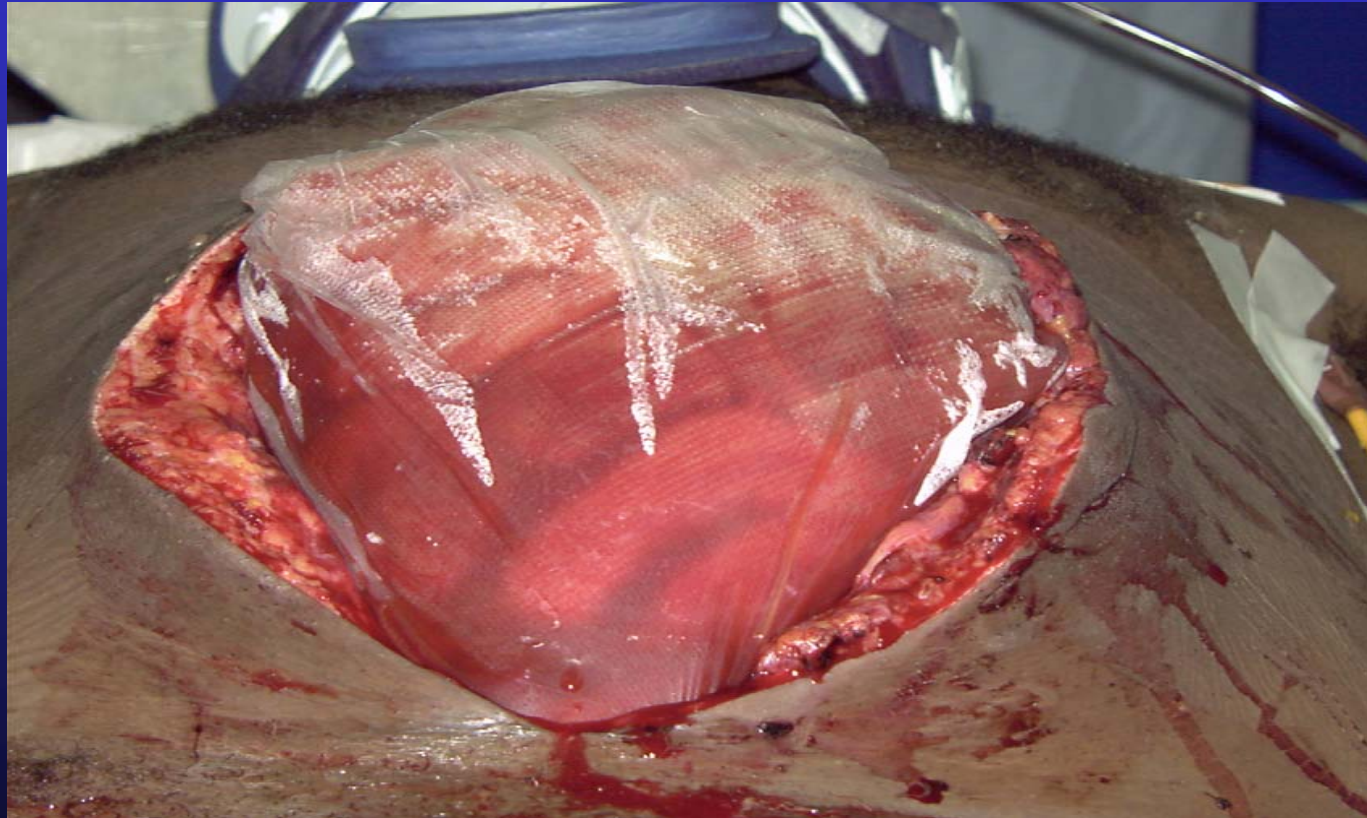




# Grade V Liver Injury



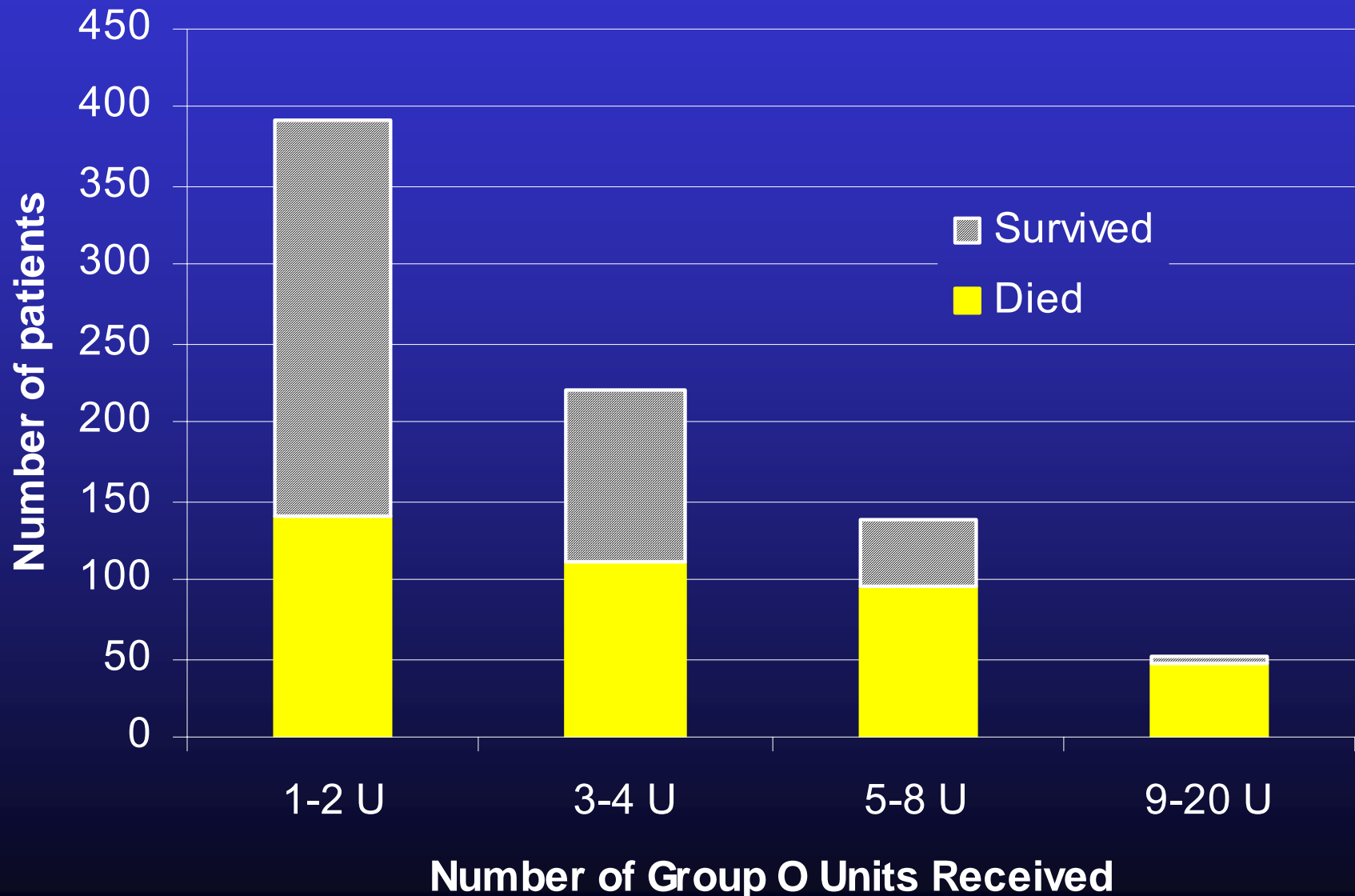
# Abdominal Packing After Damage Control Surgery



