Greater than the sum of its parts:
The use of whole blood in the resuscitation of hemorrhage

Bryan A Cotton, MD, MPH
The John B Holmes Professor of Clinical Sciences
Department of Surgery and Center for Translational Injury Research
McGovern Medical School at the University of Texas Health Science Center
Red Duke Trauma Institute at Memorial Hermann Hospital
Houston, Texas

UTHealth The University of Texas Health Science Center at Houston | McGovern Medical School

Red Duke Trauma Institute
MEMORIAL HERMANN

Disclosures

- Scientific Advisory Board for Haemonetics (TEG, CellSaver)
- Scientific Advisory Board for Cerus (IFC, pathogen-reduced cryo)
- Scientific Advisory Board for Velico (SDP, spray dried plasma)
- Medical Advisory Board for Telflex (Freeze-dried plasma)

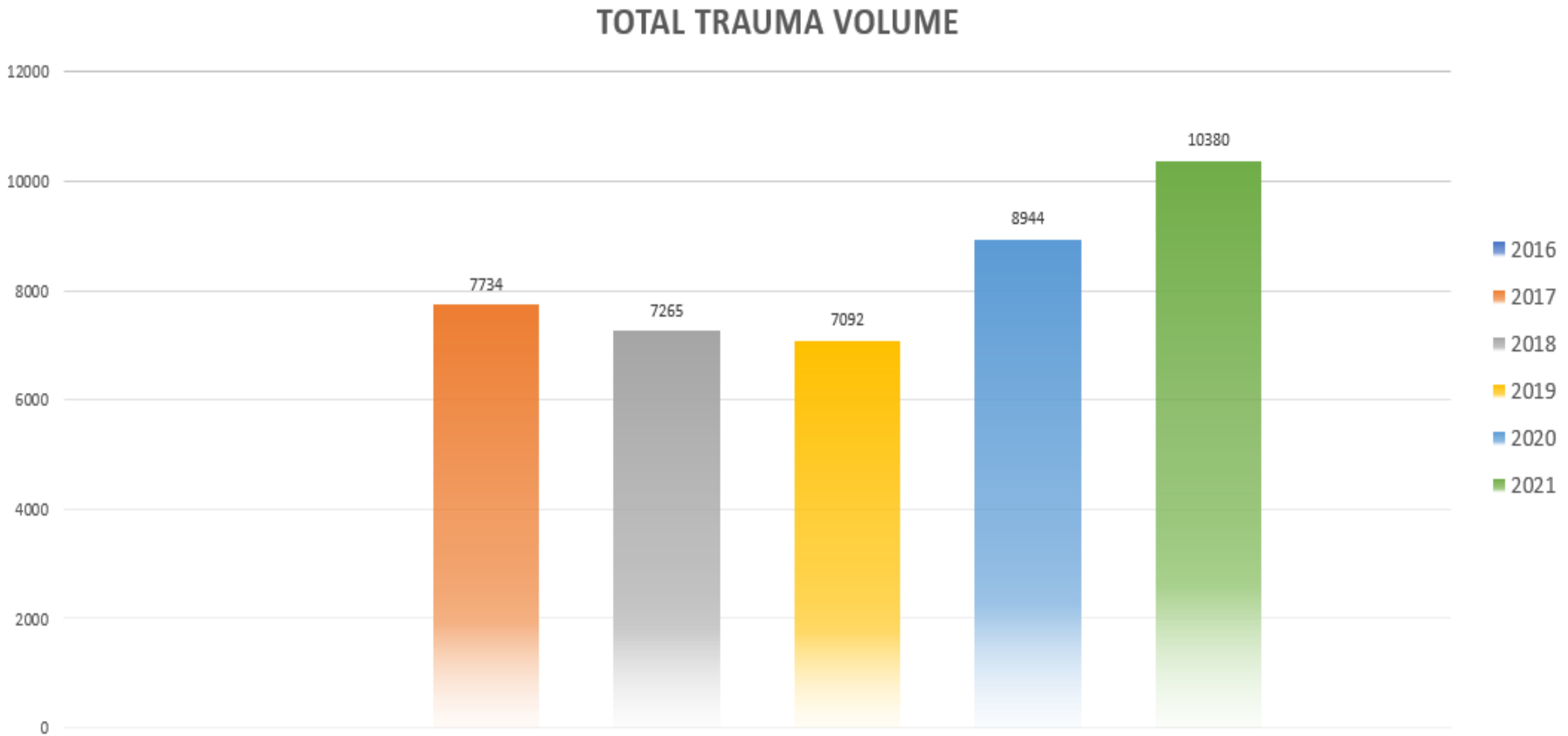
UTHealth The University of Texas Health Science Center at Houston | McGovern Medical School

Red Duke Trauma Institute

MEMORIAL HERMANN

The Red Duke Trauma Institute

- >1000 bed hospital, >130 ICU, 25 STICU beds
- ~10,000 trauma admissions last year
- >350 emergent laparotomies per year
- >150 MTP activations per year


TOTAL TRAUMA VOLUME
12000
10000
8000
6000
4000
2000
0
7734
7265
7092
8944
10380
2016
2017
2018
2019
2020
2021

Objectives

- Review the history of whole blood and where we went wrong
- Discuss the re-emergence of whole blood for trauma
- Review the recent literature associated with whole blood and its optimal handling and administration

Time Matters

- When trying to stop bleeding, time is EVERYTHING
- Put best product as close to the patient as possible
- Give minimum product necessary to get the job done
- Earliest and most aggressive therapy is indicated
- Only people who survive get a complication

A long time ago, in a galaxy far, far away…

Whole Blood

- Blood transfusion first widely used in 1918
- Freshly prepared, immediately transfused WB was effective but its remained unrefined
- End WW I, blood banking came of age and was one of most important medical advance of WW I

McPherson WG et al. History of the Great War; 1922

Robertson OH. Transfusion with preserved red blood cells. BMJ 1918

Whole Blood

- Despite use by US military docs, upon entering WW II, blood banking not part of U.S. military medical plans
- Embraced freeze-dried plasma as primary blood product (easier to produce, store, deliver)
- However, casualties resuscitated only with plasma had poorer outcomes

Hardaway RM, et al. Military Med. 2004;169(4):265–9.

Whole Blood

- WWII → early Vietnam WB preferred product for hemorrhage

  Cannon WB et al, JAMA 1918

- Advances in component separation 1960-70s led blood centers to begin providing components (RBC, plasma, platelets), with a removal of WB from supply

  Kauvar DS et al. J Trauma 2006 and Strandenes G et al. Transfusion 2013

- No studies of efficacy or hemostatic potential for patients in hemorrhagic shock

  Moore FD. N Engl J Med. 1969 and Robertson HD, Polk HC Ann Surg 1975

Complicating component therapy

- Resus paradigms further “diluted” with increased crystalloid use, catheter-directed strategies.

  Shoemaker WC Am J Surg 1983 and Fietsam R et Am Surg 1989

- Landmark studies advocated for use of saline in hemorrhage “until whole blood is available.”

  Carrico CJ et al. Crit Care Med 1976

- ATLS: plasma and platelets unnecessary early in resus; study referenced stated they were not needed to “supplement whole blood transfusions.”

  Counts RB et al. WC Ann Surg 1979

CRITICAL CARE MEDICINE
Copyright © 1976 by The Williams & Wilkins Co.
Vol. 4, No. 2
Printed in U.S.A.

Fluid resuscitation following injury: rationale for the use of balanced salt solutions

CHARLES J. CARRICO, MD; PETER C. CANIZARO, MD; G. TOM SHIRES, MD

- LR: “to replace interstitial fluid” and “support the intravascular volume until type specific WB available”
- LR at a “very rapid rate,” 1000-2000 ml over 45 minutes “until whole blood is available.”
- Base further WB transfusion on the patients response

Hemostasis in Massively Transfused Trauma Patients

Ann Surg 1979

R. B. COUNTS, C. HAISCH, T. L. SIMON, N. G. MAXWELL, D. M. HEIMBACH, C. J. CARRICO

- 27 MT patients studied to determine disorders of hemostasis evidenced by micro-vascular oozing
- Plasma transfusion is not needed to provide clotting factors as a supplement for whole blood transfusions in bleeding patients

Component Therapy

- ZERO clinical efficacy data as we moved from WB to component therapy
- Plasma removed from initial components
- Products designed for extension of shelf life
- Works very well for patients not in shock who only need a few units (majority of patients)

Greater than sum of it's parts

Component Therapy:

1U PRBC + 1U PLT + 1U FFP + 1 U cryo

680 COLD mL

- ***Hct 29%***
- ***Plt 80K***
- ***Coag factors 65% of initial concentration***
- ***1000 mg Fibrinogen***

FWB:

500 mL Warm

Hct: 38-50%

Plts: 150-400K

Coags: 100%

1000 mg Fibrinogen

Armand & Hess, Transfusion Med Rev, 2003

Thirty years later…

CASE REPORT

The Journal of TRAUMA® Injury, Infection, and Critical Care

Whole Blood Transfusion for Exsanguinating Coagulopathy in a U.S. Field Surgical Hospital in Postwar Kosovo

Steven M. Grosso, MD, FACS, and Jimmie O. Keenan, BSN, MSN, RN, CHE

January 2000

J Trauma. 2000;49:145–148.

Case report

- After multiple RBC+plasma, became progressively coagulopathic
- Because platelet components unavailable, an urgent active-duty soldier blood drive performed
- WB rapidly reversed the coagulopathy
- Whole blood transfusion should be considered when component transfusions not available

Military rational for FWB

- WB use in military environments necessary because of lack of platelets, frozen components
- Once broken down, components need to be frozen or face short shelf life
- Forward units don’t have equipment, limited storage, and long logistical lines of support
- WB uses by CSH as blood-bank enhancement

The Journal of **TRAUMA**® *Injury, Infection, and Critical Care*

The Use of Fresh Whole Blood in Massive Transfusion

Thomas B. Repine, MD, Jeremy G. Perkins, MD, David S. Kauvar, MD, and Lorne Blackborne, MD

Background: Most indications for whole blood transfusion are now well managed exclusively with blood component therapy, yet the use of fresh whole blood for resuscitating combat casualties has persisted in the U.S. military.

Methods: Published descriptions of whole blood use in military and civilian settings were compared with use of whole blood at the 31st Combat Support Hospital (31st CSH) stationed in Baghdad in 2004–2005.

Findings: Concerns about logistics, safety, and relative efficacy of whole blood versus component therapy have argued against the use of whole blood in most settings. However, military physicians have observed some distinct advantages in fresh warm whole blood over component therapy during the massive resuscitation of acidotic, hypothermic, and coagulopathic trauma patients. In this critical role, fresh whole blood was eventually incorporated as an adjunct into a novel whole-blood-based massive transfusion protocol.

Conclusions: Under extreme and austere circumstances, the risk:benefit ratio of whole blood transfusion favors its use. Fresh whole blood may, at times, be advantageous even when conventional component therapy is available.

Key Words: Fresh whole blood, Massive transfusion, Trauma, Combat casualty care, Blood banking, Walking blood bank.

J Trauma. 2006;60:S59–S69.

April 2006

Use of FWB in MT

- Began to store WB (room temperature) for 8hr
- After 8hrs, moved/stored at 4C
- Marked as non-fresh WB, considered = 1U RBC+ 1U FFP
- Majority of WB collected, transfused in 8hrs
- Add complexity of effectiveness after storage

The Journal of TRAUMA® Injury, Infection, and Critical Care

Warm Fresh Whole Blood Is Independently Associated With Improved Survival for Patients With Combat-Related Traumatic Injuries

Philip C. Spinella, MD, Jeremy G. Perkins, MD, Kurt W. Grathwohl, MD, Alec C. Beekley, MD, and John B. Holcomb, MD

April 2009

Background: Increased understanding of the pathophysiology of the acute coagulopathy of trauma has lead many to question the current transfusion approach to hemorrhagic shock. We hypothesized that warm fresh whole blood (WFWB) transfusion would be associated with improved survival in patients with trauma compared with those transfused only stored component therapy (CT).

Methods: We retrospectively studied US Military combat casualty patients transfused ≥1 unit of red blood cells (RBCs). The following two groups of patients were compared: (1) WFWB, who were transfused WFWB, RBCs, and plasma but not apheresis platelets and (2) CT, who were transfused RBC, plasma, and apheresis platelets but not WFWB. The primary outcomes were 24-hour and 30-day survival.

Results: Of 354 patients analyzed there were 100 in the WFWB and 254 in the CT group. Patients in both groups had similar severity of injury determined by admission eye, verbal, and motor Glasgow Coma Score, base deficit, international normalized ratio, hemoglobin, systolic blood pressure, and injury severity score. Both 24-hour and 30-day survival were higher in the WFWB cohort compared with CT patients, 96 of 100 (96%) versus 223 of 254 (88%), ($p = 0.018$) and 95% to 82%, ($p = 0.002$), respectively. An increased amount (825 mL) of additives and anticoagulants were administered to the CT compared with the WFWB group, ($p < 0.001$). Upon multivariate logistic regression the use of WFWB and the volume of WFWB transfused was independently associated with improved 30-day survival.

Conclusions: In patients with trauma with hemorrhagic shock, resuscitation strategies that include WFWB may improve 30-day survival, and may be a result of less anticoagulants and additives with WFWB use in this population.

Key words: Whole blood, Transfusion, Mortality, Survival, Combat.

J Trauma. 2009;66:S69–S76.

