Prehospital blood transfusion programs: Capabilities and lessons learned

Martin D. Zielinski, MD, James R. Stubbs, MD, Kathleen S. Berns, MS, Elon Glassberg, MD, Alan D. Murdock, MD, Eilat Shinar, MD, Geir Arne Sunde, MD, Steve Williams, RN, Mark H. Yazer, MD, Scott Zietlow, MD, *and* **Donald H. Jenkins, MD**, *San Antonio, Texas*

Every year since 2011near the summer solstice, the Trauma and Hemostasis Oxygenation Research (THOR) network has met in Bergen, Norway. THOR was created to faciliate collaboration among an international community of experts in hemorrage resusctiation including transfusion medicine, military medicine, and trauma surgery. The 2016 meeting provided further oppurtunities to discuss topics pertinent to remote damage control resuscitation (RDCR) includuing the Norwegian Military experience with freeze dried plasma (FDP) and whole blood resuscitation, extreme RDCR situations on oceanic cruises, and the most current updates on remote blood product resuscitation techniques at Mayo Clinic, the University of Pittsburgh, and the Israeli Military. We would like to take this oppurtunity to disseminate the lessons learned from this meeting. Of note, the blood prodcut capabilities of the each of these contributing institutions are outlined in Table 1.

BLOOD IN NORWEGIAN HELICOPTER EMERGENCY MEDICAL SERVICES

Norwegian Helicopter Emergency Medical Services (HEMS) was started 1978 and subsequently nationalized and hospital-based under Norway's National Health System in 1988. Today, the national service's 13 HEMS aircraft (12 bases) covers a population of only 5 million across an area of 385,000 km.[1] The topography of Norway (mountains and fjords), combined with the long distances between Level 1 trauma centers (minimun, 600 km), makes ground transport of critical patients challenging and demands that the EMS chain use a RDCR approach to critical patients. HEMS crews uniformily consist of an experienced prehospital anaesthesiologist, flight paramedic, and pilot. The services cover trauma, nontrauma, and interhospital transfers (30%, 60%, and 10%, respectively) including neonatal transports. All helicopters operate everday all year round, with night-vision and instrument flying capabilities. Also, fast response cars are used in urban settings. Ultrasound to allow for on-scene diagnostics (e.g., Focused Assessment with Sonography for Trauma) is deployed on all HEMS.

BLOOD ON BOARD

Several of the bases have randomly deployed blood on board on demand during the last 30 years. Recently, regular advanced deployment of FDP on HEMS bases was implemented in 2013, and two units of packed red blood cells (pRBCs; 0 type Rh negative) starting in 2014. In 2015, leukocyte reduced cold whole blood (CWB), stored for up to 7 days, was deployed on the first base as routine, and several other bases will follow in 2016 to 2017. Ground ambulance services in Norway do not carry blood products at all.

HEMS are dependent on good relations with their own blood bank for production and logistics of blood products, and they must be 100% accountable for all use of blood products outside the hospital setting. Furthermore, it is essential that HEMS must comply with good transfusion practices and that treatment is seen as nonexperimental and aligned with good in-hospital practice.

Today's transfusion practices in Norwegian HEMS are limited to patients who meet transfusion criteria based on physiology and clinical assessment on-scene, with only 1% to 2% of all patients being transfused across the board, numbering approximately 25 patients per month. Since 2013, the HEMS service has had a comprehensive blood product transfusion program allowing for novel CWB and FDP adminsitration in addition to standard blood products in within the confines of our "plasma first" transfusion policy.

PATIENTS

Patients in hemorrhagic shock needing volume replacement are eligible for receiving prehospital transfusion of blood products according to protocol. HEMS experience today

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From the Department of Surgery (M.D.Z., J.R.S.), Mayo Clinic, Rochester, Minnesota; Mayo Clinic Medical Transport (K.S.B., S.Z.), Rochester, Minnesota; Israel Defense Forces Medical Corps (E.G.), Haifa, Israel; Department of Surgery (A.D.M.), Allegheny General Hospital, Pittsburgh, Pennsylvania; Magen David Adom National Blood Services (E.S.), Israel; HEMS-Bergen, Emergency Medical Services Haukeland University Hospital (G.A.S.), Bergen, Norway; Institute of Cruise Ship Medicine (S.W.), Miami, Florida; The Institute for Transfusion Medicine (M.H.Y.), Pittsburgh, Pennsylvania; and the Department of Surgery (D.H.J.), University of Texas Health Sciences Center, San Antonio, Texas.

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Address for reprints: Donald H. Jenkins, MD, Department of Surgery, University of Texas Health Sciences Center, 4502 Medical Drive, San Antonio, TX 78229; email: JenkinsD4@uthscsa.edu.