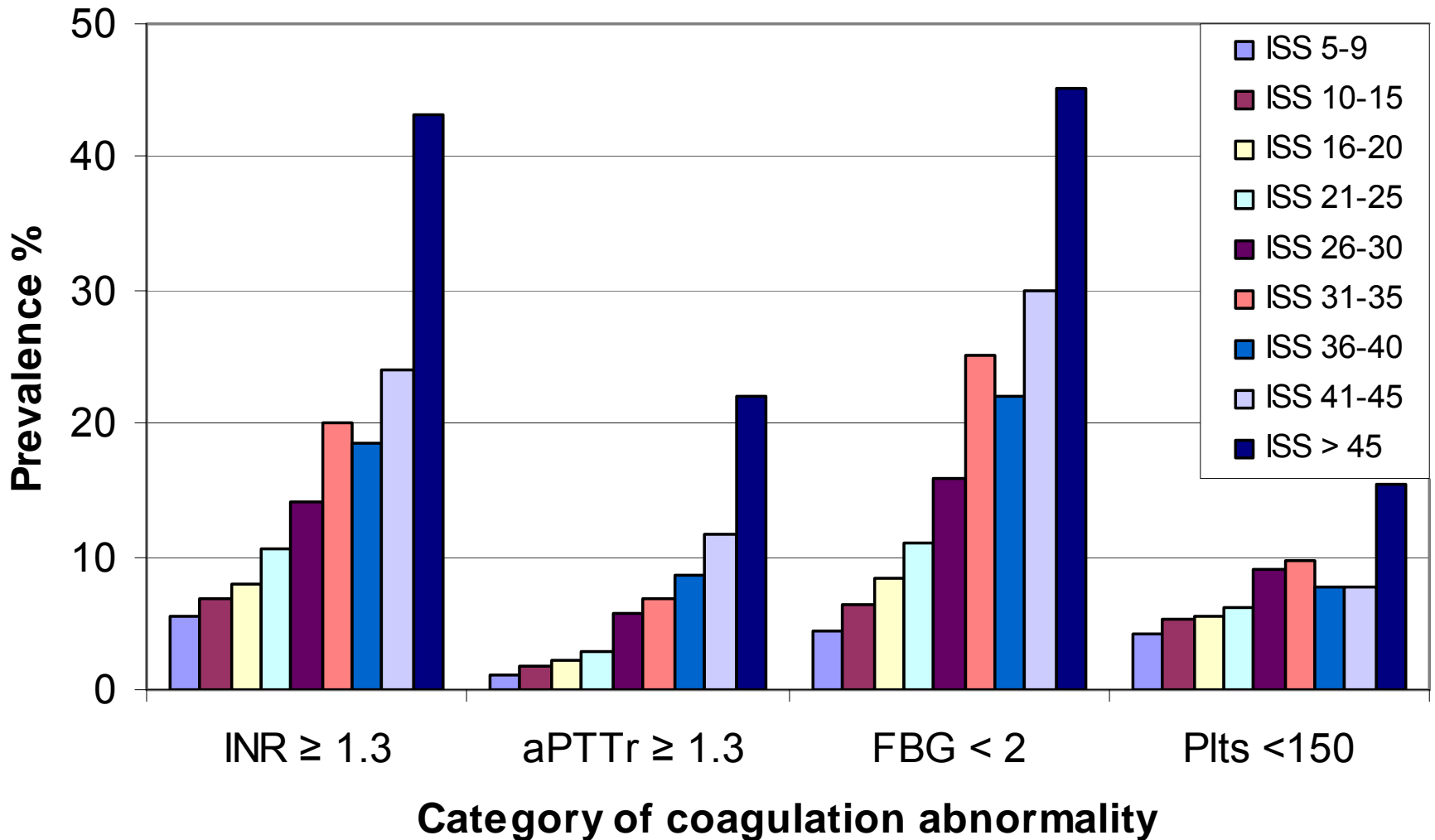
# Management of Uncrossmatched Group O RBC

- We stock 10 U of O positive and 2 U of O negative RBC in the STC refrigerator
- O negative units are given to women of child-bearing age, all others receive O positive
- More uncrossmatched units can be released by calling the blood bank
- Turnaround time for crossmatched blood is 45–50 minutes
- Blood bank is 2 blocks away

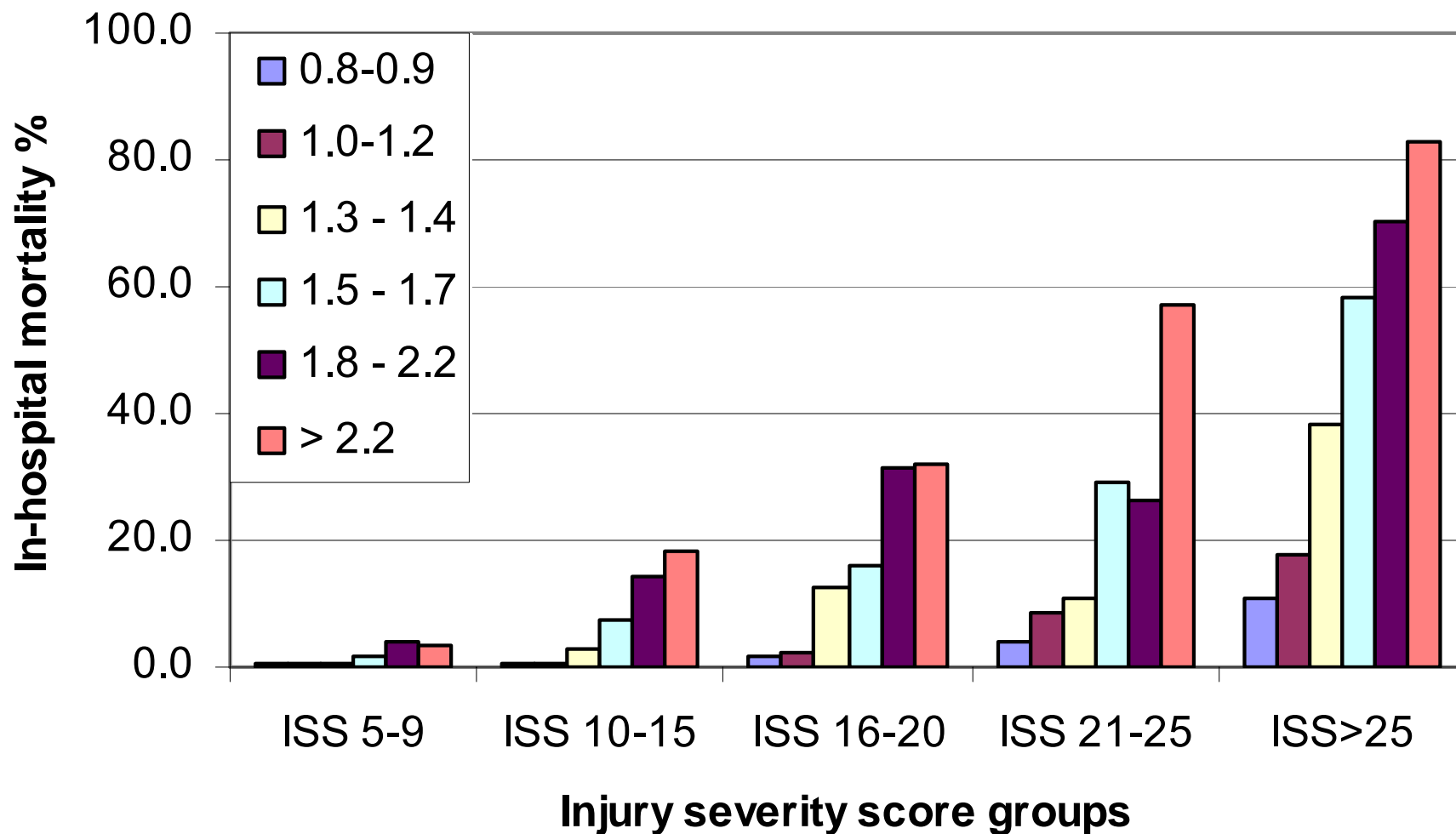
# Survival After Uncross-matched Group O RBC in 1999-2003