Table 1 Comparison of Variables Between WFWB and CT Groups

Variable	WFWB (n = 100)	CT (n = 254)	*p* Value
Age (yr)	24 (21–29)	23 (21–28)	0.16
Temperature (F)	97.6 (96.4–98.2)	98.5 (97.4–99.5)	<0.001
Heart rate (bpm)	112 (95–136)	115 (91–138)	0.88
SBP (mm Hg)	110 (80–122)	109 (80–130)	0.67
GCS eye	4 (2–4)	4 (1–4)	0.32
GCS verbal	5 (1–5)	5 (1–5)	0.53
GCS motor	6 (3–6)	6 (1–6)	0.19
Hemoglobin (g/dL)	11.6 (10–14)	11.8 (9.8–13.4)	0.44
Base deficit	6 (4–10)	6 (3–11)	0.77
INR	1.4 (1.1–1.6)	1.4 (1.2–1.8)	0.83
ISS	18 (10–26)	18 (10–26)	0.74

Table 2 Comparison of Individual Blood Products, Volumes and Ratios Between WFWB and CT Groups

Variable	WFWB (n = 100)	CT (n = 254)	*p* Value
Stored RBC (U)	9 (7–14)	16 (10–22)	<0.001
Plasma (U)	4 (3–8)	10 (6–16)	<0.001
Apheresis platelets (U)	0	2 (1–4)	<0.001
WFWB (U)	5 (3–9)	0 (0–0)	<0.001
Cryoprecipitate (U)	0 (0–0)	0 (0–1)	0.007
Total RBC (U)	16 (11–22)	16 (10–22)	0.44
Total blood volume (L)	7.4 (5.4–10.4)	9.3 (6.2–13.3)	0.006
Anticoagulant/ additives (L)	1.7 (1.3–2.5)	2.5 (1.6–3.6)	<0.001
Actual blood volume (L)	5.7 (4.1–8.)	6.8 (4.5–10)	0.03
PLT:RBC ratio	0.33 (0.2–0.5)	0.86 (0.6–1.3)	0.001
Plasma:RBC ratio	0.74 (0.55–0.9)	0.73 (0.53–1)	0.73
Massive transfusion (%)	89/100 (89%)	198/254 (78%)	0.017
rFVIIa use (%)	42/100 (42%)	101/353 (40%)	0.72

Table 5 Comparison of Survival Outcomes and Adverse Events Between Study Groups

Variable	WFWB (n = 100)	CT (n = 254)	*p* Value
24 h survival	96/100 (96%)	223/254 (88%)	0.018
30 d survival	95/100 (95%)	209/254 (82%)	0.002
Deep vein thrombosis	15/100 (15%)	21/254 (8%)	0.06
Pulmonary embolism	7/100 (7%)	11/254 (4%)	0.3
Myocardial infarction	1/100 (1%)	0 (0%)	0.28
Cerebral stroke	0 (0%)	5/254 (2%)	0.33
ARDS	7/100 (7%)	7/254 (3%)	0.08
Renal failure	8/100 (8%)	7/254 (3%)	0.04

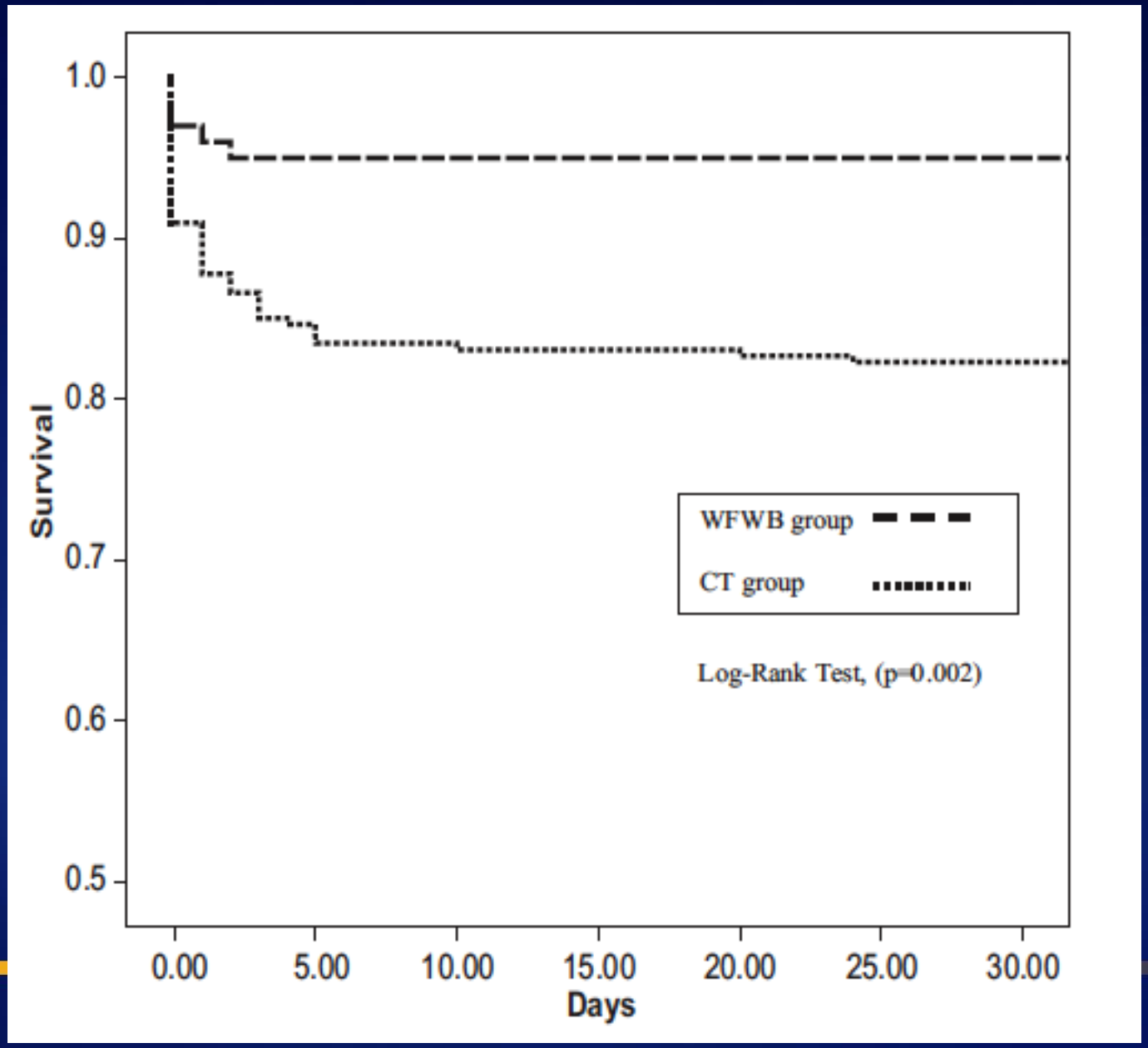

1.0
0.9
0.8
0.7
0.6
0.5
Survival
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Days
WFWB group
CT group
Log-Rank Test, (p=0.002)

Table 6 Multivariate Logistic Regression With Treatment Groups for 30-d Survival

Variables	OR (95.0% C.I.)	*p* Value
WFWB group	12.4 (1.8–80)	0.01
Plasma:RBC ratio	11.7 (2.6–52)	0.001
ISS	0.94 (0.91–0.97)	0.001
GCS eyes (normal)	4.1 (1.5–10.8)	0.004
Base deficit	0.88 (0.82–0.95)	<0.001

AUC (95% CI) for the logistic regression was 0.9 (0.85–0.95).

Table 7 Multivariate Logistic Regression Results With Blood Product Amount for 30-d Survival

Variables	OR (95.0% C.I.)	*p* Value
WFWB (U)	2.15 (1.21–3.8)	0.016
RBC (U)	0.91 (0.85–0.97)	0.003
Plasma (U)	1.09 (1.02–1.18)	0.019
Base deficit	0.91 (0.84–0.97)	0.002
GCS eyes (normal)	3.8 (1.4–10.2)	0.009
ISS	0.94 (0.91–0.98)	0.001

AUC (95% CI) for the logistic regression was 0.9 (0.86–0.95).

PAPERS OF THE 133RD ASA ANNUAL MEETING

A Randomized Controlled Pilot Trial of Modified Whole Blood Versus Component Therapy in Severely Injured Patients Requiring Large Volume Transfusions

Bryan A. Cotton, MD, MPH,† Jeanette Podbielski, BSN,† Elizabeth Camp, MSPH,† Timothy Welch, NREMT-P,† Deborah del Junco, PhD,† Yu Bai, MD, PhD,‡ Rhonda Hobbs, MT (ASCP),‡ Jamie Scroggins, MT (ASCP),§ Beth Hartwell, MD,§ Rosemary A. Kozar, MD, PhD,* Charles E. Wade, PhD,*† and John B. Holcomb, MD*† on behalf of The Early Whole Blood Investigators*

Methods- *Randomization*

Modified Whole Blood (mWB)	Component therapy (COMP)
6 U mWB	6 U RBC
+ 1 apheresis platelet	6 U Plasma
	+ 1 apheresis platelet

TABLE 5. Sensitivity Analysis Evaluating the Primary and Secondary Outcomes in Those Patients Without Severe TBI

	WB Group (n = 33)	COMP Group (n = 34)	*P*
Median 24-hr RBC transfusions, U	4 (2, 6)	6 (2, 13)	0.02
Median 24-hr plasma transfusions, U	4 (2, 7)	6 (2, 14)	0.02
Median 24-hr platelet transfusions, U	0 (0, 1)	1 (0, 2)	0.09
Median 24-hr total transfusions, U	11 (5, 17)	16 (4, 41)	0.02
24-hr mortality, %	6%	9%	0.62
30-d mortality, %	6%	9%	0.62

Continuous values are presented as median with 25th and 75th interquartile range.

DoD: Feb 2016

Classification/Indications	Low titer O whole blood is to be used in resuscitation of bleeding patients in the pre-hospital setting. This product is collected from donors who have been pre-screened with FDA approved infectious disease testing and have been tested to determine an anti-A/B titer level of ≤1:256. Low titer O is considered universal and may be administered for to all blood types.
Contraindications	Do Not: • Use for non-bleeding patients • Use solely for volume expansion
Supplied	• Volume is 450 mLs. • Hct 33%. • Whole Blood can be stored for 35 days 1 to 6°C. • Low Titer O Whole Blood will be drawn upon request and in quantities to support near term mission requirements.

Civilian use of WB?

- Too demanding to be practical
- Recruiting, interviewing, testing of poorly-defined civilian donors
- Processing of WB into components is clearly more costly of labor, time, and materiel

Hess JR, Thomas MJ Transfusion 2003
Maclennan S, Murphy MF Clin Lab Haem 2001
Counts RB et al Ann Surg 1979

Section Editor: Richard P. Dutton

NARRATIVE REVIEW ARTICLE

CME

Whole Blood for Resuscitation in Adult Civilian Trauma in 2017: A Narrative Review

Evan G. Pivalizza, MD,* Christopher T. Stephens, MD,* Srikanth Sridhar, MD,* Sam D. Gumbert, MD,* Susan Rossmann, MD,† Marsha F. Bertholf, MD,† Yu Bai, MD,‡ and Bryan A. Cotton, MD§

After a hiatus of several decades, the concept of cold whole blood (WB) is being reintroduced into acute clinical trauma care in the United States. Initial implementation experience and data grew from military medical applications, followed by more recent development and data acquisition in civilian institutions. Anesthesiologists, especially those who work in acute trauma facilities, are likely to be presented with patients either receiving WB from the emergency department or may have WB as a therapeutic option in massive transfusion situations. In this focused review, we briefly discuss the historical concept of WB and describe the characteristics of WB, including storage, blood group compatibility, and theoretical hemolytic risks. We summarize relevant recent retrospective military and preliminary civilian efficacy as well as safety data related to WB transfusion, and describe our experience with the initial implementation of WB transfusion at our level 1 trauma hospital. Suggestions and collective published experience from other centers as well as ours may be useful to those investigating such a program. The role of WB as a significant therapeutic option in civilian trauma awaits further prospective validation. (Anesth Analg 2018;127:157–62)

Safety Issues of FWB

- Total donor exposure less with WB transfusion than with component therapy
- Donor exposure of 1 U FWB vs. 1 U RBC, 1U FFP and 1 apheresis platelets

Repine TB et al. *J Trauma* 2006
Jenkins D, Holcomb JB *Transfusion* 2018.

Whole Blood Transfusion

- Logistically simpler to provide rapidly to patients with life-threatening bleeding.
- 11/01/17: Trauma team at MHH-TMC began using low-titer Type O whole blood in trauma resuscitation.
- Two (2) units on each helicopter and four (4) in the ED/Trauma Bay cooler.

Red Duke Trauma Institute/MMH

- Type O, Rh-positive and Rh-negative
- 21-day expiration; no return
- Anti-A, anti-B titers <200 to minimize risk of hemolysis
- Male donor to reduce the risk of TRALI
- Not leukocyte-reduced

2019 EAST Podium Paper

Safety profile and impact of low-titer group O whole blood for emergency use in trauma

James Williams, BS, Nicholas Merutka, BS, David Meyer, MD, MS, Yu Bai, MD, PhD, Samuel Prater, MD, Rodolfo Cabrera, BSN, EMT-P, John B. Holcomb, MD, Charles E. Wade, PhD, Joseph D. Love, DO, *and* **Bryan A. Cotton, MD, MPH**, *Houston, Texas*

Methods

- Prospective single center observation study
- November 2017 LTO-WB added to air ambulance services and ED, alongside RBCs and plasma
- 289 units of LTO-WB transfused to 198 patients
- 152 patients received component therapy

TABLE 1. Comparison of Baseline and Demographics Between Patients Receiving WB and COMP Transfusions

	LTO-WB Patients (n = 198)	COMP Patients (n = 152)	*p*
Median age, y	41 (26, 56)	38 (24, 51)	0.121
Male sex	72%	69%	0.493
Median BMI	27 (24, 29)	26 (23, 30)	0.424
Blunt mechanism	71%	65%	0.231
White race	45%	35%	0.059
Median head AIS score	3 (0, 4)	2 (0, 4)	0.367
Median chest AIS score	3 (0, 4)	2 (0, 3)	0.027
Median abdomen AIS score	2 (0, 3)	0 (0, 3)	0.201
Median extremity AIS score	2 (0, 3)	2 (0, 3)	0.280
Median ISS	25 (16, 36)	22 (16, 34)	0.203

TABLE 3. Comparison of Arrival Physiology and Shock Parameters Between Patients Receiving WB and COMP Transfusions

	LTO-WB Patients (n = 198)	COMP Patients (n = 152)	*p*
Median arrival HR	110 (83, 128)	97 (84, 122)	0.269
Median arrival SBP	94 (75, 123)	105 (88, 132)	0.005
Median arrival DBP	59 (40, 75)	65 (52, 81)	0.023
Median arrival GCS	3 (3, 15)	8 (3, 15)	0.241
Median arrival GCS-motor	4 (1, 6)	6 (1, 6)	0.302
ED (+) FAST	29%	25%	0.532
MTP activation	80%	71%	0.127
Median arrival hemoglobin	12.8 (11.2, 14.1)	11.9 (10.3, 13.8)	0.032
Median arrival platelet ct	221 (176, 275)	212 (173, 251)	0.465
Median arrival pH	7.22 (7.11, 7.29)	7.26 (7.18, 7.33)	0.011
Median arrival base excess	−7 (−11, −4)	−5 (−9, −3)	0.014
Median arrival lactate	5.1 (3.1, 7.5)	3.5 (2.3, 5.1)	<0.001