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TABLE 1. Remote Blood Product Capabilities at Contributing THOR Institutions

	Royal Caribbean	Pittsburgh	Mayo	Norwegian Military	Israeli Military
CWB					
No. patients	—	n = 22	n = 24	n = unknown	—
No. units		n = XX	n = 36	n = unknown	
Characteristics		Group O male donor titer <50 Platelet sparing LR filter; 4°C × 15 d	Group O male donor titer <200 non-LR; 1–6°C × 14 d	Group O male donor Titer <64 platelet sparing LR filter; 2–6°C × 7 d	
FDP					
No. patients	—	—	—	n = unknown	n = 130
No. vials				n > 500,000	n = unknown
Characteristics				Single male donor; room temperature	
WFWB					
No. patients	n = 73	—	—	—	—
No. units	n = Prescreened donors				
Characteristics	Group identical transfusions				
CSP					
No. patients	—	—	n = 21		—
No. units			n = 20		
Characteristics			1–6°C for 3 d		

LR, luekoreduced; X, not available.

suggests that penetrating (e.g., stabbings) and blunt trauma (e.g., fall from heights, islolated massive head injury, and entrapped/overryn MVA) dominate. Additionally, prehospital medical (e.g., gastrointestinal hemorrhage) and surgical patients (e.g., ruptured AAA or postpartum hemorrhage) may advantageously receive prehospital blood product transfusions.

In the lack of clear objective transfusion criteria, our transfusion criteria today are mechanism of injury compatible with severe hemorrhage and/or hemorrhagic shock (e.g., penetrating torso injury, visible massive bleeding), radial pulse > 100 beats per minute or absent/weak radial pulse, systolic blood pressure less than 90 mm Hg, or altered mental status (reduced Glasgow Coma Scale) in the absence of head injury or known intoxication.

All patients are treated according to modern Damage Control Resuscitation principles, including hypotensive resuscitation, internal hemorrhage control with pelvic stabilization and external hemorrhage control with tourniquet or wound packing (if necessary). Temperature conservation to prevent hypothermia and further coagulopathy is also mandatory.

PRBCS

Most services are supplied with advanced deployment of two units of pRBCs (0 Rh negative) from their respective blood banks (delivered close to the day it is produced) and is stored in a refrigerator at 4°C next to the helicopter in a transportable "golden hour box" (GHB). A few services are supplied with (0 Rh negative) pRBC units from their respective blood banks reserves by request on dispatch, where it is brought to the helicopter within 5 minutes to 10 minutes after alarm. The GHB are pretested and validated for the storage of pRBCs by the blood bank, for example, temperature stability. If the pRBCs are not used by EMS within a week, the units are returned to the blood bank and can be used in the hospital for an additional 28 days. Supplying the prehospital chain with fresh pRBCs stored for less than 8 days is less likely to cause wastage and also provides prehospital hemorrhaging patients with pRBCs with minimum "storage lesions." pRBC transfusions are documented in hospital records with product information inclusive batch number.[2]

FDP (LYOPLAS N-W)

LyoPlas N-w (Deutsches Rotes Kreuz-Blutspendedienst West, Hagen, Germany) is quarantined single-donor plasma from male donors or donors tested negative for HLA antibodies.[3] We currently carry only AB plasma, but it is available in all blood groups: O, A, B, AB. Being a EU-approved blood product and based on specifications and documentation by Deutsches Rotes Kreuz, the Norwegian Directorate for Health and Social Affairs approved the import of LyoPlas N-w to Norway by the Department of Immunology and Transfusion Medicine at Haukeland University Hospital, Norway. Our HEMS may order LyoPlas N-w through the hospital blood banks. FDP is stored at room temperature in the fast-response car and in the helicopter, making it readily available. LyoPlas N-w powder dissolves in 200 mL of sterile water and is ready for injection in 3 minutes to 6 minutes depending on water temperature. All HEMS crew, including flight paramedics and pilots, are trained in preparing and administering LyoPlas on physician's orders. It can be administered through intravenous or intraosseous vascular routes.[3,4] FDP is assessed to be safe to use, and according to Deutsches Rotes Kreuz, over 500,000 units of freeze-dried plasma now have been used without any recorded side effects at the hemovigilance register of Deutsches Rotes Kreuz-Blutspendedienst West.[5]

LEUKOCYTE-REDUCED WHOLE BLOOD

The whole blood units are donated by regular blood donors and the transfusion transmittable infection testing is in

accordance with Norwegian regulations. The whole blood unit is filtered through a platelet-sparing filter (Imuflex WB-SP; Terumo, Inc, Somerset, NJ) allowing a platelet content of above 90% of the unit prefiltration. The residual leukocyte contamination is below 1 × 106/unit, also in line with requirements for cellular blood components. To minimize risk of hemolytic transfusion reactions, all blood donors have blood groups O Rh D-neg K-neg. The titers of IgM anti-A and anti-B are below 64, and all units are correspondingly labeled "low titer." The whole blood units are stored at 4°C for up to 21 days. The preferred storage time is up to 7 days, and it is documented that the blood banks may produce high-quality red cell concentrates from the CWB units. The quality of the recovered plasma is yet not characterized. Platelet concentrates will not be produced from stored whole blood.