## Prevalence of abnormal admission coagulation tests in a trauma center population, n = 15,782



## Interaction of injury severity and admission INR on in-hospital mortality





# Causes of Coagulopathy in the Massively Transfused

- Loss
- Dilution
- Hypothermia
- Acidosis

**Coagulopathy  
of Trauma**

- Consumption
- Fibrinolysis

**DIC**

# Effect of pH on FXa/Va Activity

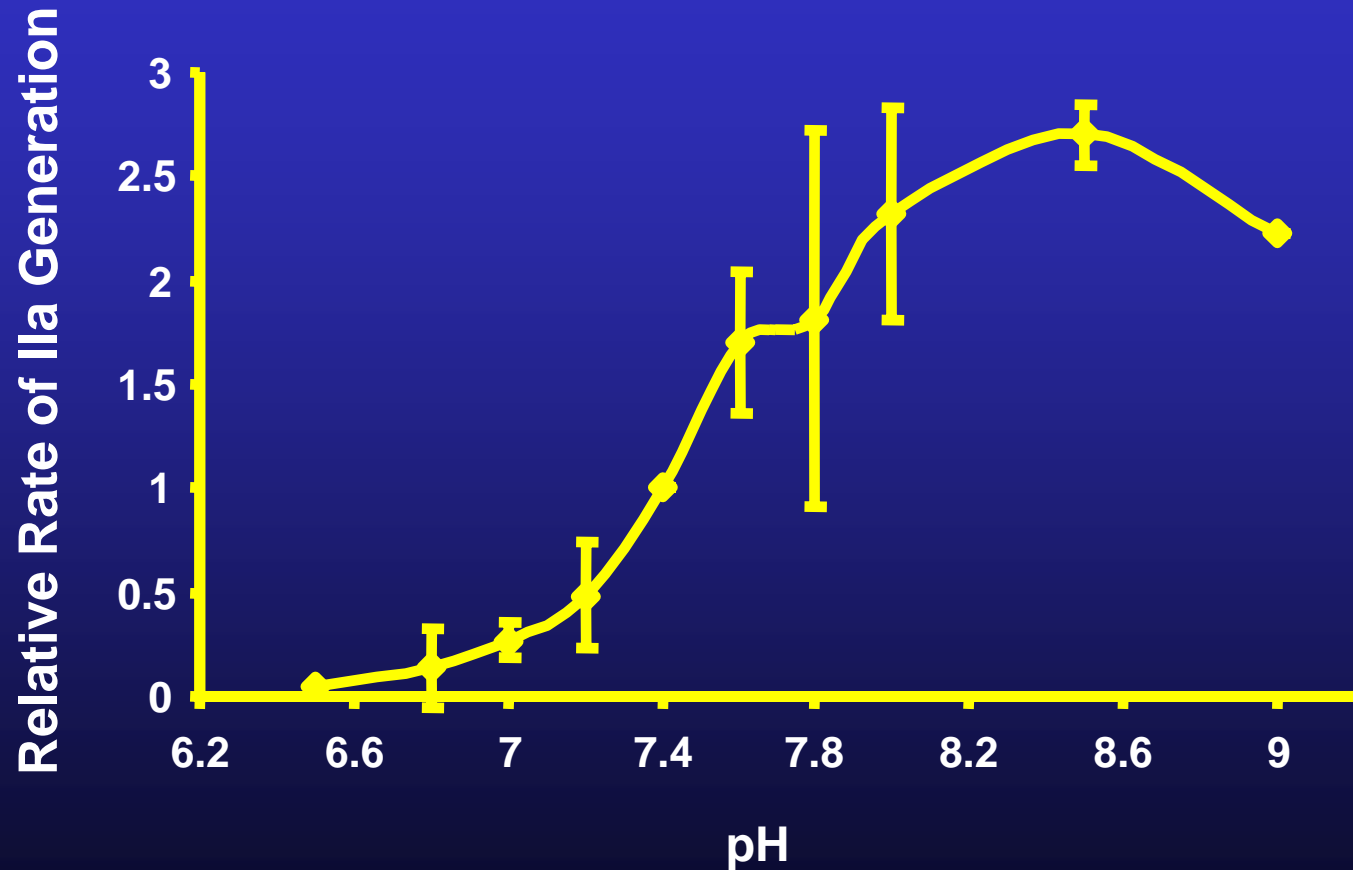
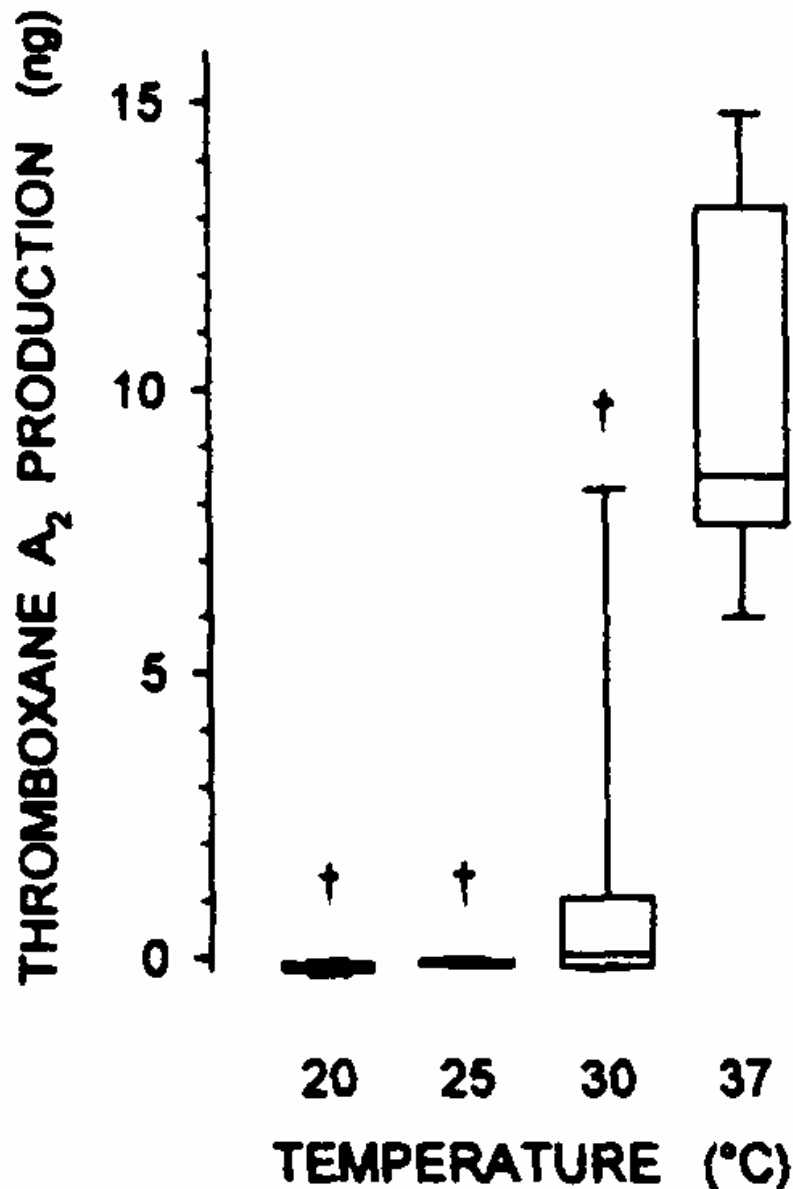


Figure 8 – from Meng et al, J Trauma, 55:886-91, 2003

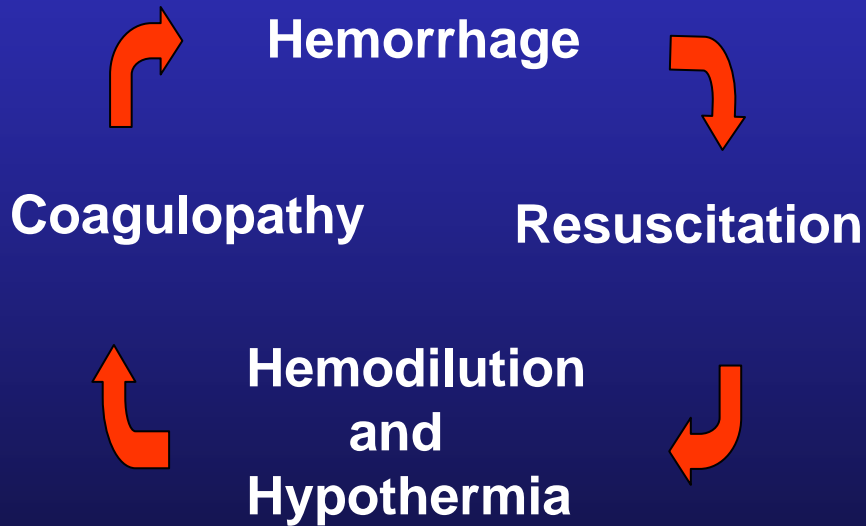
## TEMPERATURE DEPENDENCE OF vWF-INDUCED CALCIUM SIGNAL



Platelet  
activation by the  
vWF pathway is  
gone in 50% of  
individuals at  
30°C and  
profoundly  
reduced in 75%

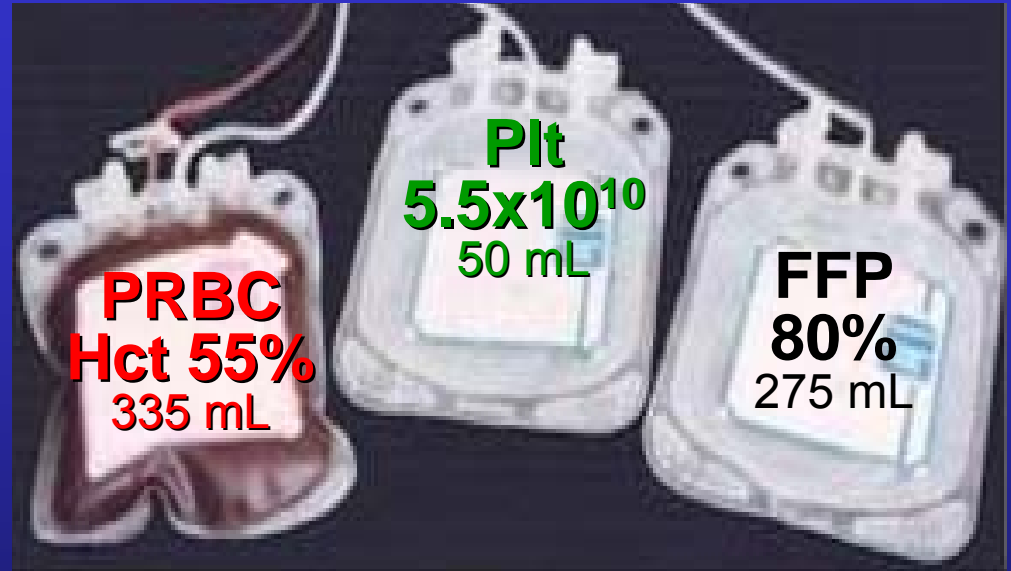
Kermode et al. Blood 1999;  
94:199-207

# Breaking the “Bloody Vicious Cycle”



- Control hemorrhage
- Use best possible resuscitation products
- Prevent hypothermia
- Prevent hemodilution
- Treat coagulopathy