WB cohort arrived more physiologically disturbed, more evidence of shock

TABLE 6. Multivariate Logistic Regression Models Evaluating the Impact of LTO-WB on 30-Day Survival and Post-ED Blood Product Transfusions

30-d Survival			
	Odds Ratio	**95% CI**	***p*-Value**
LTO-WB	2.19	1.010–4.767	0.047
Age	0.97	0.958–0.998	0.032
Chest AIS score	0.98	0.790–1.229	0.898
Prehospital SBP	0.99	0.985–1.010	0.723
Arrival base value	1.13	1.049–1.221	0.001
Blunt mechanism	1.09	0.470–2.572	0.827
Post-ED blood transfusions			
Post-ED Blood Transfusions	**Odds ratio**	**95% CI**	***p*-value**
LTO-WB	0.47	0.239–0.941	0.033
Age	0.99	0.974–1.008	0.302
ISS	1.06	1.029–1.096	<0.001
Prehospital SBP	0.99	0.986–1.008	0.623
Arrival base value	1.01	0.949–1.083	0.670
Blunt mechanism	1.72	0.823–3.608	0.148

Conclusion

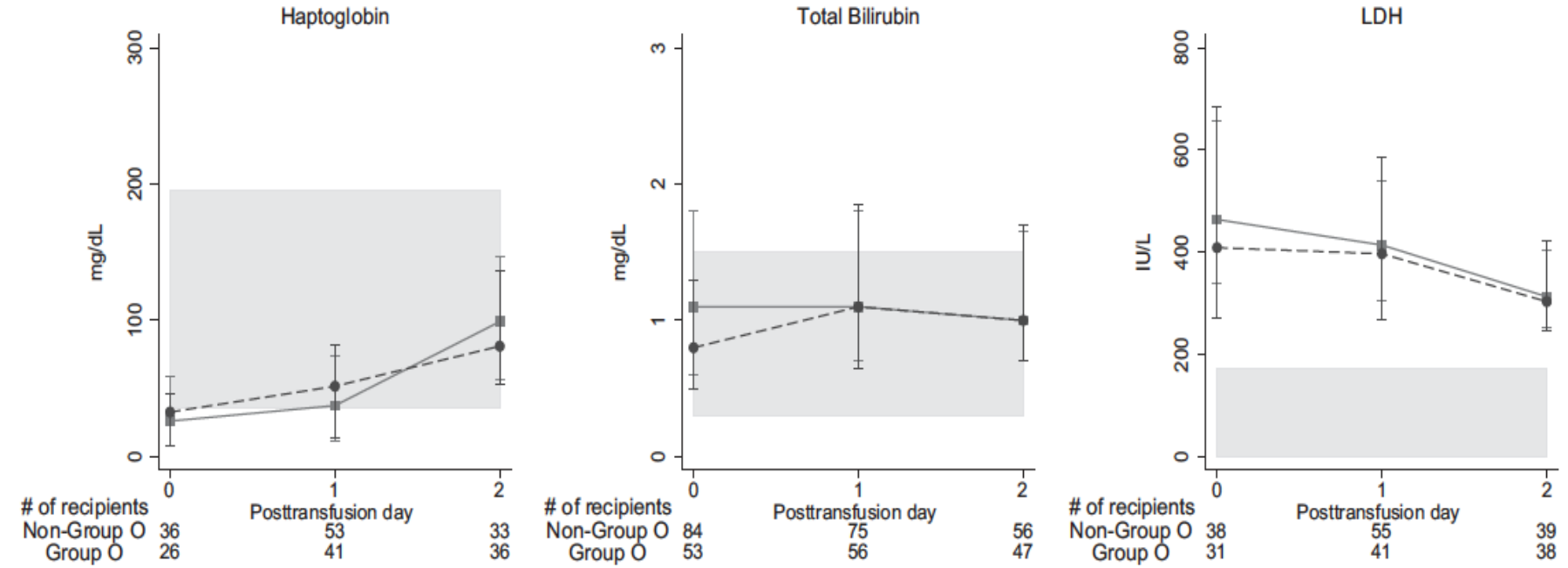
- Despite WB pts having worse hemodynamics, more evidence of shock on arrival to the ED, no difference in all cause mortality between groups.
- WB associated with a 50% ↓post-ED blood products consumption, 2-fold ↑30-day survival.
- Suggests at the very least WB is safe alternative to component therapy.

What product do you use in your MTP?

- Anti-body titer?
- Rh + or Rh- ?
- How long do you keep it?
- How do you transfuse it?

Safety profile of uncrossmatched, cold-stored, low-titer, group O+ whole blood in civilian trauma patients

Jansen N. Seheult,[1] Marshall Bahr,[2] Vincent Anto,[3] Louis H. Alarcon,[4,5] Alain Corcos,[4,5] Jason L. Sperry,[4,5] Darrell J. Triulzi,[1,6] and Mark H. Yazer[1,6]



- Children's Hospital of Pittsburgh/UPMC
- Group O WB (anti-A and B antibodies <50)
- WB stored in ED and hospital blood bank
- Patients eligible injured children >2 years, >14 kg

RESEARCH LETTER

Use of Uncrossmatched Cold-Stored Whole Blood in Injured Children With Hemorrhagic Shock

- No significant differences group O and non–group O WB recipients hemolysis markers
- No transfusion reactions were reported

2019 EAST Podium Paper

Safety profile and impact of low-titer group O whole blood for emergency use in trauma

James Williams, BS, Nicholas Merutka, BS, David Meyer, MD, MS, Yu Bai, MD, PhD, Samuel Prater, MD, Rodolfo Cabrera, BSN, EMT-P, John B. Holcomb, MD, Charles E. Wade, PhD, Joseph D. Love, DO, *and* **Bryan A. Cotton, MD, MPH**, *Houston, Texas*

1:200 anti-A, anti-B titer

TABLE 5. Comparison of Hemolysis Panel and P/F Ratio Trends Over the First 48 Hours After Arrival Between Patients Receiving WB and COMP Transfusions

	LTO-WB Patients (n = 198)	COMP Patients (n = 152)	*p*
Median arrival creatinine	1.2 (1.1, 1.5)	1.2 (0.9, 1.6)	0.609
Median ICU creatinine	1.1 (0.8, 1.4)	1.0 (0.7, 1.3)	0.102
Median 24-h creatinine	1.0 (0.7, 1.4)	0.9 (0.7, 1.4)	0.352
Median 48-h creatinine	0.8 (0.6, 1.2)	0.9 (0.7, 1.1)	0.398
Median arrival K+	3.8 (3.3, 4.3)	3.7 (3.4, 4.3)	0.921
Median ICU K+	4.1 (3.7, 4.5)	4.2 (3.8, 4.5)	0.713
Median 24-h K+	4.2 (3.8, 4.4)	4.1 (3.8, 4.4)	0.323
Median 48-h K+	4.0 (3.6, 4.3)	4.1 (3.8, 4.4)	0.198
Median arrival bilirubin	N/A	N/A	
Median ICU bilirubin	1.0 (0.7, 1.5)	1.1 (0.7, 2.0)	0.811
Median 24-h bilirubin	0.7 (0.5, 1.1)	1.1. (0.7, 2.5)	0.014
Median 48-h bilirubin	0.6 (0.4, 0.8)	1.1 (0.4, 2.1)	0.068
Median arrival LDH	N/A	N/A	
Median ICU LDH	461 (293, 695)	379 (69,480)	0.252
Median 24-h LDH	408 (279, 593)	492 (301, 593)	0.898
Median 48-h LDH	361 (227, 536)	456 (201, 533)	0.932
Median arrival haptogobin	N/A	N/A	
Median ICU haptogobin	60 (35, 103)	68 (42, 94)	0.871
Median 24-h haptogobin	67 (30, 112)	81 (29, 134)	0.985
Median 48-h haptogobin	118 (63, 171)	167 (73, 211)	0.478
Median arrival P/F ratio	344 (230, 480)	393 (239, 532)	0.247
Median ICU P/F ratio	351 (227, 481)	388 (233, 488)	0.245
Median 24-h P/F ratio	377 (275, 442)	333 (198, 426)	0.118
Median 48-h P/F ratio	325 (247, 405)	292 (232, 379)	0.161

What product do you use in your MTP?

- Anti-body titer? *Pick the lowest possible for your center that allows you to stock enough WB*
- Rh + or Rh- ?
- How long do you keep it?
- How do you transfuse it?

Prehospital low-titer cold-stored whole blood: Philosophy for ubiquitous utilization of O-positive product for emergency use in hemorrhage due to injury

Ashley C. McGinity, MD, Caroline S. Zhu, Leslie Greebon, MD, Elly Xenakis, MD, Elizabeth Waltman, MBA, Eric Epley, Danielle Cobb, MD, Rachelle Jonas, Susannah E. Nicholson, MD, Brian J. Eastridge, MD, Ronald M. Stewart, MD, *and* **Donald H. Jenkins, MD**, *San Antonio, Texas*

- San Antonio: Moved forward with low titer cold stored O RhD positive whole blood
- Had to consider the potential risk of isoimmunization, especially in women of childbearing age.

O- or O+ ???

- Rh- prevalence 7-18% of the population
- 2/3 possible donors/potential recipients have Rh+ blood, thus limiting Rh- supply but also decreases likelihood of mismatch
- Analysis lead them to believe that O- donors would not be able to maintain the inventory of LTO+WB necessary

O- or O+ ???

- 80% of patients that receive emergency blood products are Rh+
- 75% male, many of the females are >50
- Immunosuppression of trauma patients well-described, impaired function of both adaptive and innate immunity.

O- or O+ ???

- Women of childbearing age are main focus of isoimmunization, most concerning is Hemolytic Disease of the Fetus and Newborn (HDFN).
- Women who develop anti-D antibodies may adversely affect an RhD positive fetus.
- Anti-Rh antibodies (IgG) can cross placenta during pregnancy, inducing hemolysis of the fetal RBCs, resulting in severe morbidity+mortality

The Math

- 30 months, 124 total MTP patients, only one female of childbearing age that received an MTP was Rh-

- Anti-D conversion rate between 3-30%, the risk of isoimmunization of 0.012 to 0.12 patients/year

The Math

- 3000 months (250 years) to have 100 Rh- women of childbearing age receive LTO+WB and approximately somewhere between 3 and 30 of them would develop isoimmunization without the administration of RhIg.

- RhIg admin decreases isoimmunization rate 1%, 0.3 Rh- women of childbearing age developing this

2021 EAST PODIUM

Can RH+ whole blood be safely used as an alternative to RH– product? An analysis of efforts to improve the sustainability of a hospital's low titer group O whole blood program

C. Cameron McCoy, MD, Kelsey Montgomery, MD, Madeline E. Cotton, BS, David E. Meyer, MD, MS, Charles E. Wade, PhD, *and* **Bryan A. Cotton, MD, MPH**, *Houston, Texas*

- We set out to identify the impact (if any) of Rh donor status among LTO-WB recipients and whether LTO-WB can be considered a "universal product" even in Rh- patients.

RH

to

ability

m

C.

MD, MS,

- We ecipients an ients.

UTH
The Univer
Health Science

ed Duke
ma Institute

MORIAL
RMANN

O- or O+ ???

- Following IRB approval, information on all trauma patients receiving prehospital or ED transfusion of uncrossed, emergency release LTO-WB (11/17-10/19) were evaluated.

- Patients were divided into those who received Rh- vs. Rh+ product, the assessed by Rh of the recipient.

- Serial hemolysis panels (3-hr, 24-hr, 48-hr), transfusion reactions, and outcomes were compared.

	Rh+ LTO WB (n=448)			Rh- LTO WB (n=189)		
	Rh+ recipient (n=407)	Rh- recipient (n=41)	p-value	Rh+ recipient (n=170)	Rh- recipient (n=19)	p-value
Transfusion reactions	1.0%	0.0%	0.520	2.6%	0.0%	0.476
Renal failure	9.1%	4.0%	0.270	7.1%	14.3%	0.267
Sepsis	25%	15%	0.153	26.9%	21.4%	0.606
Thromboembolism	6.0%	3.8%	0.564	5.5%	0.0%	0.291
ARDS	3.5%	0.0%	0.223	3.2%	7.1%	0.376
Hosp free days	9 (0, 22)	12 (0, 21)	0.616	12 (0, 23)	11 (0, 20)	0.985
ICU free days	20 (0, 28)	22 (0, 27)	0.896	25 (4, 28)	19 (0, 24)	0.082
Vent free days	26 (0, 30)	28 (0, 29)	0.764	29 (14, 30)	27 (0, 30)	0.398
30-day Survival	74%	71%	0.595	78%	79%	0.935

What product do you use in your MTP?

- Anti-body titer? *Pick the lowest possible for your center that allows you to stock enough WB*
- **Rh + or Rh-** ? *If Rh- unavailable or in short supply, Rh+ safe alternative in both Rh+ and Rh- patients.*
- How long do you keep it?
- How do you transfuse it?

What product do you use in your MTP?

- Anti-body titer? *Pick the lowest possible for your center that allows you to stock enough WB*
- Rh + or Rh- ? *If Rh- unavailable or in short supply, Rh+ safe alternative in both Rh+ and Rh- patients.*
- **How long do you keep it?**
- How do you transfuse it?