MANAGEMENT OF CATASTROPHIC HEMORRHAGE AT SEA—THE CRUISE INDUSTRY CHALLENGE

In 2016, nearly 24 million people from around the world will take a cruise, 11.5 million of the them, US citizens.[6] As cruise lines take their guests to more distant and remote ports of call, the challenge to provide excellent medical care, particularly acute emergency care and surgical intervention becomes more difficult. Many of the ports visited by cruise ships have challenges meeting the health care needs of their local populations on an average day. Additionally, with some ships spending 7 days to 9 days crossing the Pacific and Atlantic Oceans, sometimes it is simply logistically impossible to transfer a patient with acute blood loss to a shoreside hospital for definitive medical care.

Cruise ship passengers have high expectations for the quality of medical care on board ships, and they often present with complex medical conditions. The growth in use of antiplatelet therapy and anticoagulation for cardiovascular disease has seen an increase in severe hemorrhage at sea, particularly gastrointestinal bleeding. After the death of a Canadian patient in 2008 from GI hemorrhage, one US-based cruise line opted to implement a warm fresh whole blood (WFWB) transfusion program using on-board blood donors.[7]

Since 2009, cruise line medical staff working for this US-based cruise line have managed 73 patients with hemodynamically significant blood loss by administering WFWB from volunteer donors. After initial evaluation of the hemorrhaging patient, if the treating physician determined WFWB was needed, or possibly needed, a call would be put out across the ship public address system asking for guests who are blood donors to report to the medical facility. A typical call out for volunteer donors would usually result in at least five or six potential donors coming forward. Of the patients transfused, 67 survived to hospital admission and 64 survived to be discharged home. The mean hemoglobin of all patients who presented was 6.31 mg/dL, demonstrating the point that these patients had all bled significantly. Retrospective analysis by corporate cruise line medical specialists indicated that of the 64 patients who survived to be discharged home, at least 56 of them would have died without the availability of the on-board blood transfusion program.

In implementing the WFWB transfusion process on board, considerable focus was placed on training physicians and nurses to optimally manage patients who were bleeding, minimize crystalloid fluids, optimize hypotensive resuscitation and where possible reverse any anticoagulation and, if appropriate, administer Tranexamic Acid. The "trigger" for blood donation is hemodynamic instability in the context of known hemorrhage, rather than a set level of hemoglobin (Fig. 1).

Additional training emphasized the importance of the selection of appropriate donors to adequately screen and test blood for HIV and hepatitis and administer the blood while closely observing for transfusion-related complications. Training physicians and nurses dispersed across the world on 40 different cruise ships and keeping them updated on the transfusion protocol have probably been the single largest challenge to the implementation of a shipboard transfusion protocol. Approximately 5 years after the cruise ship transfusion program started, the corporate medical operations team surveyed the 225 cruise ship physicians and nurses working for the cruise line to determine if they felt they had been adequately trained and prepared to implement the WFWB program on board. Of 225 physicians and nurses surveyed, 164 stated that they had been involved with the administration of WFWB on board the ship. Of the 225 survey responders, 84% felt that they had been adequately trained to manage the complexities of an on-board blood transfusion. Retrospective analysis of the 73 patients transfused since the implementation of the cruise line transfusion protocol, where timely evacuation to a hospital for definitive medical care was not possible, has demonstrated that when used in the appropriate clinical setting, the use of WFWB can be lifesaving.

PREHOSPITAL ADMINISTRATION OF BLOOD: THE MAYO CLINIC PLAN OF CARE

An institutional decision has been made to start carrying CWB and cold stored platelets (CSP) on our helicopters for prehospital transfusion therapy in trauma victims. Administration of blood products in our prehospital practice is based on criteria in the Mayo Clinic Trauma Center guidelines. These prehospital criteria mirror those used once in the Trauma Center with some additional criteria (Fig. 2).