# Component Therapy vs What we bleed



So Component Therapy Gives You  
**1U PRBC + 1U PLT + 1U FFP**

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

# Making blood available quickly in emergencies

The blood bank refrigerator in the trauma receiving unit



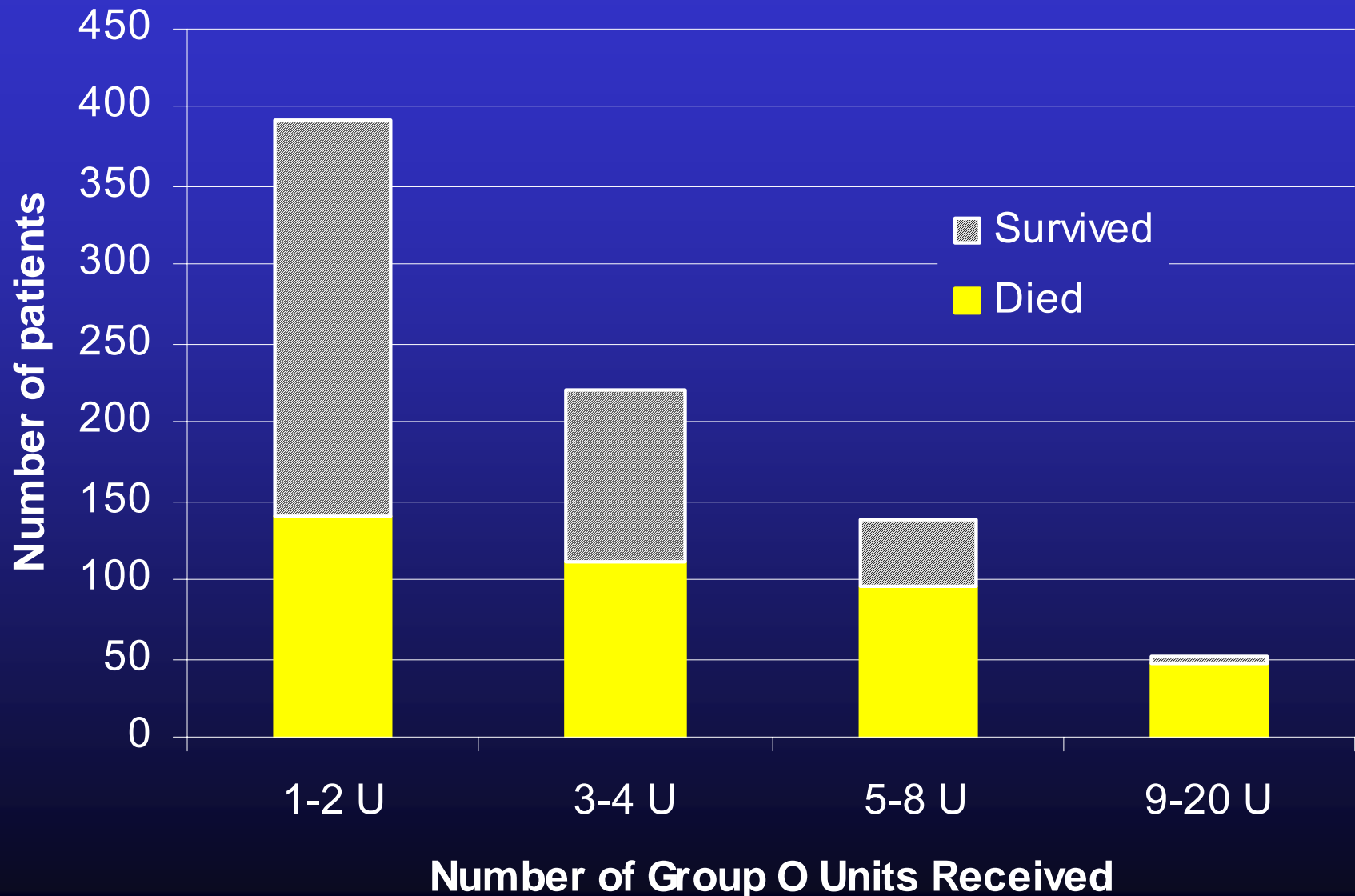
- In the Trauma Center
  - 10 units of O Pos RBC
  - 2 units O Neg RBC
  - 4 U AB thawed plasma
- In the Blood Bank
  - 600 more U RBC
  - A, B, & O thawed plasma
  - Apheresis platelets
  - Pre-pooled 6 U cryo



# Uncrossmatched Group O RBC

- 161/490 patients transfused RBC at STC in 2000 received initial treatment with uncrossmatched group O RBC
- 18% of all RBC given on first day were uncrossmatched group O RBC
- 11% of all RBC given in STC are uncrossmatched group O RBC
- 51% of patients who receive uncrossmatched group O RBC during resuscitation at STC survive

# Survival After Uncross-matched Group O RBC in 1999-2003



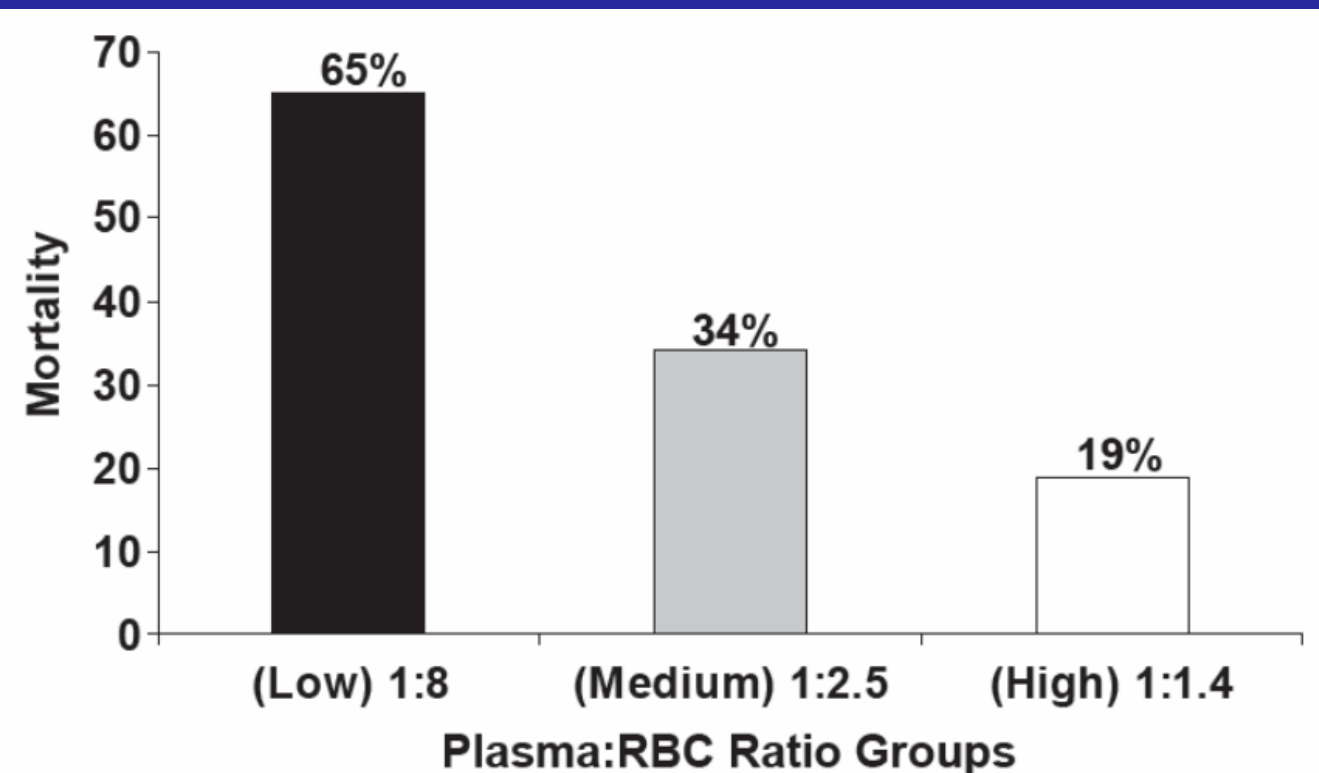
# Safety of Uncrossmatched Group O RBC

- No hemolytic transfusion reactions, which are always a concern in chaotic situations where identification is difficult
- Alloimmunization is rare: 9 cases of new anti-D among 800 patients in 5 years
- One woman of reproductive age alloimmunized to RhD in 5 years

J Trauma 2007 Nov; 63:805-813

# The Ratio of Blood Products Transfused Affects Mortality in Patients Receiving Massive Transfusions at a Combat Support Hospital