Hemostatic potential of cold-stored non-leukoreduced whole blood over time: An assessment of platelet function and thrombin generation for optimal shelf life

Scott Assen, MD, Jessica Cardenas, PhD, Mitchell George, MD, Yao-Wei Wang, PhD, Charles E. Wade, PhD, David Meyer, MD, MS, *and* **Bryan A. Cotton, MD, MPH**, *Houston, Texas*

Background

- Changes in composition and function of blood products due to time or storage conditions termed “storage lesion”

- Current storage limit of whole blood of 21 days has been the accepted limit for many decades
  Jennings, Transfusion 1968; Jennings, Manag Sci 1973

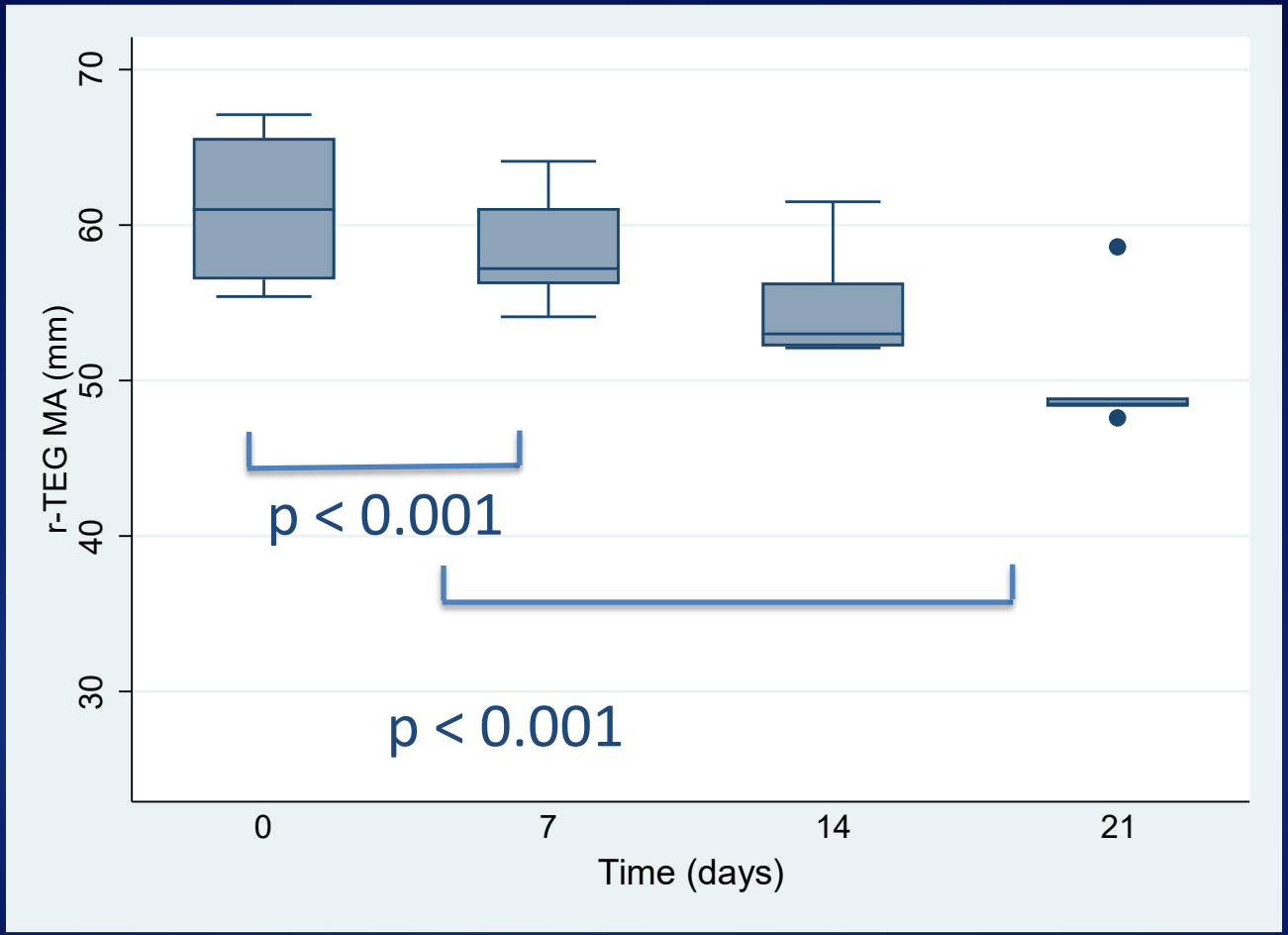
- Little research on validating this limit in the era of improved measurement of hemostatic parameters (14 days to 35 days)

Methods

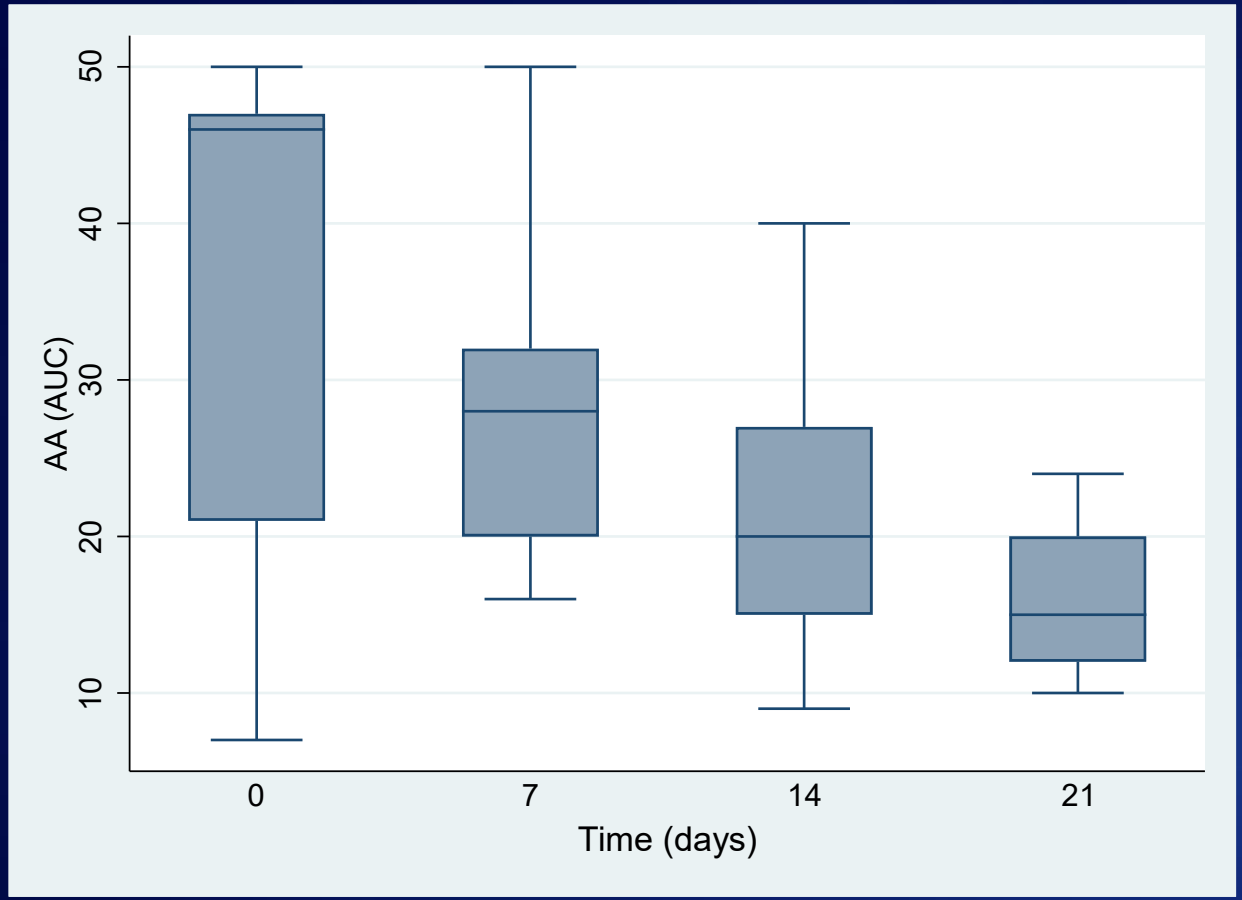
- Five units of fresh, low-titer group O non-leukoreduced whole blood, and five units of fresh liquid plasma
- Stored for 21 days at 4°C
- Hemostatic parameters measured at 0, 7, 14, 21 days
  - Rapid TEG, kaolin TEG, multiple impedance aggregometry, CAT

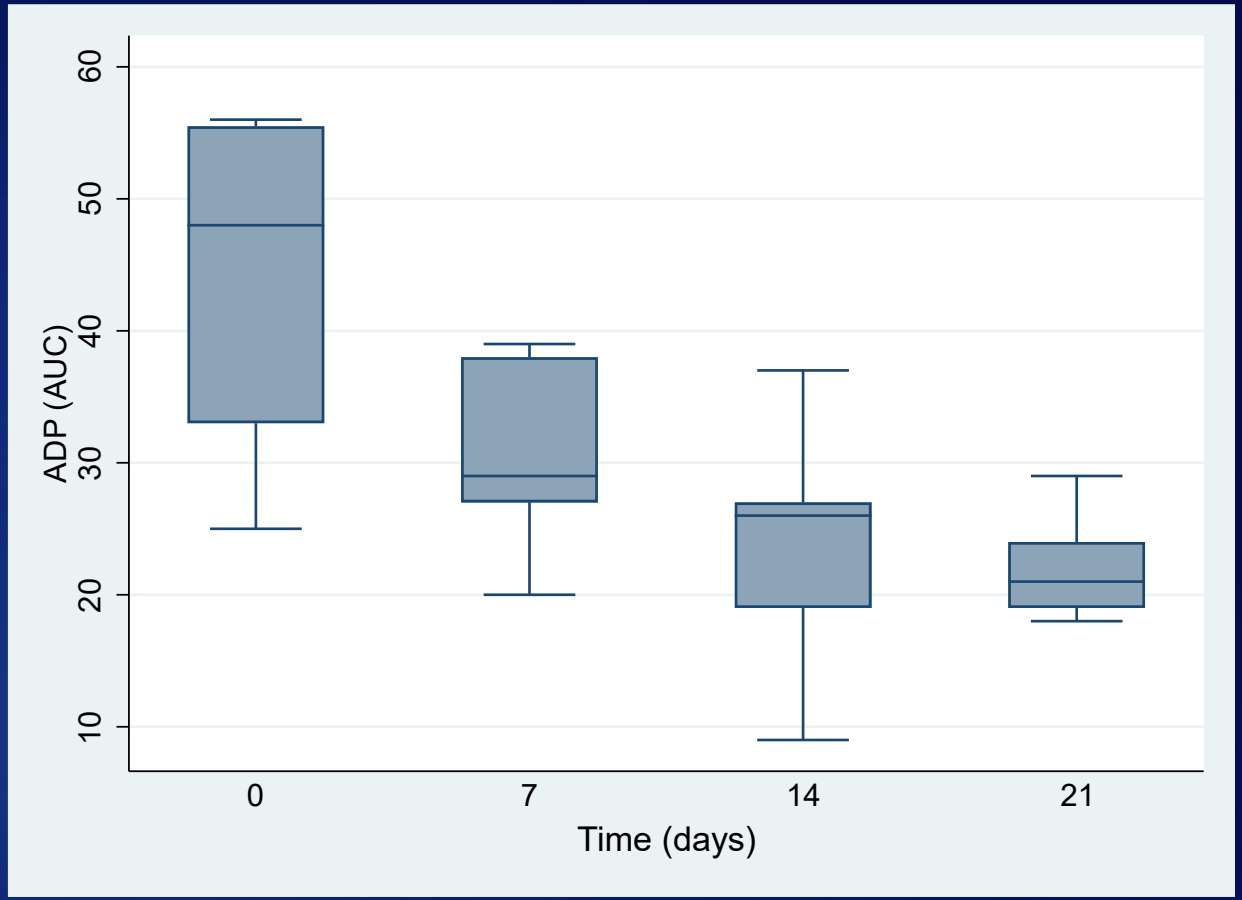
Results – Whole Blood – Platelet Function