Component therapy has been used for years, but following recent military experiences, there has been renewed interest in using whole blood for patients suffering from trauma-related hemorrhage.[8–11] Having the ability to bring CWB and CSP to the prehospital transport environment would enable patients to receive potentially lifesaving products sooner. Although our transfusion colleagues worked on the feasibility of taking these products on the helicopter or critical care ground transports, our task was to decide which product should be given first. The mix of blood products currently consists of one unit group O CWB, one unit of group A CSP, two units group O negative pRBC, and two units group A thawed plasma. Since CSP expires in 3 days, we start with CSP which inherently provide a unit of platelets and a unit of plasma (i.e., platelet-rich plasma). With most patients getting pRBCs at the referring facility, giving the unit of platelets approximates equal ratios of pRBCs, plasma, and platelets. In addition, coagulopathy after trauma is a known entity and plasma should be given as soon as possible with a 1:1 ratio of pRBC to begin damage control resuscitation.[8–13] Next, CWB would be given resulting in the patient getting another

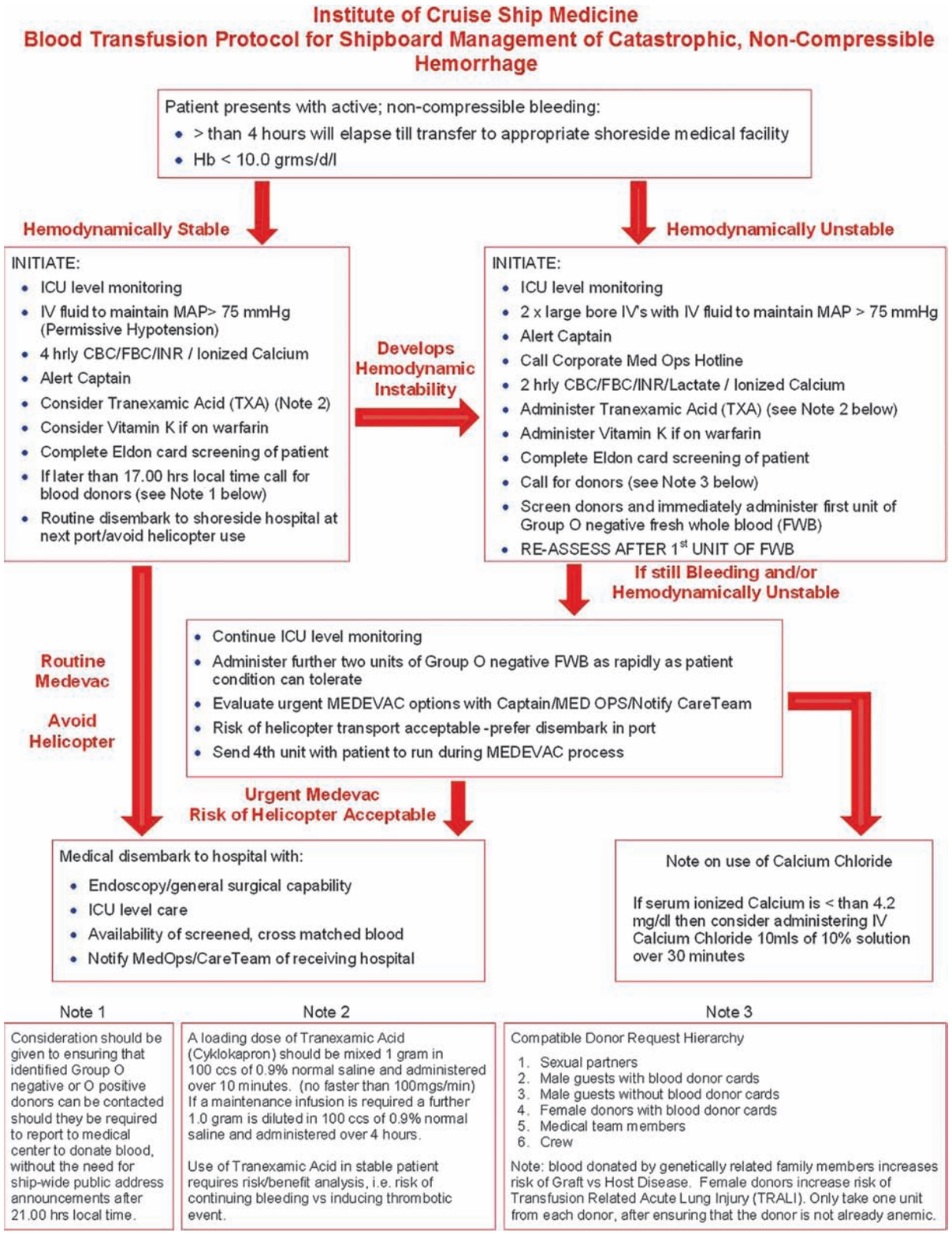

Figure 1. Institute of Cruise Ship Medicine Blood Transfusion Protocol for Shipboard Management of Catastrophic, Non-Compressible Hemorrhage.