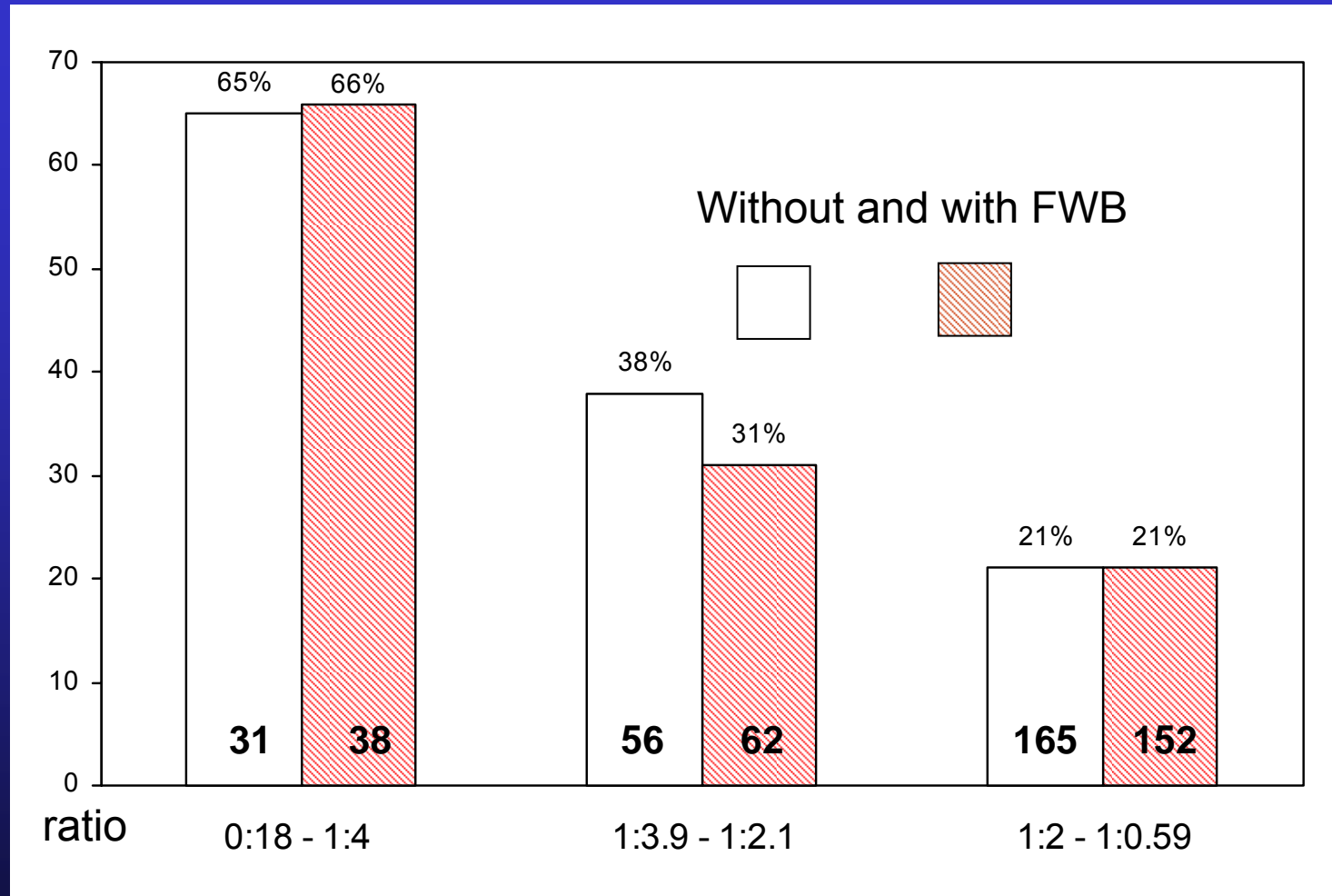
Matthew A. Borgman, MD, Philip C. Spinella, MD, Jeremy G. Perkins, MD, Kurt W. Grathwohl, MD, Thomas Repine, MD, Alec C. Beekley, MD, James Sebesta, MD, Donald Jenkins, MD, Charles E. Wade, PhD, and John B. Holcomb, MD



- 252 patients receiving >10 U of RBC in 24 hours.

- Mortality by plasma:RBC unit ratio

# Impact of FFP:RBC Ratio On Overall Mortality



ISS (IQR)  
%ISS >25

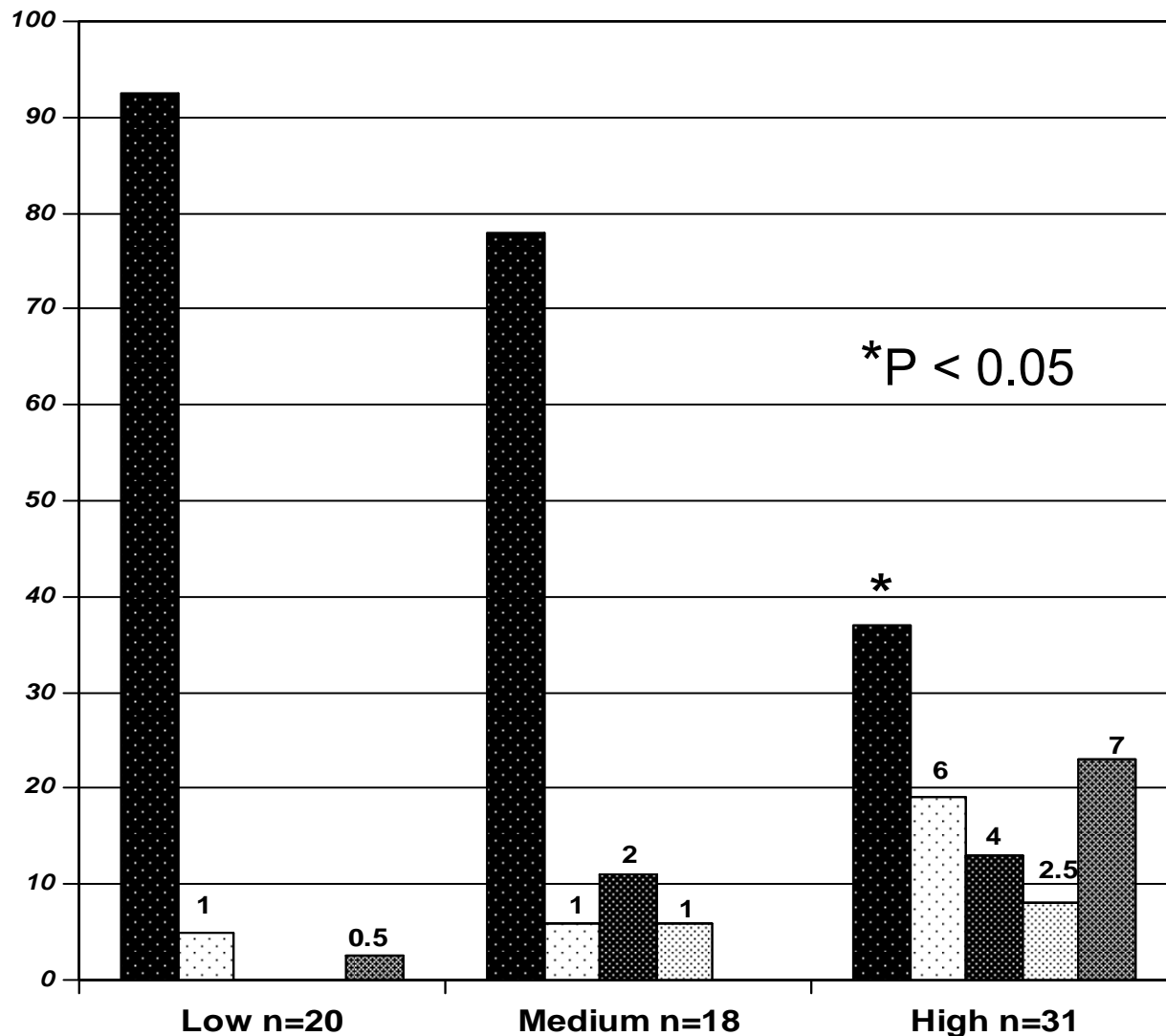
16 (11-20)  
13%

17 (12-30)  
20%

17 (14-25)  
21%



# Comparison of the primary causes of death in each plasma: RBC ratio group

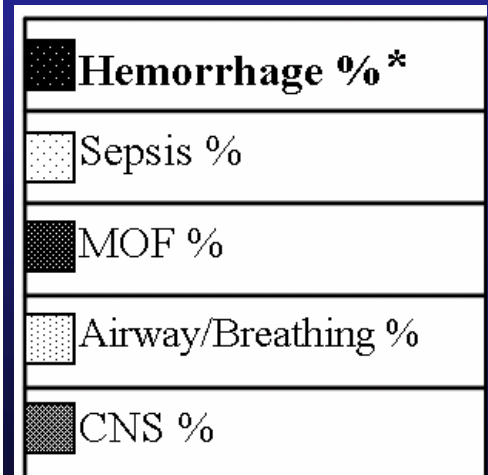


Time to death

<sup>a</sup>Low = 2 hrs (1-4)

<sup>b</sup>Med = 4 hrs (2-16)

<sup>c</sup>High = 38 hrs (4-155)