r-TEG MA

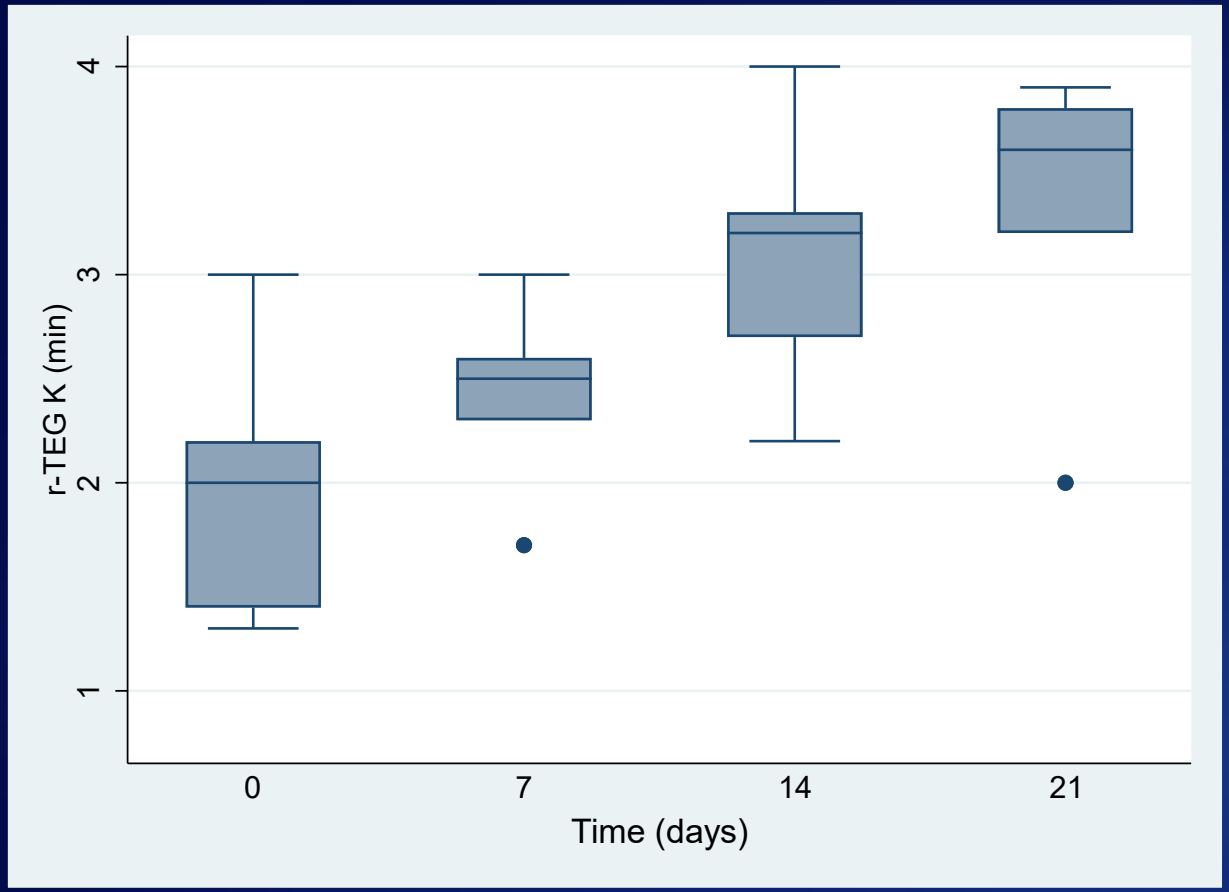


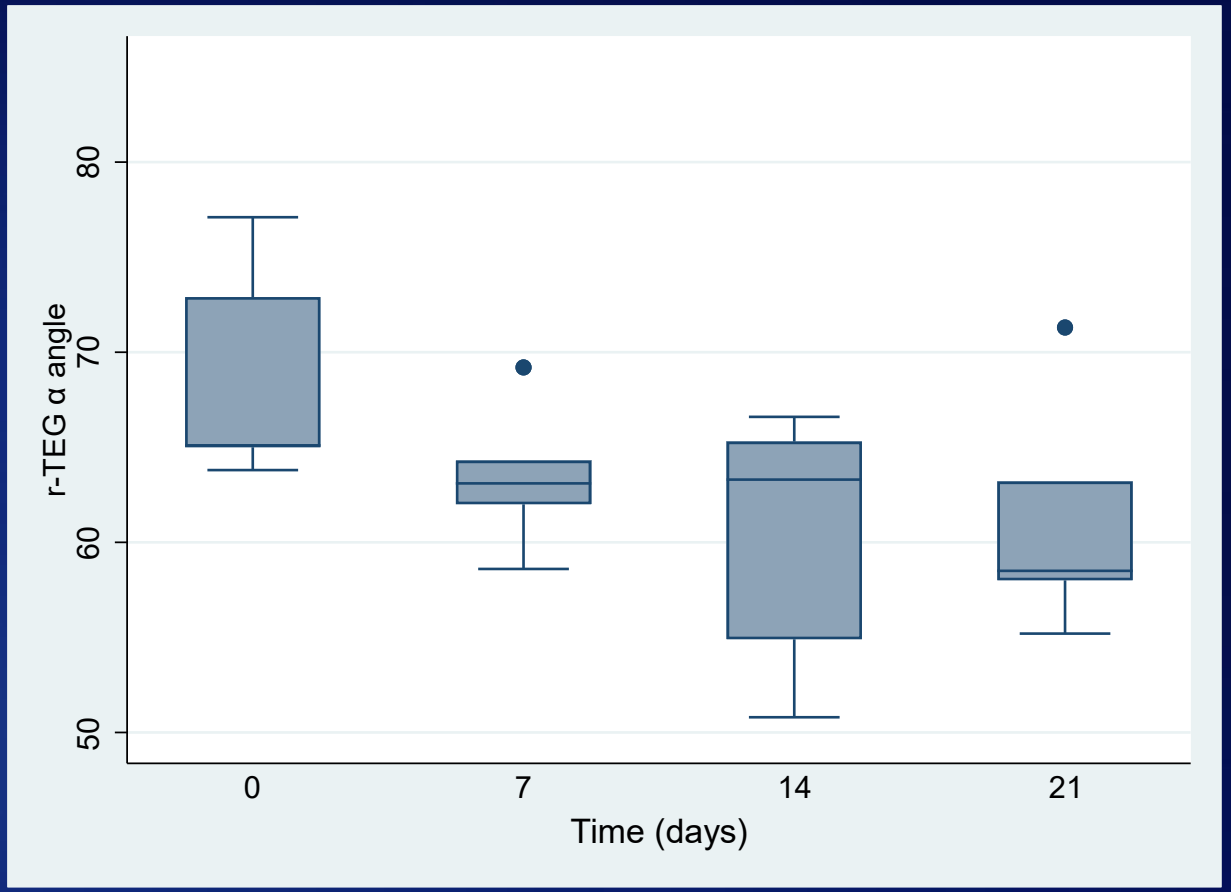
Results – Whole Blood – Platelet Function