- *Indications for haemorrhagic shock: Blood product administration is indicated for treatment of haemorrhagic shock. Blood products should be administered if an adult patient has 2 of the following after traumatic injury or other evidence of bleeding:*
  - *Hypotension (single reading of systolic blood pressure ≤ 90 mmHg)*
  - *Tachycardia (single reading of heart rate ≥ 90 mmHg)*
  - *Penetrating mechanism*
  - *Lactate ≥ 5mg/dL*
  - *INR ≥ 10.*
  - *Base deficit ≥ -5 mmol/L*
  - *$StO_2 \leq 70\%$*
- *Using clinical judgement, consider blood products for known large blood loss and/or decreasing hemoglobin/hematocrit.*

Figure 2. Indications for prehospital transfusion at Mayo Clinic.

1:1:1 ratio of pRBC/plasma/platelets. If additional blood products are needed, pRBC and plasma would be given to maintain a 1:1 ratio.[14–17] To date, we have transfused more than 1,000 units of universal group A plasma, 20 units of CSP (20 patients), and 25 units of CWB (XX patients).

To have proceeded with our RDCR practice, the blood transport coolers on the helicopters required validation for acceptable storage temperature (1–6°C) with these blood components. Technologists in the transfusion laboratory (TL) conducted cooler configuration tests to determine the best standardized method of packing the blood transport coolers. The products transported in the helicopter coolers (Credo Cooler; Pelican BioThermal Plymouth, MN). Previously, these coolers carried three units of group O negative RBC and three units of group A TP. The replacement of one unit of RBCs and one unit of TP with the CWB and CSP units resulted in a group of blood components with an increase in total volume to be stored in the cooler.

Because of the increased volume of blood components, with the current packing configuration, the top thermal isolation chamber panel, which is on the top of the cooler and is required for the maintenance of an acceptable storage temperature, did not sit "flush" in the storage container any more. Different packing configurations, therefore, had to be evaluated, and an alternative acceptable packing method was developed. Figures 3A and B demonstrate the most satisfactory cooler configuration, which will be adopted for blood component transport, is shown in these photographs: The packing of the cooler consists of two RBCs, one CWB, and one TP in a row, one TP on the side, and a flattened CSP on top with part of the bag tucked on the side with the TP. To date, this configuration has been shown to maintain storage temperature at 1°C to 6°C for 24 hours.

In addition to validating the length of time for which the appropriate temperature for the blood products is maintained in the transport coolers, platelet function testing will be performed on the CSP to ascertain whether function is maintained in the closed cooler storage environment. Platelet bag systems are designed to allow gas exchange between the bag contents and the external environment. These platelets will potentially be in a closed cooler environment with minimal gas exchange for up to 6 hours. Maintenance of platelet function under these conditions will be validated. The newly configured helicopter blood storage coolers are scheduled to begin to be carried on flights during the fourth quarter of 2016. This will then bring CWB and CSP to the prehospital environment and further advance RDCR capabilities in trauma care.

With regard to blood product rotation, the helipad blood storage refrigerator will be continuously monitored by the TL electronically, and TL personnel will physically check on the products at the helipad at least three times daily. CWB units that only have 24 hours or less of storage time before product expiration will be returned to the TL to assure control of it when the expiration time is reached. This will mitigate the risk of taking an expired CWB unit on a helicopter flight. The blood product rotation scheme for CSP will be determined after all validation studies have been completed.

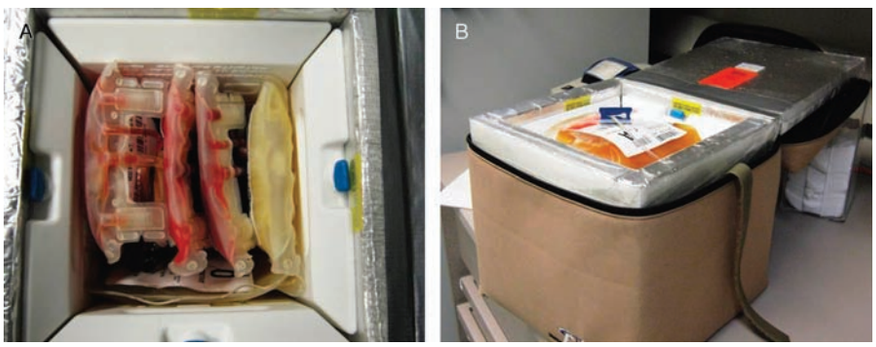

Figure 3. A and B, Optimal blood product configuration for blood product transportion.