# **Damage Control Resuscitation: Directly Addressing the Early Coagulopathy of Trauma**

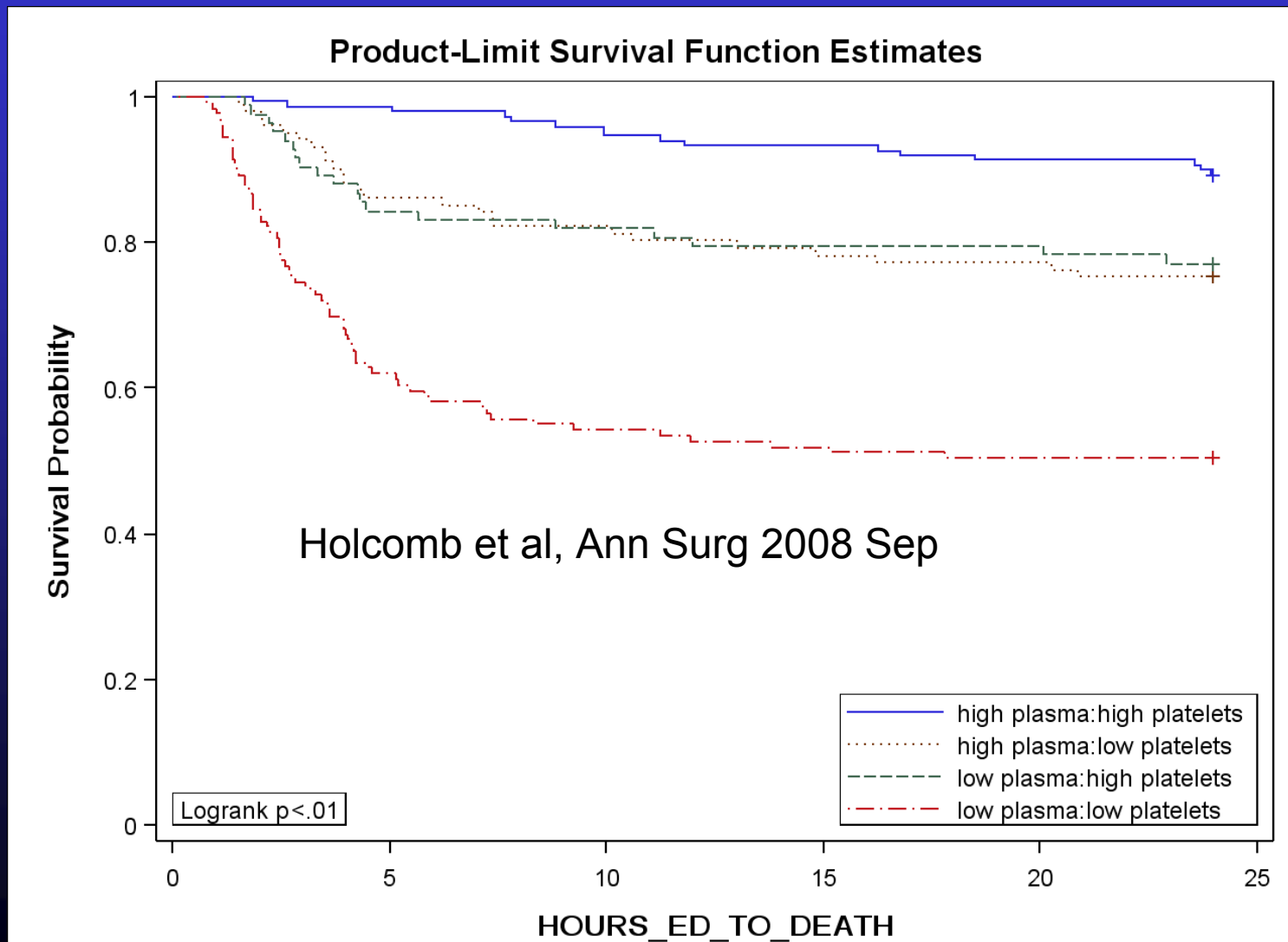
*John B. Holcomb, MD, FACS, Don Jenkins, MD, FACS, Peter Rhee, MD, FACS, Jay Johannigman, MD, FS, FACS, Peter Mahoney, FRCA, RAMC, Sumeru Mehta, MD, E. Darrin Cox, MD, FACS, Michael J. Gehrke, MD, Greg J. Beilman, MD, FACS, Martin Schreiber, MD, FACS, Stephen F. Flaherty, MD, FACS, Kurt W. Grathwohl, MD, Phillip C. Spinella, MD, Jeremy G. Perkins, MD, Alec C. Beekley, MD, FACS, Neil R. McMullin, MD, Myung S. Park, MD, FACS, Ernest A. Gonzalez, MD, FACS, Charles E. Wade, PhD, Michael A. Dubick, PhD, C. William Schwab, MD, FACS, Fred A. Moore, MD, FACS, Howard R. Champion, FRCS, David B. Hoyt, MD, FACS, and John R. Hess, MD, MPH, FACP*

*J Trauma.* 2007;62:307–310.

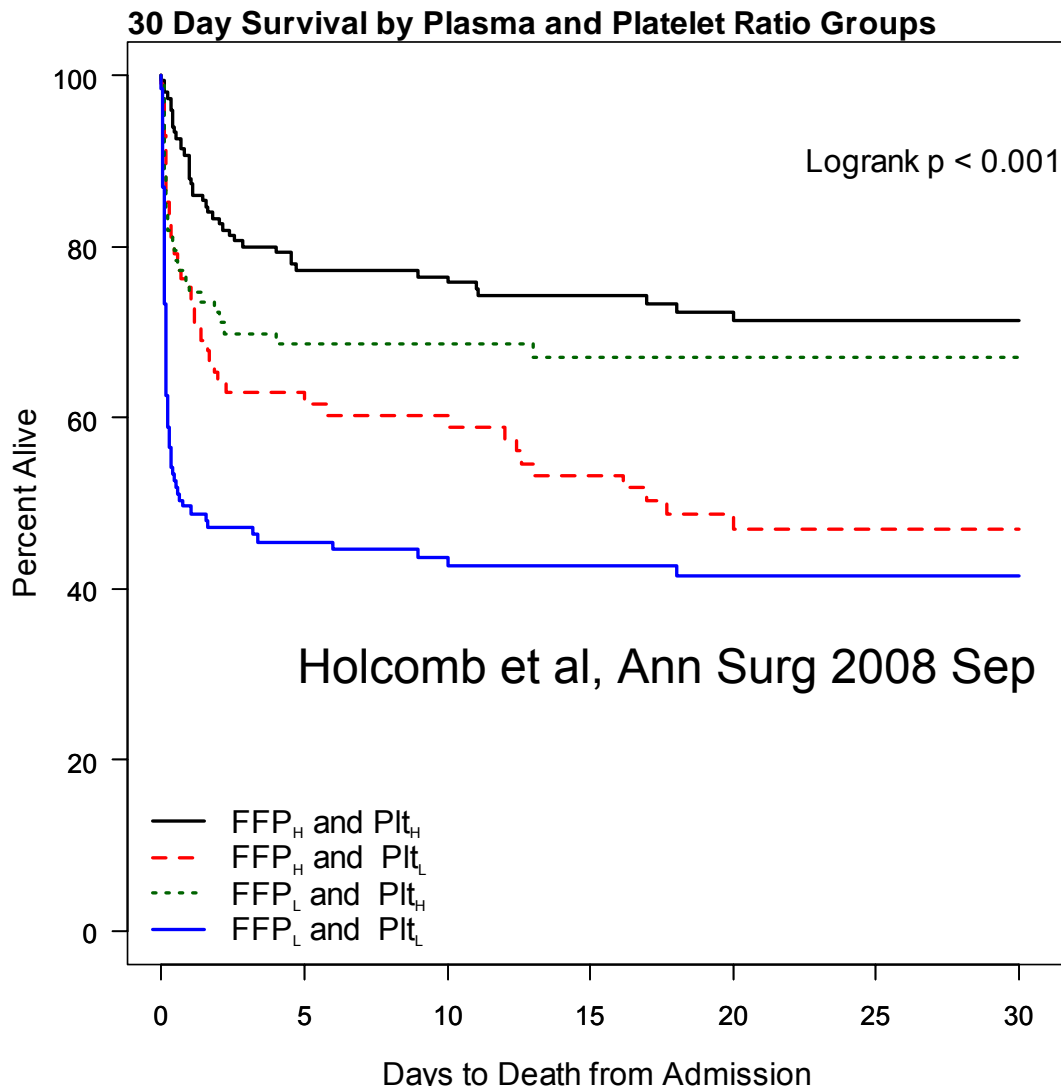
- Resuscitation with a 1:1:1 ratio of RBCs, plasma, and platelets is the recommendation of the Army Surgeon General and his Trauma Consultant.

*J Trauma,* 2007.