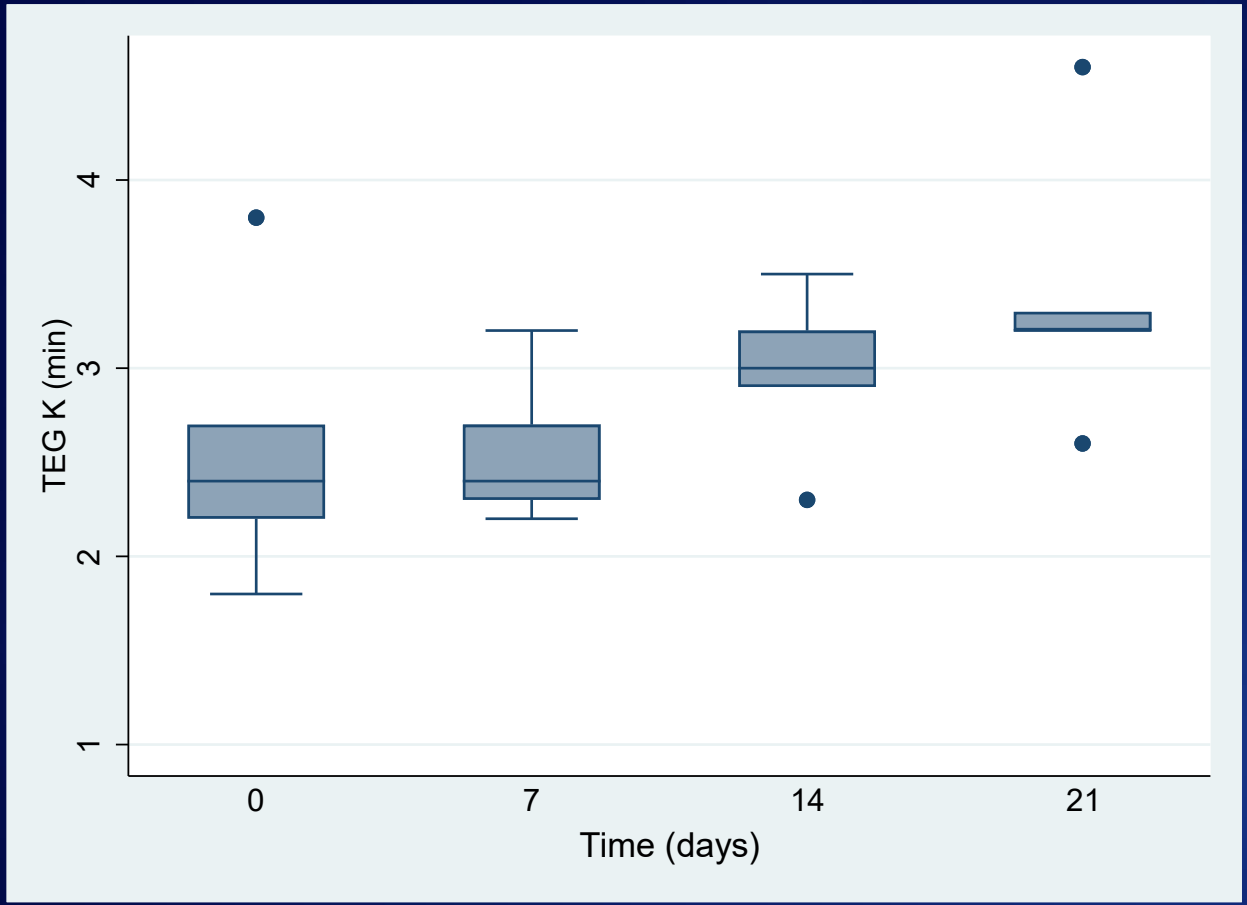


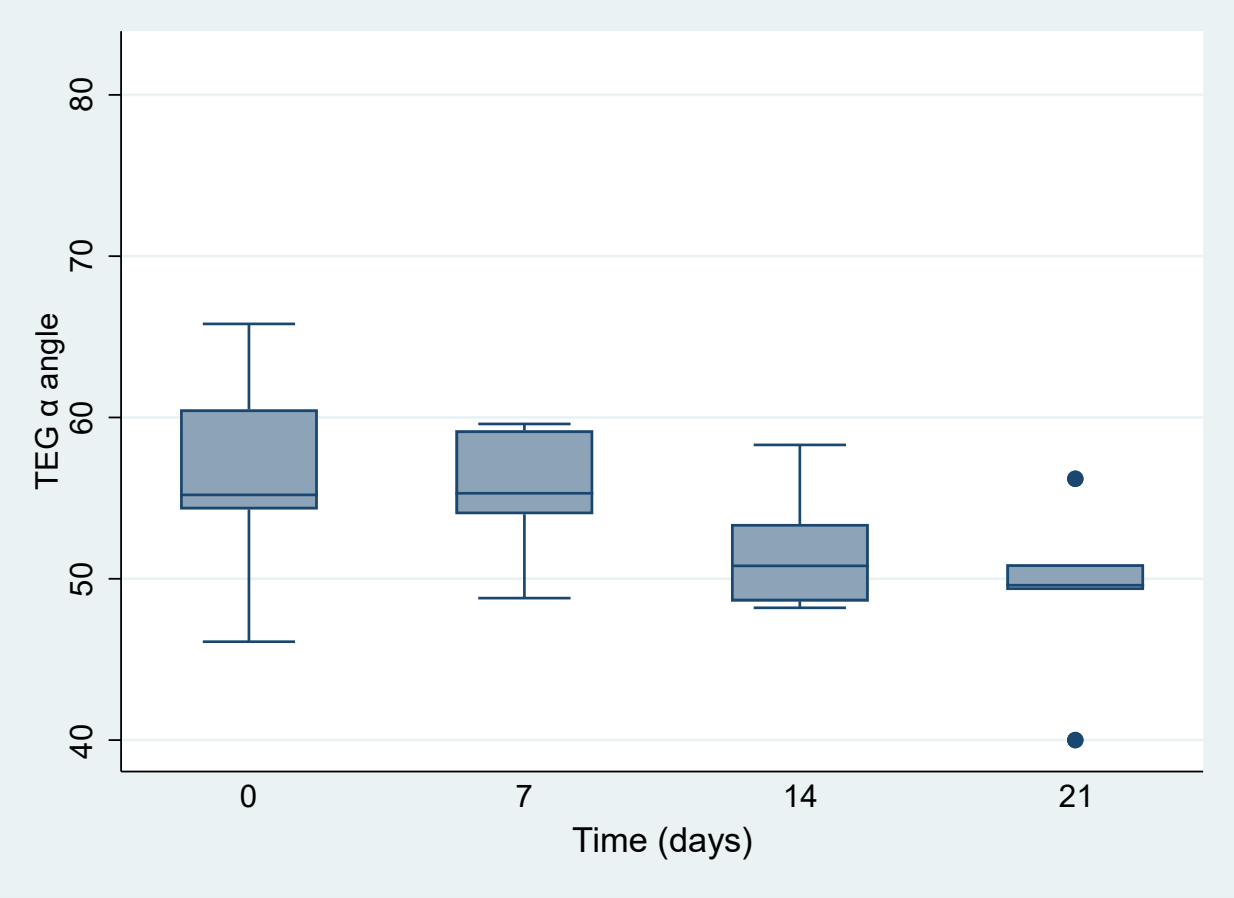
Results – Whole Blood – Clot Initiation



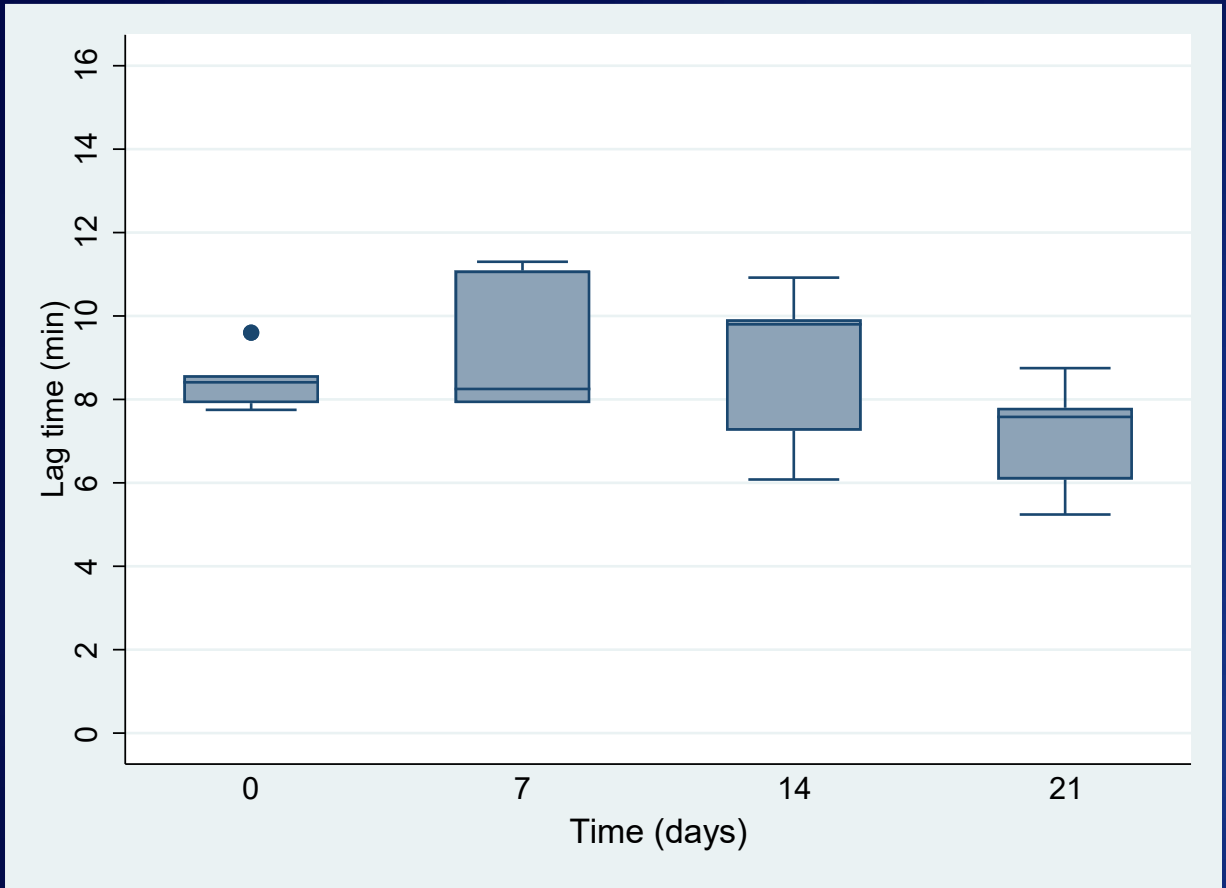


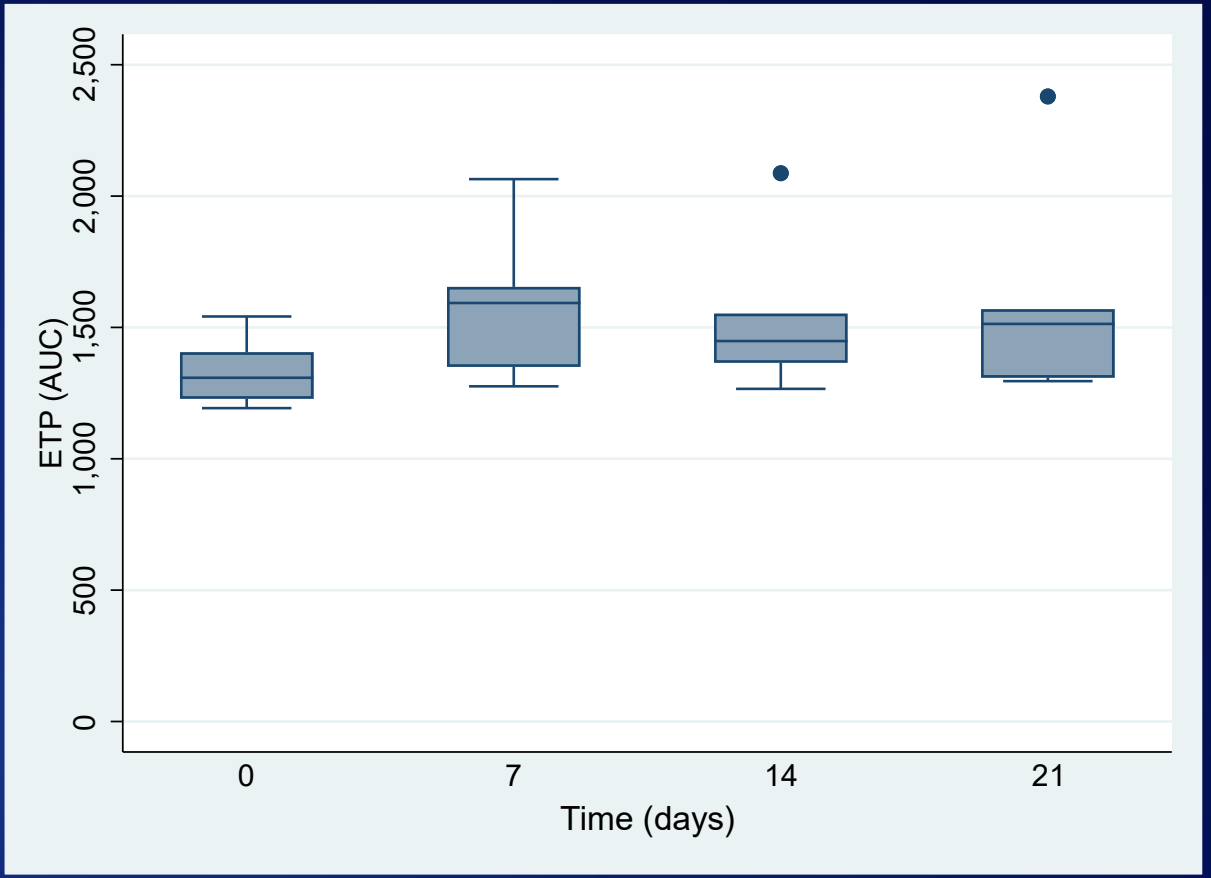
Results – Whole Blood – Clot Initiation



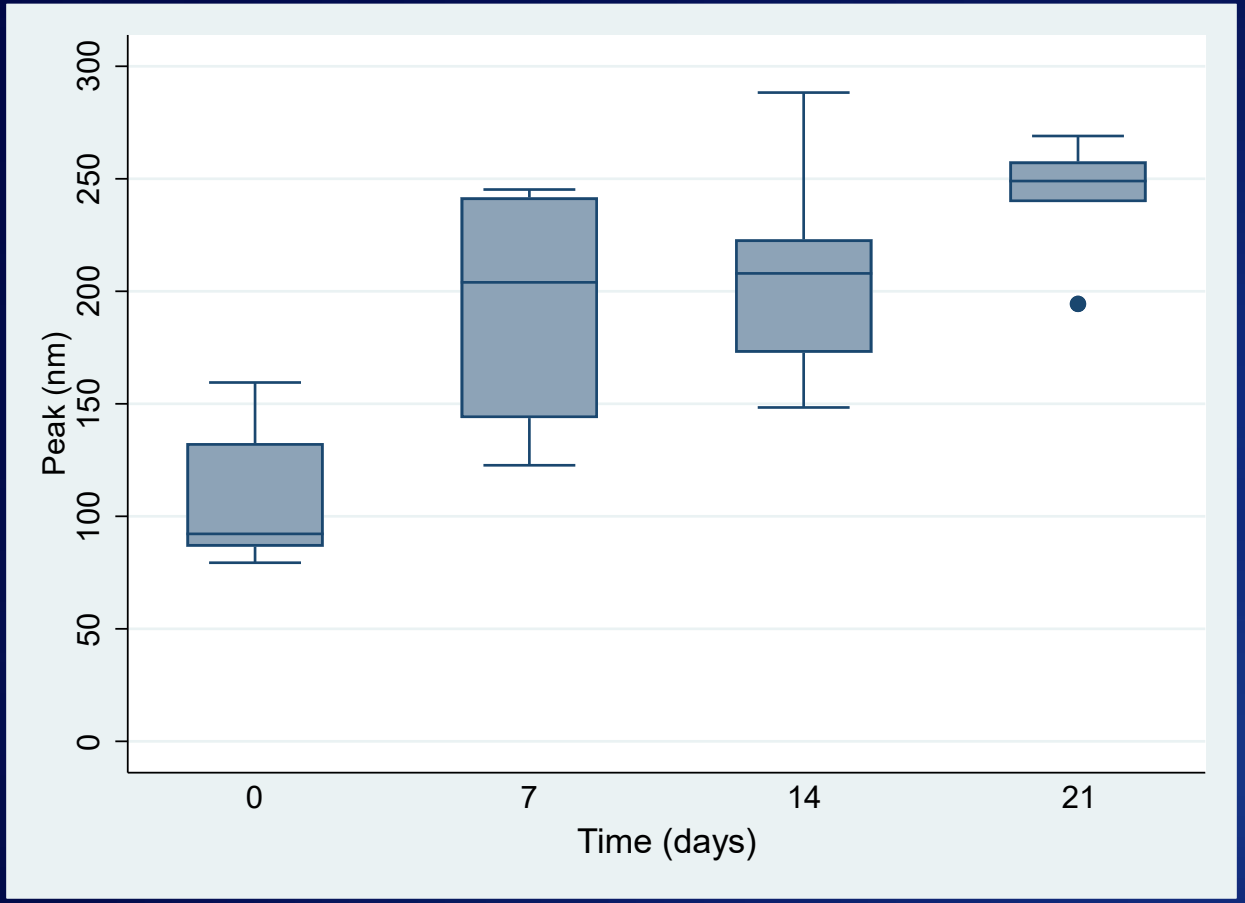


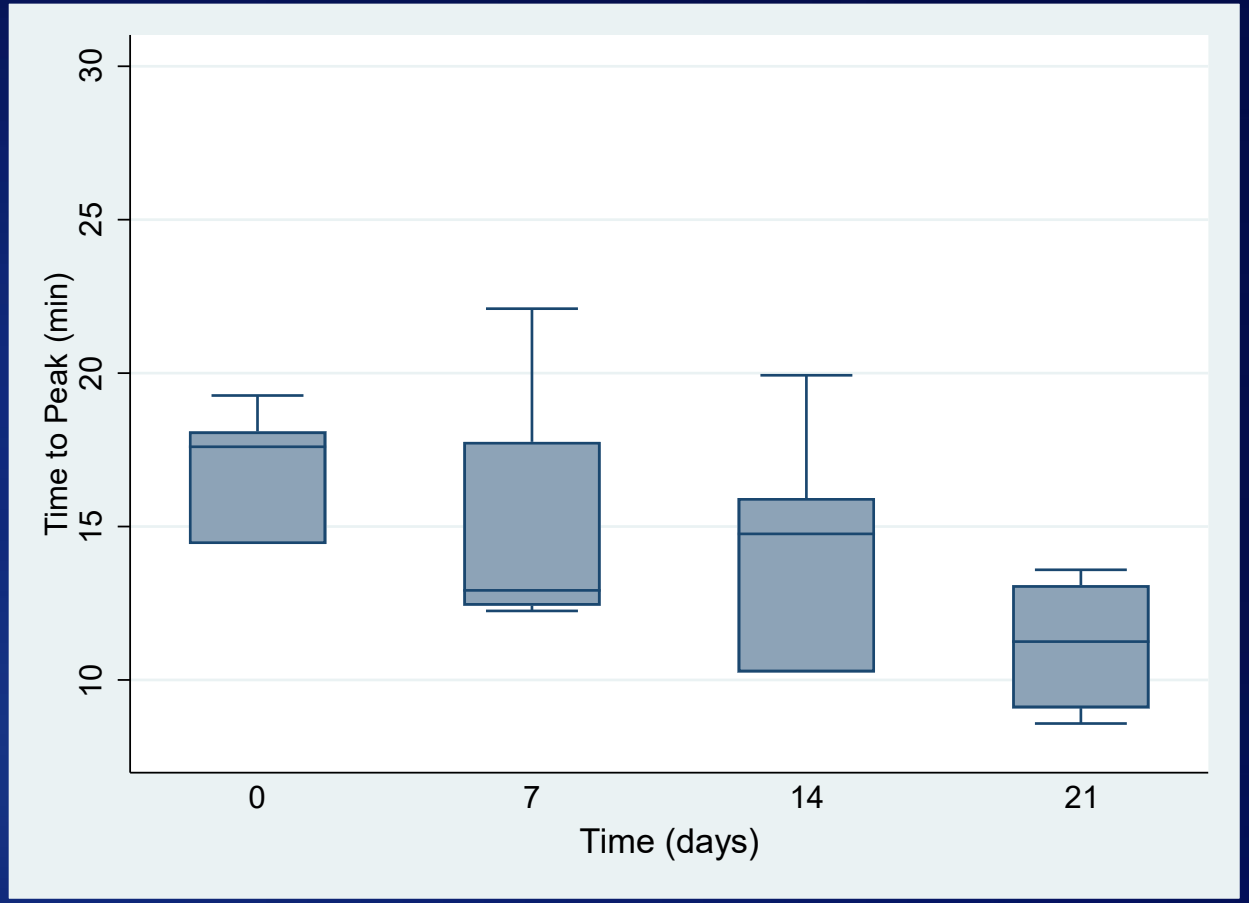
Results – Whole Blood – Thrombin Generation





Results – Whole Blood – Thrombin Generation





Conclusions

- Platelet function of whole blood degrades significantly at 7 days, and again at 14 days

- Clot initiation and thrombin generation of whole blood remain stable over 21-day shelf life

Conclusions

- The current 21-day shelf life of whole blood should be evaluated with clinical endpoints

- Taking into account economics and logistics of WB availability and supply, a new storage limit for non-LR whole blood (CPD) should be considered

AAST 2020 Podium Paper

The prehospital use of younger age whole blood is associated with an improved arrival coagulation profile

Thomas Clements, MD, Cameron McCoy, MD, Scott Assen, MD, Jessica Cardenas, PhD, Charles Wade, PhD, David Meyer, MD, *and* **Bryan A. Cotton, MD, MPH**, *Houston, Texas*

Definitions

- WB defined as “young” if transfused with ≤ 14 days of cold storage time, > 14 days was termed “old”
- Patients were included in the “young” group on analysis if receiving 1 or more units of “young” WB, regardless of other products
- Primary outcome: Coagulation profile on arrival defined by r-TEG and platelet counts
- Secondary Outcomes: Mortality, resus volumes, hospital/ICU/ventilator free days, complications including renal failure, sepsis, respiratory failure, VTE

TABLE 2. Prehospital Scene Vitals and Field Resuscitation Volumes for Patients Receiving Young (≤14 Days of Cold-Storage Time) and Old (>14 Days of Cold-Storage Time) Units of WB

	YOUNG (n = 153)	OLD (n = 67)	*p*	Standardized Mean Difference
Heart rate, bpm	114 (93–134)	109 (92–125)	0.276	0.014
Systolic blood pressure, mm Hg	100 (84–126)	90 (73–117)	0.130	0.189
Diastolic blood pressure, mm Hg	65 (49–82)	62 (47–71)	0.211	0.192
Glascow Coma Scale	8 (3–14)	10 (3–15)	0.178	0.077
Positive field focused assessment with sonography in trauma	66%	76%	0.146	0.074
Crystalloid, mL	275 (50–610)	400 (0–1,000)	0.753	0.240
Red blood cells, U	0 (0–0)	0 (0–0)	0.633	0.115
Plasma, U	0 (0–0)	0 (0–0)	0.860	0.161
WB, U	1 (1–1)	1 (1–1)	0.245	0.082

TABLE 3. Arrival Vital Signs and Laboratory Values of Patients Receiving Young (≤14 Days of Cold-Storage Time) and Old (>14 Days of Cold-Storage Time) Units of WB

	YOUNG (n = 153)	OLD (n = 67)	*p*
r-TEG ACT, s (<128 s)	113 (105–121)	113 (105–128)	0.080
r-TEG *k* time, min (<2.5 min)	1.5 (1.1–1.8)	1.8 (1.2–2.1)	0.024
r-TEG α angle, ° (>60°)	73 (70–76)	71 (66–75)	0.014
r-TEG MA, mm (>55 mm)	63 (58–68)	60 (55–65)	0.063
r-TEG LY-30, % (<3%)	0.6 (0.0–2.7)	0.6 (0.0–1.8)	0.612

TABLE 4. ED and Post-ED Blood Products Administered to Patients Receiving Young (≤14 Days of Cold-Storage Time) and Old (>14 Days of Cold-Storage Time) Units of WB

	YOUNG (n = 153)	OLD (n = 67)	*p*
ED RBC, units	1 (0–5)	1 (0–5)	0.287
ED plasma, units	1 (0–5)	2 (0–6)	0.220
ED platelet, units	0 (0–1)	0 (0–1)	0.936
ED WB, units	0 (0–0)	0 (0–0)	0.593
post-ED RBC, units	1 (0–4)	0 (0–5)	0.506
post-ED plasma, units	0 (0–2)	0 (0–2)	0.713
post-ED platelet, units	0 (0–1)	0 (0–2)	0.301

Conclusion

- Consistent with *in-vitro* data, the current study demonstrated decreased hemostasis in older WB.
- Most notable in values related to fibrinogen and platelet interactions, but did not affect transfusion requirements.
- Further studies are needed to determine the optimal storage duration for cold-stored WB in the bleeding trauma patient

What product do you use in your MTP?