CWB AND CSP AT MAYO CLINIC

The in-hospital CWB protocol for trauma patients at our facility has been previously described.[18] The goal is to collect two low-titer (immediate spin anti-A and anti-B titers < 200) group O CWB units from male donors every week and maintain a CWB inventory of 2 O negative and 2 O positive units in the TL. CWB transfusions began in November 2015. From November 2015 through August 2016, 76 CWB units were collected, 66 units were placed into transfusable inventory, 10 were not used due to high anti-A or anti-B isoagglutinin titers, 25 units (25 [38%] of 66 transfusion rate) have been transfused, and 41 units expired during storage (41 [62%] of 66 wastage rate). There have been no changes in Transfusion Medicine's CWB procedure since the November go-live date. One process that was adopted after the implementation of CWB was the addition of a laminated whole-blood "fact" card that is added to each CWB unit. This card is also attached to the front of the shelf in the blood storage refrigerator that holds the CWB units. This card was created to help the TL technologists understand that the intended transfusion population for CWB is trauma service patients who are at least 18 years of age and weigh more than 40 kg. A challenge for the TL since implementation is that most CWB units are initially ordered verbally and the follow-up documentation of such orders through the electronic or paper order systems often lags behind—sometime months behind.

With regard to CSP, on March 27, 2015, the US Food and Drug Administration approved our facility's use of an alternative procedure to store apheresis platelets collected using the TerumoBCT Trima Accel automated blood collection system at refrigerator temperature (1–6°C) without agitation for up to 3 days for the use in the resuscitation of actively bleeding patients. Bacterial testing of CSP would not be performed. The Food and Drug Administration approval to store apheresis platelets at 1°C to 6°C enabled our facility to successfully request a variance from standards 5.1.5.1 and 5.1.8A of Standards for Blood Banks and Transfusion Services, 29th edition, from the AABB's Blood Banks/Transfusion Services Standards Program Unit.[19] On October 8, 2015, our facility was notified by the Blood Banks/Transfusion Services Standards Program Unit that the variance request was granted. The AABB variance applied only to apheresis platelets collected using the TerumoBCT Trima Accel® automated blood collection system and limited the use of CSP to the resuscitation of actively bleeding trauma patients. The CSP "may be stored for a maximum of 3 days at 1°C to 6°C without agitation." They "shall not" be released to the general transfusable inventory. The major challenge associated with the CSP program is product wastage. This is a twofold problem. First, the 3-day storage period is a very tight window, especially since this 3-day period is compromised on the front-end because units must be quarantined until donor infectious disease testing is performed and yields acceptable results. This consumes approximately 12 hours to 18 hours of the 3-day period. Therefore, the actual transfusable time for CSP is a little over 2 days. The end result results is a large outdate rate for CSPs. The second problem is clotted units. Plasma-rich platelets stored in a refrigerator have a tendency to form clots, which is not surprising given that the platelets are in an environment rich in fibrinogen. Group A CSP were initially made available for the transfusion of Trauma patients in October 2015. The goal is to collect three CSP per week. Between October 2015 and the end of August 2016, a total of 119 CSP were collected by a blood donor center. Nine (7.6%) of 119 units were discarded before distribution into the TL inventory (five definitively had clots and four were clots versus lipemia). One hundred ten CSP were shipped and placed into inventory in the TL, and 21 (19.1%) of 110 were transfused to 20 patients. Eighty-nine (80.9%) were discarded. Twenty (18.2%) developed clots during storage and were discarded. Sixty-five (59.1%) expired during storage in the TL without being issued and were discarded. One (0.9%) unit was returned after issue and was discarded due to expiration. One (0.9%) unit was stopped due to a suspected transfusion reaction, and two (1.8%) units were discarded because they were transported via the pneumatic tube system before validation of the tube system for CSP transport. There have been no changes to the CSP process since implementation.

THE PITTSBURGH EXPERIENCE WITH CWB

CWB could be the ideal trauma resuscitation fluid because it is less dilute than reconstituted whole blood and contains CSP, which have been shown to be more hemostatically active than warm stored platelets (PLT) in in vitro and human tests.[20,21] It is also more convenient for emergency responders to carry CWB as opposed to blood components because CWB comes in one bag, and it can be stored under conditions that already exist for transporting pRBCs to the site of injury. Because CWB contains pRBCs, it must be group O when used for the emergent resuscitation of trauma patients whose blood groups are unknown (such as at the scene of injury or as soon as the patient arrives in the emergency department). However, group O CWB also contains anti-A and anti-B in the plasma component that can cause clinically significant hemolysis if transfused to non–group O recipients. Thus, steps should be taken to mitigate this risk, such as by providing low titer CWB for use in trauma patients.