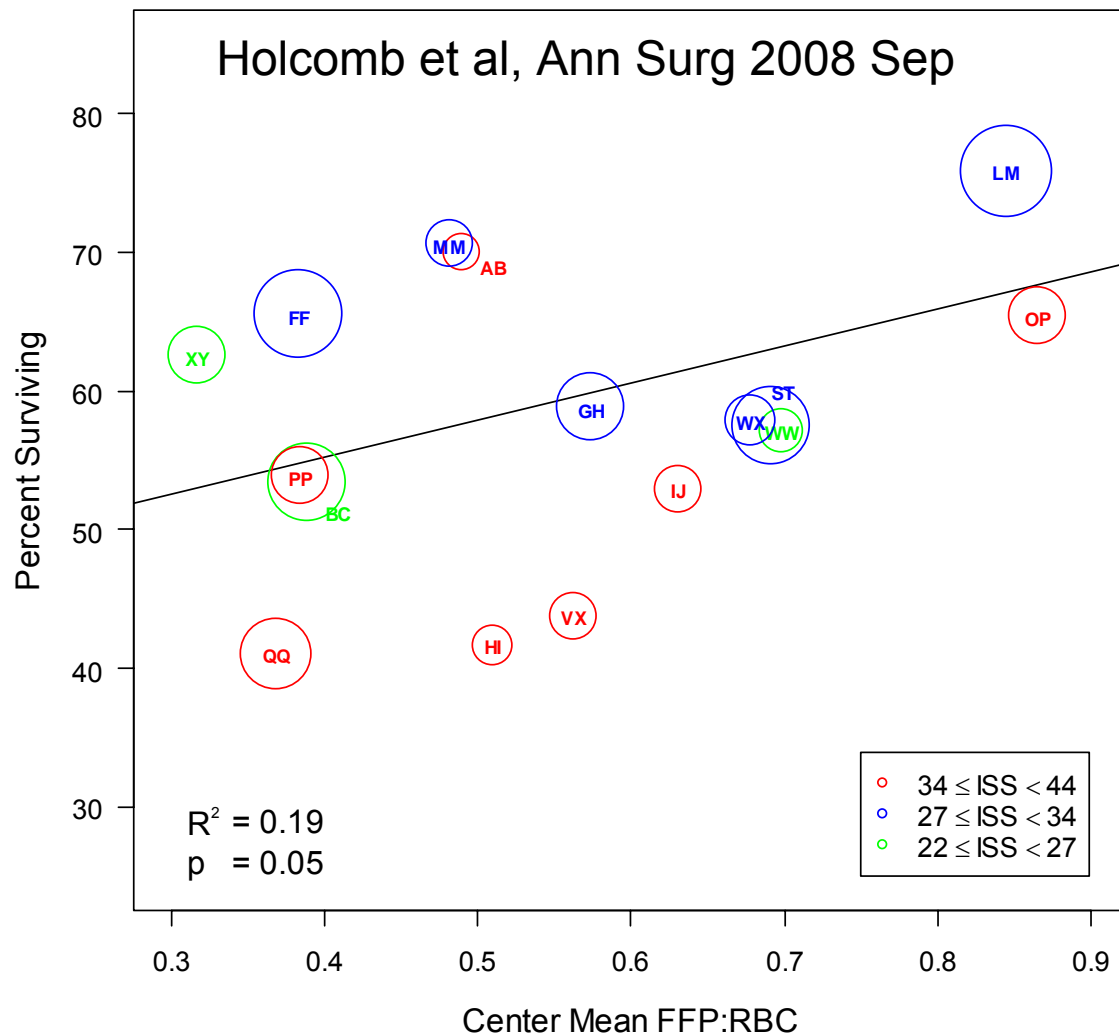
# 24 hr mortality of 466 massively transfused trauma patients seen in 2006 at 16 academic trauma centers by units of plasma to units of RBC ratio



# 30 day mortality of 466 massively transfused trauma patients seen in 2006 at 16 academic trauma centers by units of plasma to units of RBC ratio



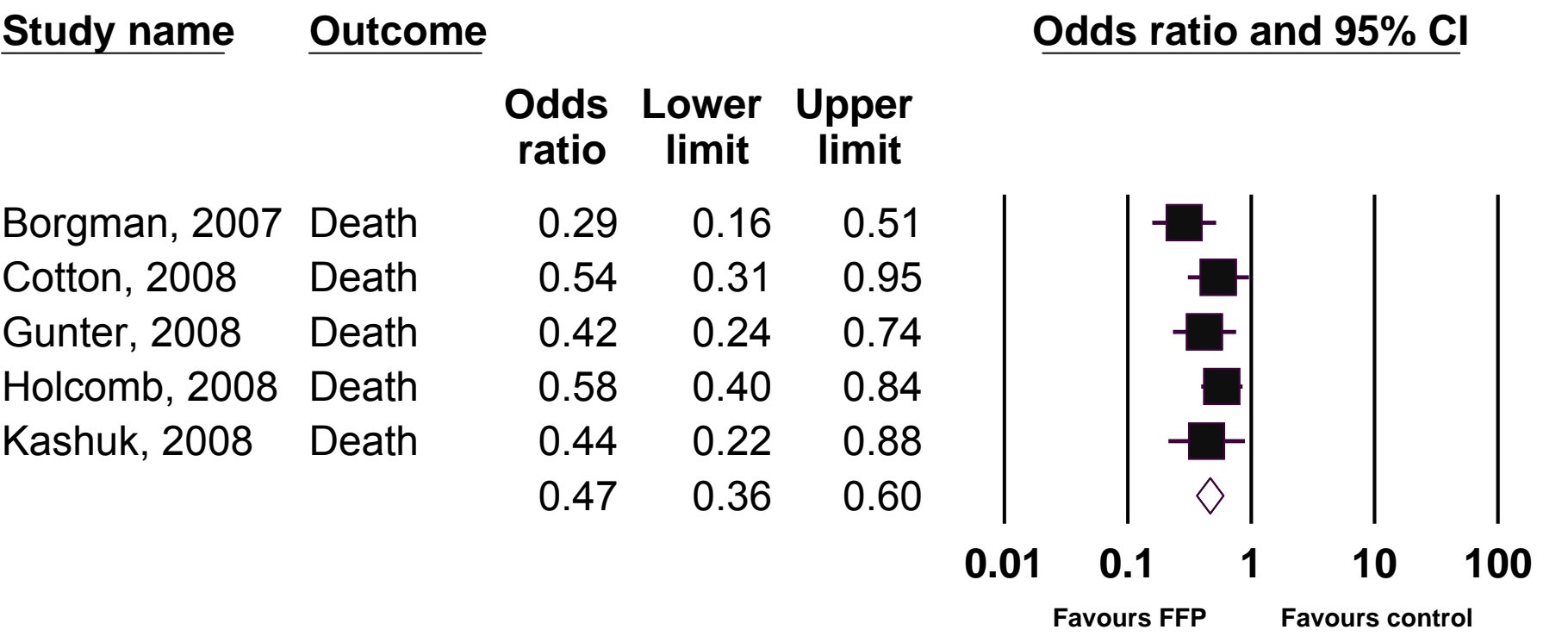
# 30 day mortality of 466 massively transfused trauma patients seen in 2006 at 16 academic trauma centers by units of plasma to units of RBC ratio





# Mayo evidence-base review for the AABB plasma guidelines project

- John Roback, Chair



Meta Analysis

Massive transfusion appears to be the one situation where giving plasma prevents death and MOF despite increases in acute lung injury.

# U. of Copenhagen Series

- In 2002-2003 most massively transfused patients became coagulopathic and many deaths were ascribed to coagulopathy
- In 2004 they developed an aggressive policy of giving extra plasma and platelets to all massively transfused patients
- In 2005 and 2006 they collected data on all massively transfused patients.

**Table 1. Demographic variables and laboratory results in patients receiving more than 10 units of red blood cells within 24 h in 2002-2003 and 2005-2006.**