- Anti-body titer? *Pick the lowest possible for your center that allows you to stock enough WB*
- Rh + or Rh- ? *If Rh- unavailable or in short supply, Rh+ safe alternative in both Rh+ and Rh- patients.*
- **How long do you keep it?** *14 days clinically optimal, but may not be logistically/economically feasible*
- How do you transfuse it?

What product do you use in your MTP?

- Anti-body titer? *Pick the lowest possible for your center that allows you to stock enough WB*
- Rh + or Rh- ? *If Rh- unavailable or in short supply, Rh+ safe alternative in both Rh+ and Rh- patients.*
- How long do you keep it? *14 days clinically optimal, but may not be logistically/economically feasible*
- **How do you transfuse it?**

Rapid Infuser Impact on Whole Blood Platelet Count, Platelet Function, and Hemostatic Potential

Mouayyad Zaza, MD, Yao-Wei Wang, PhD, Mitchell George, MD,
Katherine Daniels, BSN, Charles E Wade, PhD,
Jessica C Cardenas, PhD, Bryan A. Cotton, MD, MPH

The McGovern Medical School at the University of Texas Health Science Center-Houston
The Red Duke Trauma Institute at Memorial Hermann Hospital

UTHealth The University of Texas Health Science Center at Houston | McGovern Medical School

Red Duke Trauma Institute
MEMORIAL HERMANN

JOURNAL OF SURGICAL RESEARCH • APRIL 2021 (260) 76–81

ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.JournalofSurgicalResearch.com

The Impact of Rapid Infuser Use on the Platelet Count, Platelet Function, and Hemostatic Potential of Whole Blood

Mouayyad Zaza, MD,[a] *David E. Meyer, MD, MS,*[a,b,*] *Yao-Wei Wang, PhD,*[b] *Mitchell George, MD,*[a] *Katherine Daniels, BSN,*[b] *Jessica C. Cardenas, PhD,*[b] *and Bryan A. Cotton, MD*[a,b]

[a] *Department of Surgery at the University of Texas Health Science Center's McGovern Medical School, Houston, Texas*

[b] *Center for Translational Injury Research (CeTIR) at the University of Texas Health Science Center's McGovern Medical School, Houston, Texas*

WARNING!

The Belmont *FMS2000* is not for use in warming platelets, cryo-precipitates, or granulocyte suspensions.


BELMONT
INSTRUMENT CORPORATION
Rapid Infuser
Max Rate: 1000 ml/min
NO PLATELETS
BIOMED
1153829
The Belmont® Rapid Infuser

Purpose

To evaluate the impact of rapid infusers on whole blood platelet count, platelet function, and overall clot strength

Methods

- Five units of WB were obtained from our blood center

- The following samples were obtained from each unit

- non-filtered infusion line
- filtered blood tubing
- primed Belmont FMS 2000 run at 70 mL/hr
- primed Belmont FMS 2000 run at 100 mL/hr
- Filtered tubing on a pressure bag at 300 mmHg

Methods

- The following tests were performed on each sample

Platelet Count	Platelet Function	Hemostatic Potential	Thrombin Generation
HemaVet 950	Multiple Electrode Aggregometry (Multiplate)	Thrombelastography (TEG and r-TEG)	Calibrated Automated Thrombogram (CAT)
Flow cytometry			

Table 1 – Absolute platelet count. Mean cell counts are provided as 1000 cells/μL (±standard deviation). Significance was assigned at $P < 0.05$, and significant values are highlighted with bold text.

Platelet counts	BASELINE	FILTER	BELMONT70	BELMONT100	FILTER +PRESSURE
Platelet count	168 (±42)	134 (±34)	**97 (±24)***	**94 (±25)†**	130 (±38)
Platelet granulocyte	3.9 (±2.8)	4.3 (±3.2)	2.6 (±1.9)	2.7 (±2.2)	4.6 (±3.4)
Platelet monocyte	12.0 (±2.1)	12.1 (±3.4)	9.2 (±2.0)	10.5 (±4.1)	11.9 (±2.9)
Platelet lymphocyte	7.1 (±0.9)	6.7 (±1.1)	5.3 (±0.9)	5.4 (±0.7)	6.9 (±1.2)

Table 2 – Platelet function as measured by multiple electrode aggregometry (MEA). Adenosine diphosphate (ADP), arachidonic acid (AA), thrombin, and ristocetin were used as reagents. The mean area under the aggregation curve [units] (±SD) is presented. Significance was assigned at $P < 0.05$. No values differed significantly from the baseline samples.

MEA value	BASELINE	FILTER	BELMONT70	BELMONT100	FILTER + PRESSURE
ADP	0.38 (±0.22)	0.42 (±0.30)	0.43 (±0.23)	0.42 (±0.24)	0.50 (±0.35)
AA	0.30 (±0.15)	0.35 (±0.22)	0.38 (±0.11)	0.41 (±0.21)	0.41 (±0.23)
Thrombin	0.55 (±0.24)	0.64 (±0.32)	0.78 (±0.26)	0.77 (±0.30)	0.70 (±0.36)
Ristocetin	0.52 (±0.26)	0.60 (±0.30)	0.71 (±0.28)	0.79 (±0.40)	0.69 (±0.41)

Table 4 – Thrombin generation as measured by calibrated automatic thrombogram (CAT). Significance was assigned at $P < 0.05$. ETP = endogenous thrombin potential; ttPeak = time-to-peak.

CAT value	BASELINE	FILTER	BELMONT70	BELMONT100	FILTER + PRESSURE
Lag time [min]	8.9 (±1.4)	8.8 (±1.6)	**6.5 (±1.1)***	**6.0 (±0.9)***	8.6 (±1.2)
ETP [nmol•min]	803 (±171)	781 (±181)	**1203 (±101)†**	**1228 (±132)†**	813 (±155)
Peak [nmol]	56.5 (±18.7)	53.6 (±20.5)	**96.1 (±18.9)†**	**119 (±30.2)†**	60.8 (±28.4)
ttPeak [min]	18.5 (1.9)	18.7 (±2.0)	**13.4 (±1.4)‡**	**11.7 (±1.3)‡**	18.1 (±2.1)
Velocity index [nmol/min]	6.2 (±2.7)	5.7 (±2.8)	14.5 (±4.5)	**22.4 (±9.1)§**	7.1 (±5.1)
Tail [min]	43.6 (±3.2)	44.5 (±3.9)	38.9 (±5.8)	34.9 (±6.5)	42.4 (±4.4)
Alpha	5.5 (±1.7)	5.6 (±1.8)	**9.2 (±1.6)‖**	**9.1 (±1.9)‖**	5.5 (±1.7)

RESULTS

- There was a statistically significant *decrease in platelet count* when samples were obtained from rapid infusers

- However, this *did not result in detectable differences in platelet function* between infusion models

- *Thrombin generation (CAT) values were accelerated* (stronger clot) when a rapid infusion device was used.

What product do you use in your MTP?

- Anti-body titer? *Pick the lowest possible for your center that allows you to stock enough WB*
- Rh + or Rh- ? *If Rh- unavailable or in short supply, Rh+ safe alternative in both Rh+ and Rh- patients.*
- How long do you keep it? *14 days clinically optimal, but may not be logistically/economically feasible*
- **How do you transfuse it?** *Rapid transfuser or pressure bag are both acceptable*

What product do you use in your MTP?

- **Anti-body titer?** *Pick the lowest possible for your center that allows you to stock enough WB*
- **Rh + or Rh- ?** *If Rh- unavailable or in short supply, Rh+ safe alternative in both Rh+ and Rh- patients.*
- **How long do you keep it?** *14 days clinically optimal, but may not be logistically/economically feasible*
- **How do you transfuse it?** *Rapid transfuser or pressure bag are both acceptable*

Do blood groups matter?

- We set out to examine laboratory evidence of hemolysis labs, complications, and patient outcomes associated with the use of LTO-WB across the various recipient blood groups.

- All trauma patients (16 years and older) receiving prehospital or ED transfusion of LTO-WB (11/17-07/20) were evaluated.

Do blood groups matter?

- 736 patients met inclusion; 368 group O, 236 group A, 101 group B, and 31 group AB recipients.
- There were no differences in demographics, method of transport, mechanism of injury, or injury severity (ISS).
- No differences in prehospital vitals or resuscitation products/volumes, 24-hr, 48-hour, and 72-hr hemolysis panels (potassium, bilirubin, LDH, haptoglobin) among blood groups.

Do blood groups matter?

- Arrival SBP was lower in group B (median 91 mmHg) compared to the other blood types (O: 100, A; 100, AB: 111 mmHg); p=0.017.

- Median arrival lactate was worse in blood group B patients (median 5.3) compared to other groups (O: 4.1, A: 4.0, AB: 4.1); p=0.040.

- There was also a trend towards higher number of early transfusions in group B versus other blood groups, but these did not reach significance; p=0.059.

Do blood groups matter?

- While survival and most major complications were similar between blood types, acute kidney injury (AKI) was significantly higher among those with blood group B (19%) compared to other blood types (O: 8%, A: 10%, AB: 13%); p=0.017.

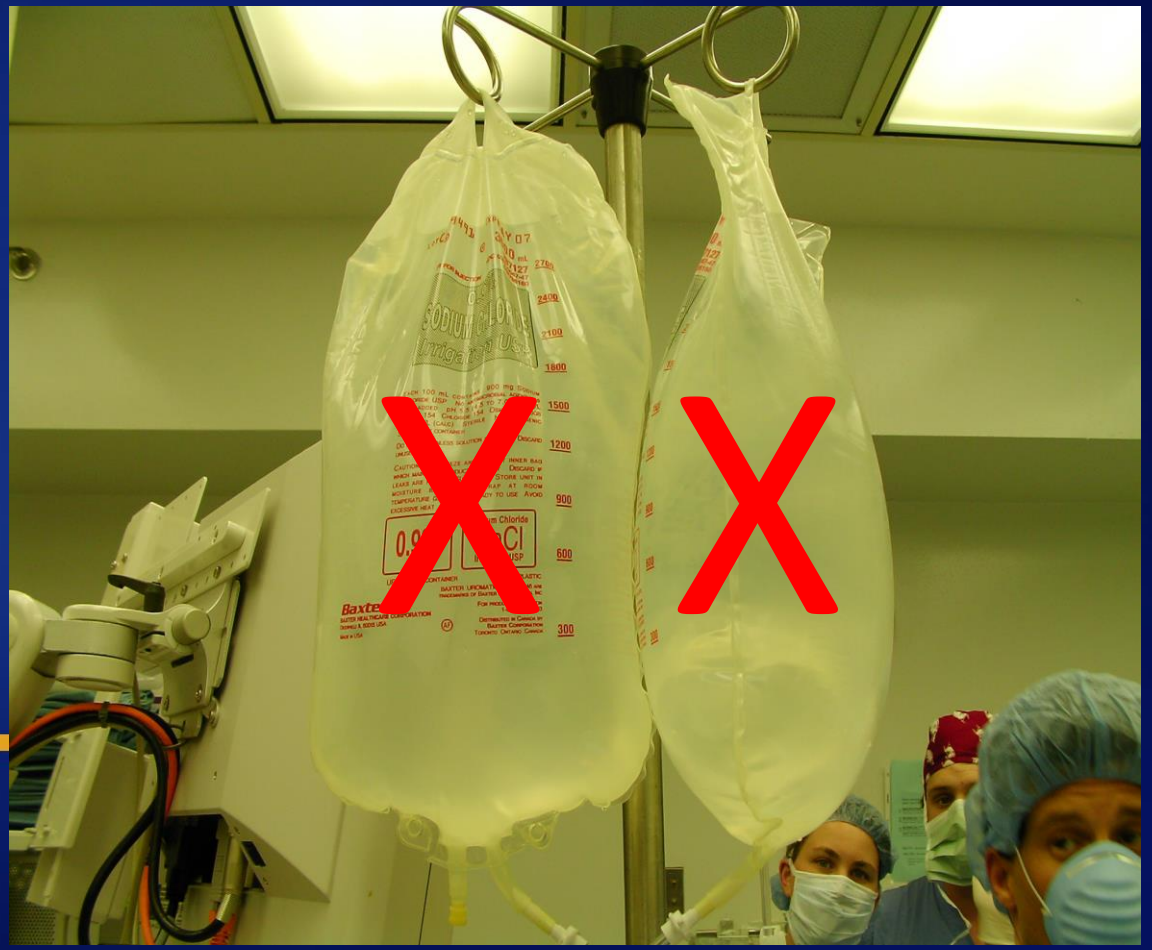
	Group O (n=368)	Group A (n=236)	Group B (n=101)	Group AB (n=31)	p-value
Scene SBP	108 (85, 133)	101 (80, 122)	97 (74, 126)	116 (86, 139)	0.068
ED lactate	4.1 (2.9, 6.9)	4.0 (2.5, 6.9)	5.5 (3.1, 8.1)	4.2 (2.8, 6.0)	0.048
ED SBP	100 (80, 122)	100 (82, 123)	91 (80, 111)	111 (90, 130)	0.017
30-d Survival	76%	72%	78%	80%	0.490
AKI	8%	11%	19%	13%	0.017

Do blood groups matter?