At Allegheny General Hospital, a Level 1 trauma hospital in southwestern Pennsylvania, CWB has been used in the resuscitation of trauma patients since April 2016. Building on our successful use of CWB at another local Level 1 trauma center,[14] the following describes the protocol for using CWB: any male who is hypotensive from traumatic bleeding is eligible to receive up to four units of CWB in their initial resuscitation in the emergency department and/or in the operating room. The units of CWB are collected as described previously using the Terumo Imuflex-SP whole-blood collection system,[14] which features an in-line leukocyte reduction filter. The CWB units are collected exclusively from group O–positive male donors to comply with transfusion-related acute lung injury risk mitigation requirements, and the anti-A and anti-B titers of each donor are determined upon each donation. If both antibody titers are less than 50, the CWB unit can be issued for transfusion. If either or both are more than 50, the units are immediately processed into pRBC concentrates for general use. The CWB units are maintained as such for 15 days, and if they are not used, they are returned to the transfusion service where they are processed into pRBC units and the platelet-rich plasma is discarded. Currently, two CWB units are kept in the emergency department

TABLE 2. Demographics of Patient Who Received Whole Blood

Mechanism of Injury	
Blunt	13/22 (59%)
MVC	11/13 (85)
MVC vs pedestrian	1/13 (7.5%)
Fall	1/13 (7.5%)
Penetrating	7/22 (41%)
GSW	5/7 (71%)
SW	2/7 (29%)
Hemorrhage control	
Patients requiring immediate invasive procedures	19/22 (86%)
Location of procedures	
ED	5/19 (26%)
OR	11/19 (59%)
Interventional radiology	3/19 (16%)
Mortality	
Overall	7/22 (31%)
Hemorrhage	3/22 (13%)
TBI	4/22 (18%)

MVC, motor vehicle crash; GSW, gunshot wound; SW, stab wound; ED, emergency department; OR, operating room; TBI, traumatic brain injury.

blood refrigerator for immediate use, and two more CWB units are stored in the blood bank, which are available for use as part of the initial massive transfusion protocol. The clinical team can transfuse up to four units of CWB per trauma patient. After transfusion of CWB, the resuscitation is guided by thromboelastography and clinical evidence of coagulopathy.

Through the end of August 2016, a total of 22 trauma patients have received CWB during their initial resuscitation. The demographics of these patients are listed in Table 2. Blunt injury was the predominant mechanism of injury secondary to motor vehicle crashes whereas gunshot wounds accounted for the majority of the penetrating trauma. Immediate invasive procedures for the direct control of hemorrhage were required in 86% of the patients with the majority occurring in the operating room. Overall mortality was 31%. Hemorrhage-related mortality was 13%, and traumatic brain injury-related mortality was 18% with two of these patients becoming organ donors after being declared brain dead.

The CWB recipients were further stratified by their ABO blood group into group O versus non–group O to evaluate the potential risk of hemolysis (Table 3). One patient died before an ABO group could be obtained and was therefore excluded from this analysis. Group O CWB recipients cannot hemolyse after receipt of group O CWB; however, non–group O recipients might be at risk of hemolysis although this risk is expected to be low due to the extent of their bleeding and the low maximum titer of the antibodies in the CWB. There was no significant difference in the age of the recipients between these two groups. In terms of blood product receipt during the first 24 hours of admission, the median number of CWB units transfused to these two groups of patients also did not differ significantly. There was a trend toward more cryoprecipitate units transfused to the group O recipients but this likely reflects the overall small number of CWB recipients rather than an advantage of being a group O recipient. The small sample size also likely explains the higher median number of CSP units transfused to the group O recipients as well. Overall, there was no difference between these two groups in terms of the percentage of recipients who received additional blood products after the CWB was transfused during their first

TABLE 3. Demographic and 24-Hour Transfusion Parameters Between the Non–Group O and Group O WB Recipients

	Non–Group O WB Recipients	**Group O WB Recipients**	***P***
No. recipients	15	6	
Caucasian, n (% of recipients of known ethnicity)	10/12 (83%)	4/6 (67%)	0.57
Age: median (25%–75%), y*	41.3 (28.8–56.8)	37.9 (23.1–53.8)	0.63
Haptoglobin level, mean (SD)	82.7 (48.5)	50.6 (16.6)	0.36
No. patients who received products other than WB in first 24 h, n (%)			0.43
Plasma	9 (60)	3 (50)	
Platelets	5 (33.3)	3 (50)	
RBC	13 (86.7)	4 (66.7)	
Cryoprecipitate	2 (12.3)	3 (50)	
Total number of units transfused in first 24 h, median (25%–75%)			
WB	2 (1–2)	2.5 (1–3.75)	0.25
Plasma	6 (1–17)	9 (1–21)	0.89
Platelets (whole-blood PLT units)	2 (1–7)	5.5 (1–13.25)	0.6
RBC	5 (3–9)	6.5 (2.5–17)	0.89
Cryoprecipitate (whole-blood derived units)	2 (1–2)	4 (2.5–10)	0.051
Volume of ABO incompatible plasma: median (25%–75%), mL	600 (300–600)	N/A	
Plasma/RBC ratio, mean (SD)	1.21 (0.63)	1.14 (0.64)	0.83
Platelet/RBC ratio, mean (SD)	0.67 (0.34)	0.84 (0.46)	0.5

Note that the PLT and cryoprecipitate units are expressed as whole blood units, not doses (e.g., there might be four whole-blood PLTs in a dose). Each unit of WB was considered to have contributed one unit each of RBC, plasma, PLT, and cryoprecipitate for the purposes of calculating the total number of units transfused in the patient's first 24 hours in the hospital.