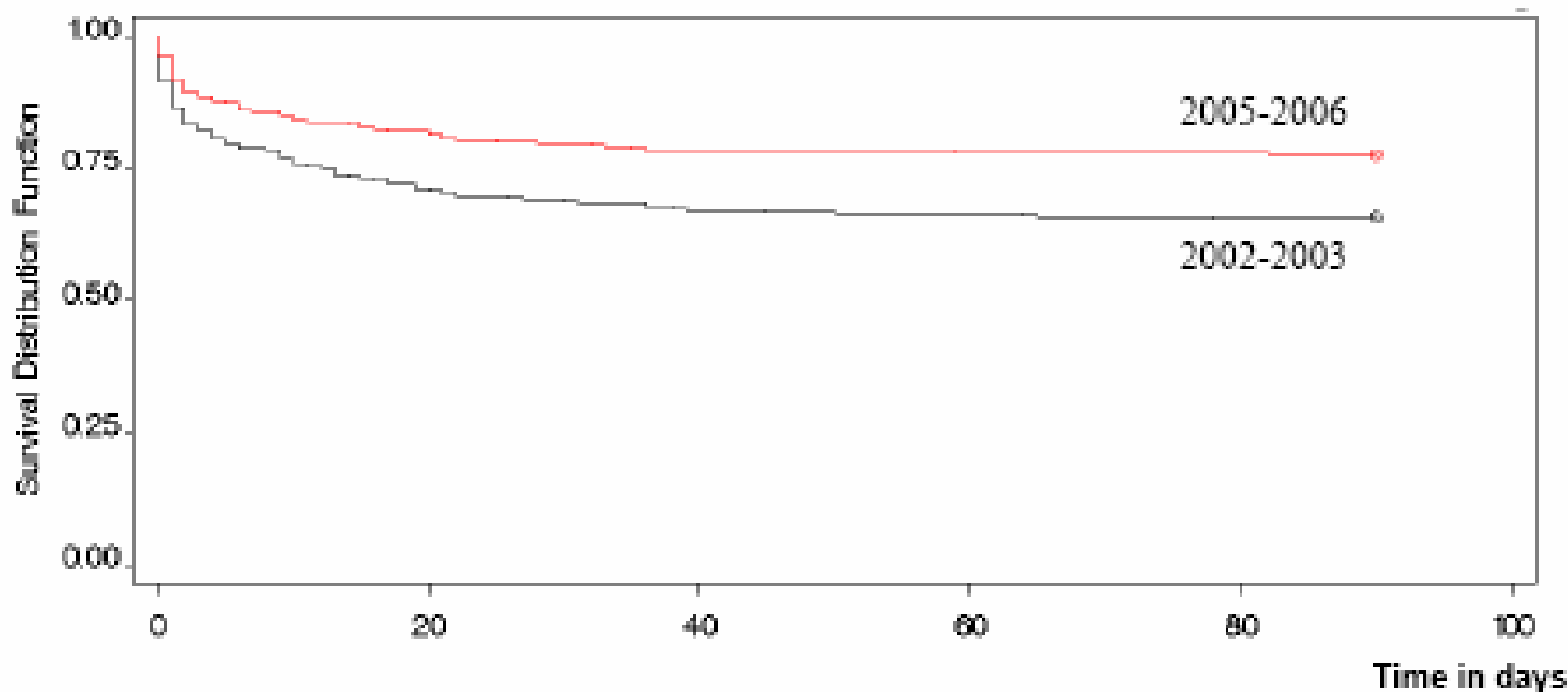
	<b>2002-2003 (N=390)</b>	<b>2005-2006 (N=442)</b>	<b>All</b>	<b>P value <sup>#</sup></b>
Age in years	58.4 (18.4)	58.3 (18.5)	58.3 (18.5)	0.97
Male gender	268 (68.7%)	315 (71.3%)	583 (70.1%)	0.42
Type of admission				
<i>Abdominal-vascular surgery</i>	176 (45.1%)	231(52.3%)	407 (48.9%)	0.1357
<i>Cardio-thoracic surgery</i>	87 (22.3%)	83 (18.8%)	170 (20.4%)	
<i>Trauma surgery</i>	61 (15.6%)	60 (13.6%)	121 (14.5%)	
<i>Orthopaedic surgery</i>	27 (6.9%)	38 (8.6%)	65 (7.8%)	
<i>Miscellaneous</i>	24 (6.2%)	22 (5.0%)	46 (5.5%)	
<i>Burn surgery</i>	15 (3.9%)	8 (1.8%)	23 (3.4%)	
Pre-bleeding sample time, from blood sampling to 1 <sup>st</sup> transfusion (h)	11.8 (12.6)	13.6 (13.1)	12.7 (12.9)	0.1437
Post-bleeding sample time, from 1 <sup>st</sup> transfusion to blood sample (h)	32.1 (18.8)	32.6 (12.2)	33.6 (11.8)	0.4653

Data are mean (Standard Deviation) if not marked as n %. Two-sample t-test and Chi-square test

<sup>#</sup> Difference between 2002-2003 and 2005-2006.

# Benefit of giving more plasma and platelets to massively transfused patients

Figure 1. Kaplan-Meier curve for 90-day survival



Number at risk

2005-2006	442	385	362	352	347	345	345	344	343	343
2002-2003	390	308	281	267	257	255	255	255	255	255

Log-rank,  $p < 0.0001$

On average, patients got 3 more pooled 4U platelet concentrates on day 1 and saved 2 U RBC by day 30

**Table 2. Blood component use during and after initial bleeding episode in 832 patients receiving more than 10 units of red blood cells within 24 h.**

	<b>2002-2003 (N=390)</b>	<b>2005-2006 (N=442)</b>	<b>P value</b>
<b>No. of RBC 24 h</b>	19.2 (15.8)	18.0 (12.6)	0.2409
<b>No. of FFP 24 h</b>	12.1 (15.2)	13.5 (12.3)	0.1489
<b>No. of PC 24 h</b>	1.7 (2.0)	5.0 (4.2)	<0.0001
<b>No. of blood components 24 h</b>	33.0 (30.4)	36.5 (27.9)	0.0816
<b>No. of RBC 30 days</b>	28.7 (25.5)	26.6 (24.2)	0.2263
<b>No. of FFP 30 days</b>	17.5 (23.5)	17.5 (17.8)	0.9489
<b>No. of PC 30 days</b>	3.4 (7.5)	7.0 (9.2)	<0.0001
<b>No. of blood components 30 days</b>	49.5 (51.0)	51.1 (48.0)	0.6444

No=Number; RBC= Red blood cells; FFP= Fresh frozen plasma; PC= Platelet concentrate.  
Data are mean (Standard Deviation). Two-sample t-test.

## **Giving plasma at a 1:1 ratio with red cells in resuscitation: who might benefit?**

*John R. Hess, Richard B. Dutton, John B. Holcomb, and Thomas M. Scalea*

- Patients who are:
  - critically injured
  - actively bleeding
  - will go on to be massively transfused



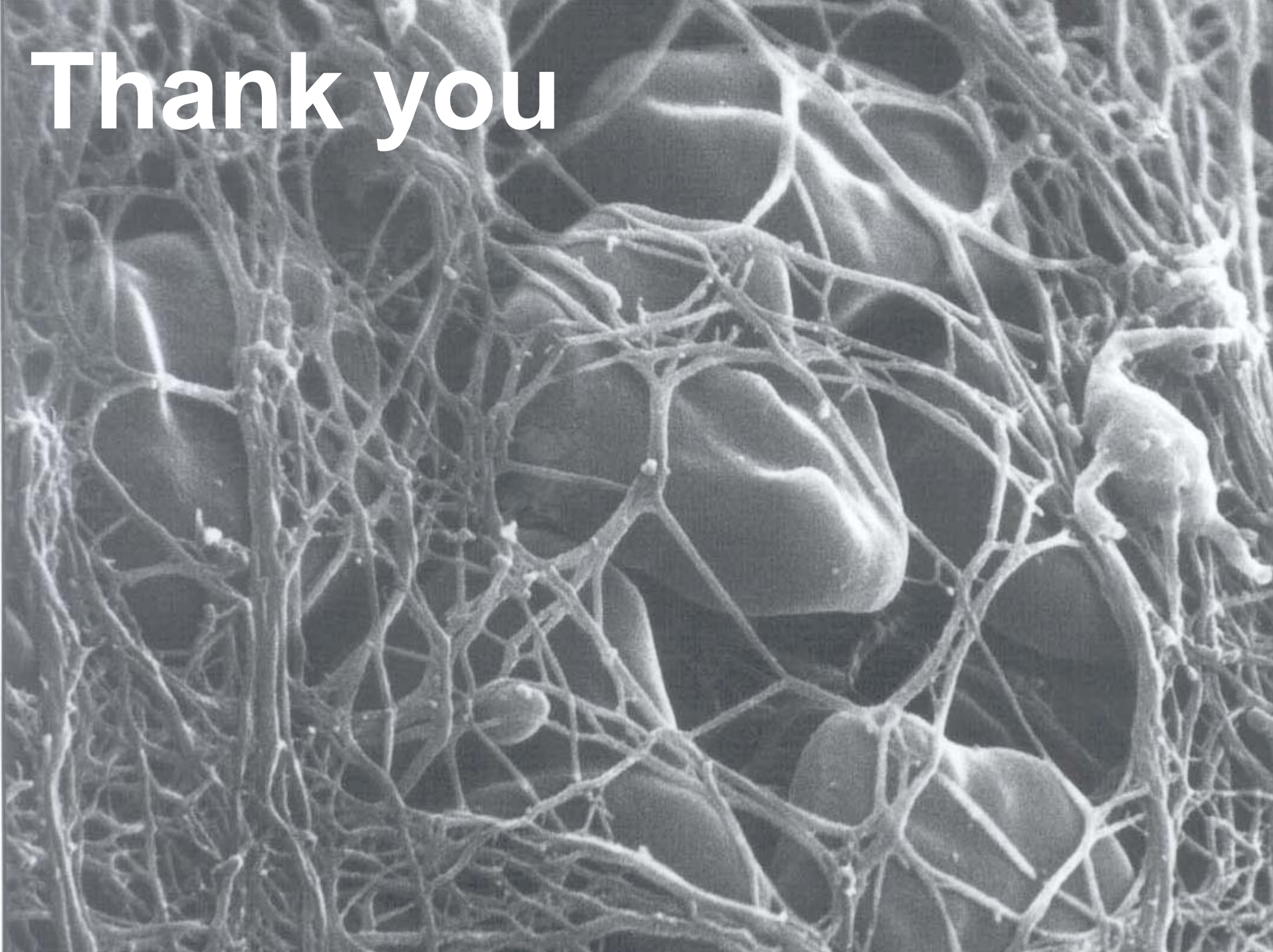


Thanks to many individuals  
in Baltimore and Baghdad



**The Team  
That Works Together...  
Saves Together**  
The Shock Trauma Team





**Thank you**