- Multivariate model noted group B patients had 2-fold increased likelihood of AKI (OR 2.12, 95% C.I. 1.15-3.90, P=0.015).

- Analysis was repeated in patients receiving emergency release RBCs and plasma (rather than WB). Group B (15%) was noted to have increased likelihood of AKI compared to other groups (O: 7%, A: 10%, AB: 11%); p=0.041.

Life-threatening Bleeding on Arrival



Every minute counts: Time to delivery of initial massive transfusion cooler and its impact on mortality

Time to cooler-PROPPR

- Median time arrival to MTP activation: 9 min, median time activation to 1st cooler: 8 min.
- Increase in time to MTP activation, time to 1st cooler associated w/ prolonged time to achieving hemostasis.
- Increased time to MTP activation, time to first cooler were also associated with increased mortality.

Every minute counts: Time to delivery of initial massive transfusion cooler and its impact on mortality

TABLE 3. Multivariate Regression Predicting 30-d Mortality

	OR	95% CI	*p*
Time to receipt of first cooler, min	1.05	1.01–1.09	0.016
Anatomic injury severity (ISS)	1.05	1.03–1.06	<0.001
Disturbed arrival physiology (w-RTS)	0.61	0.53–0.69	<0.001
Randomization group (1:1:2)	1.46	0.92–2.29	0.102
RI, units	1.03	0.60–1.44	0.184

Time to cooler-PROPPR

- Multiple logistic regression noted time to arrival of first cooler was associated with increased mortality at 24-hours (OR 1.05, p=0.035), 30-days (OR 1.05, p=0.016).

- Independent of ratios, every minute from time of MTP activation to time of initial cooler arrival increases the odds of mortality by 5%.

Impact of Incorporating Whole Blood into Hemorrhagic Shock Resuscitation: Analysis of 1,377 Consecutive Trauma Patients Receiving Emergency-Release Uncrossmatched Blood Products

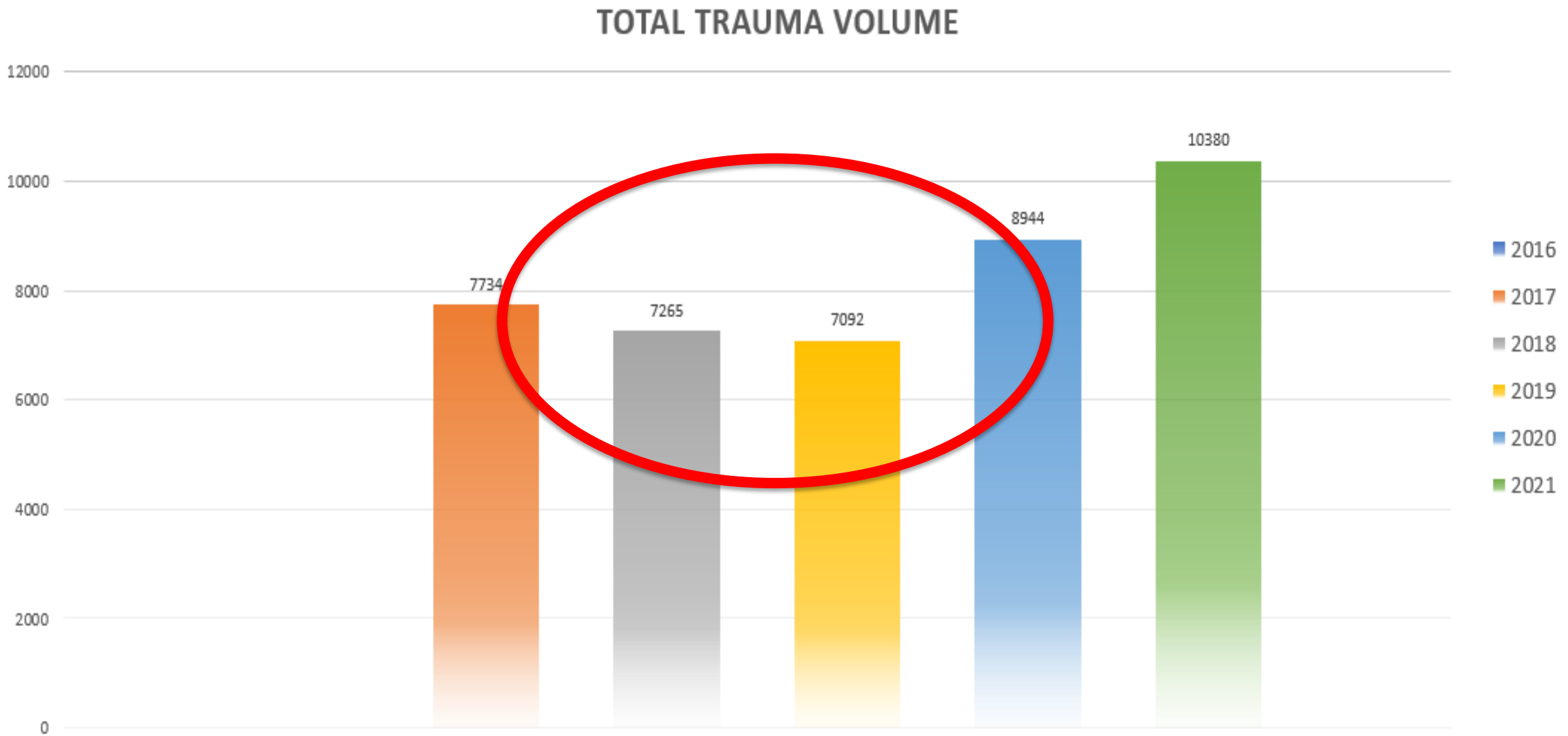
Jason B Brill, MD, Brian Tang, BS, Gabrielle Hatton, MD, Krislynn M Mueck, MD, C Cameron McCoy, MD, Lillian S Kao, MD, MS, FACS, Bryan A Cotton, MD, MPH, FACS

Results

• 23,301 patients were entered into the trauma registry during this time frame.

• 1, 377 patients received emergency-release WB in the prehospital and or emergency department setting.

•Of these, 840 received at least one unit of LTO-WB (WB), while 537 received no units of LTO-WB, solely receiving component therapy (COMP).


TOTAL TRAUMA VOLUME
12000
10000
8000
6000
4000
2000
0
7734
7265
7092
8944
10380
2016
2017
2018
2019
2020
2021

Impact of Incorporating Whole Blood into Hemorrhagic Shock Resuscitation: Analysis of 1,377 Consecutive Trauma Patients Receiving Emergency-Release Uncrossmatched Blood Products

Table 5. Multivariable Analyses Evaluating the Impact of Low-Titer Group O Whole Blood on 30-Day Survival Among All Patients

	Unweighted analysis		Weighted analysis	
30-day survival	**Odds ratio (95% CI)**	**p Value**	**Odds ratio (95% CI)**	**p Value**
WB group	4.10 (2.22-7.45)	<0.001	1.59 (1.28-1.98)	<0.001
Age, per year	0.97 (0.96-0.98)	0.001	0.99 (0.98-0.99)	<0.001
Male sex	0.46 (0.24-0.87)	0.018	0.77 (0.60-0.98)	0.04
ISS, per point	0.93 (0.92-0.95)	<0.001	0.95 (0.94-0.96)	<0.001
Scene SBP, per mmHg	1.00 (0.99-1.01)	0.286	1.009 (1.006-1.012)	<0.001
Arrival lactate, per mmol/L	0.82 (0.76-0.88)	<0.001	0.89 (0.87-0.92)	<0.001

CI, confidence interval; ISS, Injury Severity Score; SBP, systolic blood pressure; WB, whole blood arm.

Impact of Incorporating Whole Blood into Hemorrhagic Shock Resuscitation: Analysis of 1,377 Consecutive Trauma Patients Receiving Emergency-Release Uncrossmatched Blood Products

Table 6. Multivariable Analyses Evaluating the Impact of Low-Titer Group O Whole Blood on 24-Hour Blood Product Use Among All Patients

	Unweighted analysis		Weighted analysis	
24-hour blood product use	**Rate ratio (95% CI)**	**p Value**	**Rate ratio (95% CI)**	**p Value**
Whole blood group	0.38 (0.21-0.70)	0.002	0.93 (0.91-0.96)	<0.001
Age, per year	1.00 (0.99-1.02)	0.602	0.996 (0.995-0.997)	<0.001
Male sex	1.80 (0.98-3.26)	0.055	1.22 (1.18-1.26)	<0.001
ISS, per point	1.07 (1.04-1.09)	<0.001	1.023 (1.022-1.024)	<0.001
Scene SBP, per mmHg	0.99 (0.99-1.01)	0.639	0.998 (0.998-0.991)	<0.001
Arrival lactate, per mmol/L	1.12 (1.02-1.25)	0.019	1.038 (1.036-1.039)	<0.001

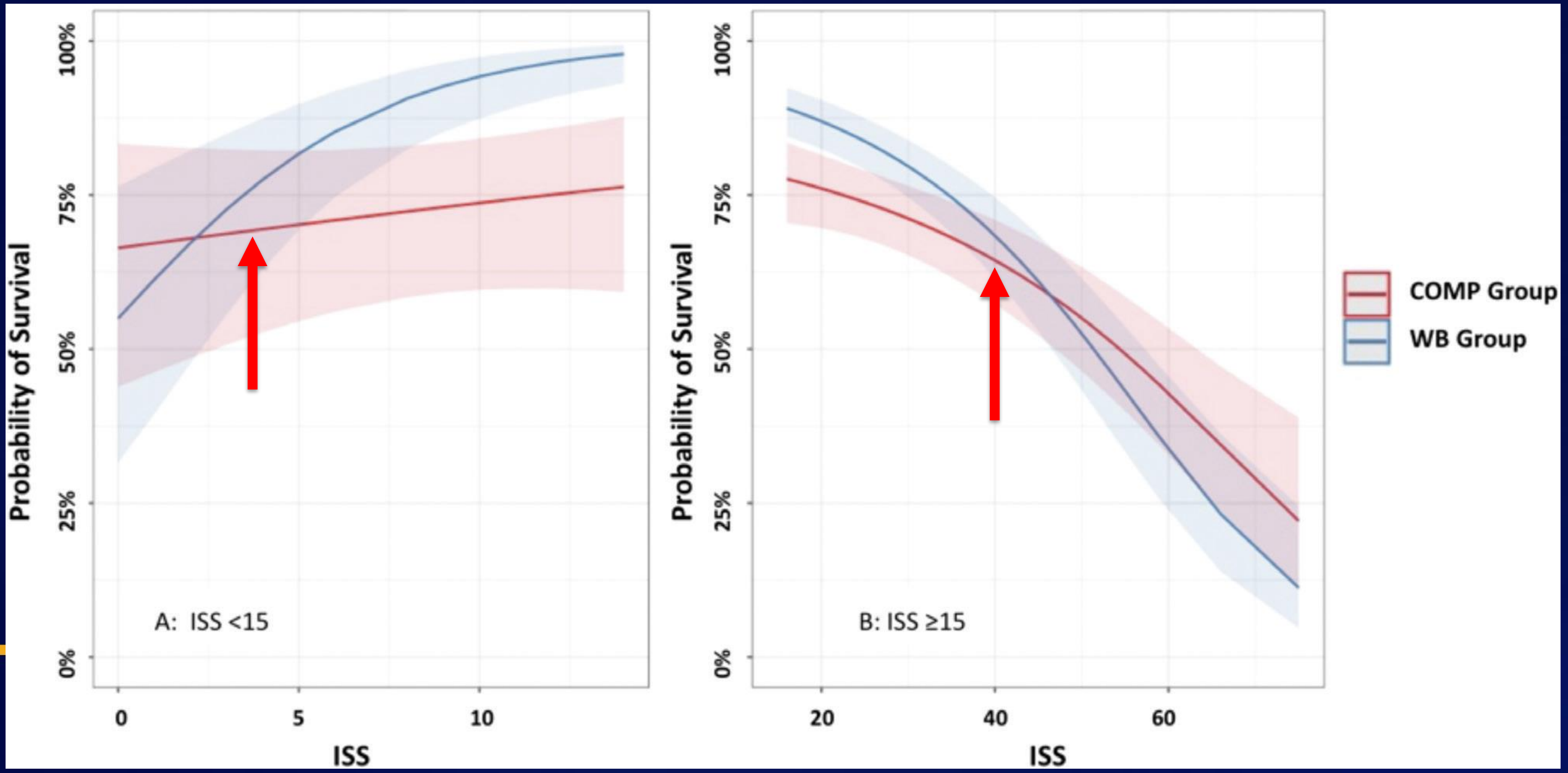
CI, confidence interval; ISS, Injury Severity Score; SBP, systolic blood pressure; WB, whole blood arm.

Results

- In-hospital transfusion only; WB were more likely to survive with an OR 2.30 (CI 1.63–3.26, $p < 0.001$).

- Pre- and in-hospital transfusion, WB more likely to survive, effect less (OR 1.50, CI 0.98–2.31, $p=0.06$).

- For patients with TBI, OR for survival was 1.4 (CI 1.0–1.8, $p = 0.04$) whereas without OR 1.8 (CI 1.3–2.5, $p<0.001$).


Probability of Survival
100%
75%
50%
25%
0%
A: ISS <15
0
5
10
ISS
Probability of Survival
100%
75%
50%
25%
0%
B: ISS ≥15
20
40
60
ISS
COMP Group
WB Group

Time Matters

- When trying to stop bleeding, time is EVERYTHING
- Put best product as close to the patient as possible
- Earliest and most aggressive therapy is indicated
- Give minimum product necessary to get the job done
- Is this whole blood?

Greater than the sum of its parts:
The use of whole blood in the resuscitation of hemorrhage

Bryan A Cotton, MD, MPH
The John B Holmes Professor of Clinical Sciences
Department of Surgery and Center for Translational Injury Research
McGovern Medical School at the University of Texas Health Science Center
Red Duke Trauma Institute at Memorial Hermann Hospital
Houston, Texas

UTHealth The University of Texas Health Science Center at Houston | McGovern Medical School

Red Duke Trauma Institute
MEMORIAL HERMANN