*Age unknown for two non–group O and one group O recipient.

24 hours in the hospital ($p = 0.43$). For example, only 33.3% of the non–group O patients received CSPs and only 12.3% received cryoprecipitate.

The non–group O patients received a median of 600 mL of incompatible plasma (from the CWB and from PLT transfusions) during their first 24 hours in the hospital. This fact, taken together with the similar number of pRBC transfusions administered to the group O and non–group O CWB patients after their initial resuscitation with CWB was encouraging because it suggests that the non-O recipients were not experiencing hemolysis from the incompatible plasma in the CWB units. Additionally, the haptoglobin (a marker of hemolysis with a low value suggesting hemolysis was occurring) values were not significantly different between the two groups. The average 24-hour plasma/pRBC ratios did not differ between the groups, in fact the mean values were both greater than 1. Similarly, there was no difference between the two groups with respect to the 24-hour PLT/RBC ratios, although both were less than 1. This was not unexpected given the relatively small number of patients who received additional PLT doses after the CWB was transfused.

The initial use of CWB at this Level 1 trauma center compares similarly to our previous report with no laboratory evidence of hemolysis among the non-O CWB recipients.[21] More clinical and biochemical data on more recipients will be required to confirm this initial finding, as well as the potential for CWB transfusion to reduce the overall volume of blood products required during the initial resuscitation. Future directions for the use of CWB include making it available for use in the prehospital setting for trauma patients who are being transported in a helicopter or by ambulance to the hospital.

BLOOD PRODUCTS USE IN THE PREHOSPITAL ARENA IN ISRAEL

The Israel Defence Forces Medical Corps (IDF-MC) has been using blood to resuscitate trauma casualties for decades. The IDF does not operate a military blood bank and blood products supplied by the Magen David Adom (MDA) National (civilian) Blood Services are used to support operational scenarios—spanning from special operations to full-blown wars.[22] Indeed, there are historic indications that plasma may have been transfused to the defenders of Beit-Haarava, a kibbutz under siege by Jordanian forces during the independence war in 1949 and that whole blood units were dropped in special containers to the paratroopers in Sinai during the 1956 Suez Crisis (the drop was unsuccessful as the containers broke).[23] A- and O-positive pRBCs were used during the raid on Entebbe, Uganda.

Since the 1970s, medical platoons (forward resuscitation companies and surgical teams) have been equipped with O-positive pRBC and have transfused severely injured casualties in several scenarios, including during humanitarian missions.[24]

Generally speaking, warm WFWB is not used in the IDF, other than anecdotally in the 1973 Yom Kippur war, where a surgeon, who used to work in a hospital blood bank during his medical studies, while deployed in a forward evacuation hospital in Sinai, collected three units from his medics and transfused them to two severely wounded soldiers, who went on to survive the war.[24] Similar heroic actions were performed during humanitarian missions, such as in Haiti and the Philippines. However, in preparations for a prospective use (for example, specific special operations), team members were tested by the National Blood Services for blood type, pRBC antibodies screen, and transfusion-transmitted diseases to serve as potential donors. In addition, a group medic was trained in proper collection of blood, and the needed blood collection bags were provided.[25] As said, this was not actually used under combat scenarios and abandoned for the sake of O-positive pRBC (carried in GHB) and FDP.

O-positive pRBC have also been carried by the aerial evacuation unit (designated 669) for the last 30 years. This military unit is supplied by the National MDA Blood Services. Special standard operating procedures are in place to ensure proper storage before and during evacuation. The current usage is a few dozens of units/year.[26]

Since 2011, the IDF has deployed FDP as the resuscitation fluid of choice for the physicians and paramedics. FDP is, of course, also carried by units carrying pRBC (including medical platoons and special forces) and is used on a regular basis.[27] The Israeli civilian emergency medical services did not use blood products for prehospital resuscitations until recently, when FDP was introduced by for the treatment of shock in patients suspected to be bleeding and an evacuation time that is expected to exceed 30 minutes.

CONCLUSION

THOR is a rapidly growing society which promotes best practices in hemorrage resuscitation with an emphasis on RDCR for military and civilian practice. The current state of the art in RDCR focuses on providing the novel blood products, including CWB, to the field. In addition, novel storage methods, such as cold platelets and FDP, are becoming increasingly available as data emerges to their efficacy. As the THOR group has grown, each meeting has matured in content and fellowship. We antcipate the upcoming meeting in 2017 will continue this trend.

DISCLOSURE

The authors declare no conflicts of interest.

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