Operationalizing the Deployment of Low-Titer O-Positive Whole Blood Within a Regional Trauma System

LTC Randall Schaefer, AN, USA, (Ret.)*; Tasia Long, MHS*; David Wampler, PhD, FAEMS†; Rena Summers, BA*; Eric Epley, NREMT-P*; Elizabeth Waltman, MBA‡; COL Brian Eastridge, MC, USAR†; Col Donald Jenkins, USAF, MC, (Ret.)†

**ABSTRACT**

**Introduction:**
The implementation of a low-titer O+ whole blood (LTOWB) resuscitation algorithm, particularly in the prehospital environment, has several inherent challenges, including cost, limited and inconsistent supply, and the logistics of cold-chain management. The Southwest Texas Regional Advisory Council has implemented the nation’s first multidisciplinary, multi-institutional regional LTOWB program. This research effort was to illustrate the successful deployment of LTOWB within a regional trauma system.

**Materials and Methods:**
A deliberate systems approach to the deployment of LTOWB was used. Tenets of this program included the active management of blood donor sources and blood supply levels to minimize wastage as a result of expiration, maximize product utilization, the use of prehospital transfusion triggers, and efforts to decrease program costs prehospital agencies. A novel LTOWB rotation system was established using the concept of a “rotation site” and “rotation center.” Standardized transfusion criteria, a regional approved equipment list, a regional Prehospital Blood Product Transfusion Record, and a robust multilevel communication plan serves as the framework for the program. The San Antonio Whole Blood Consortium was developed to create a consensus driven forum to manage and guide the program.

**Results:**
From January 2018 to October 2019, LTOWB has been placed at 18 helicopter emergency medical services (HEMS) bases, 12 ground emergency medical service (EMS) agencies, 1 level I trauma center, and 1 level IV trauma center. A total of 450 patients have received a prehospital LTOWB transfusion. Program wide, the wastage rate of LTOWB due to expiration is between 1% and 2%. No complications related to prehospital LTOWB administration have been identified.

**Discussion:**
This work demonstrates a novel model for the development of a trauma system LTOWB program. The program’s implementation augments remote damage control resuscitation strategies and requires the integration and collaboration of a multidisciplinary stakeholder team to optimize efficiency, performance, and safety of the program.

**INTRODUCTION**
The resurgence in the use of whole blood-based resuscitation across the continuum of care has captured the attention of trauma systems worldwide. The use of prehospital blood has been advanced by research findings from military combat operations in Operation Iraqi Freedom, Operation Enduring Freedom, Operation Inherent Resolve, and Operation Freedom’s Sentinel. Civilian research studies and analysis have identified the utility and indication for prehospital whole blood use. Initial efforts have primarily focused on placing blood products on helicopter emergency medical services (HEMS) platforms with an expanding interest in placing Low-Titer O-Positive Whole Blood (LTOWB) in ground ambulances.

Emergency medical services (EMS) are often the first entry point into the healthcare system when experiencing a life-threatening event. EMS have undergone a paradigm shift from a “scoop and run” system to a “stay and play” system to initiate lifesaving interventions at or near the point of injury. The existing capabilities of the emergency department (ED) are now extended beyond the hospital doors. The early use of LTOWB is emerging as an essential treatment modality to decrease morbidity and mortality associated with prehospital hemorrhage.

In collaboration with their regional blood providers, trauma systems have initiated efforts to determine the
appropriate methods to provide, utilize, and sustain this valuable resource for their patients within the context of their respective system infrastructures.\textsuperscript{2,10,14} The implementation of a LTOWB resuscitation algorithm, particularly in the prehospital environment, has several inherent challenges, including the cost of the blood and equipment, limited and inconsistent donor supply, and the logistics of cold chain management. Current efforts to expand LTOWB into the field as part of a remote damage control resuscitation strategy acknowledge the inherent challenge of assuming a high discard rate attributable to expiration when the blood is not used. Unlike their hospital counterparts, many EMS agencies cannot currently do line-item billing to recoup the cost of transfused blood. Blood production suppliers directly charge the agency for both used and unused blood. The agencies absorbing the cost of discarded blood every 21 days is also of concern.\textsuperscript{11} A prehospital blood program that addresses these concerns is important, especially for the smaller rural and frontier EMS systems.

Previous research efforts have focused on patient outcomes and not the associated costs, wastage rates, donor management, or the inclusion of a collaborative regional trauma system effort cultivating a consensus-driven forum to manage and guide a program. Using the identified elements, the purpose of this study is to illustrate the successful deployment of LTOWB within a regional trauma system.

**METHODS**

The University of Texas Health San Antonio Institutional Review Board reviewed the research and categorized it as nonhuman exempt research.

**Study Setting**

The Southwest Texas Regional Advisory Council (STRAC) is one of the 22 regional advisory councils in Texas that comprises the Texas Trauma and Emergency Healthcare System. STRAC is designated by the Texas Department of State Health Services to develop, implement, and maintain the regional trauma and emergency healthcare system for the 22 counties in Trauma Service Area-P. Trauma Service Area-P has a mixture of urban, suburban, rural, and frontier areas, including San Antonio, the seventh largest city in the United States. It extends to the Mexican border encompassing over 26,000 square miles of southwest Texas. Secondary to the characteristic geographic expanse of the region, transport to definitive surgical care can exceed 3 hours (Fig. 1). At the “hub” of the trauma system are two Level I trauma centers within San Antonio. The “spokes” of the trauma system include 3 urban level III trauma centers and 24 level IV critical access hospital facilities distributed across the region, which provide temporizing resuscitative care until transfer to a higher to trauma center care. Over 70 public and private ground EMS agencies support the regional trauma system. The largest of which is

![FIGURE 1. Southwest Texas Regional Advisory Council.](https://academic.oup.com/milmed/article/186/Supplement_1/391/6119408)
LTOWB Deployment Within a Regional Trauma System

The San Antonio Fire Department, which responds to approximately 160,000 9-1-1 calls per year. Within the region, there are 4 HEMS providers with 18 aircrafts.

Four-Phased Systematic Deployment Approach
The STRAC developed and implemented the nation’s first multidisciplinary, multi-institutional system wide LTOWB program. A four-phased approach was developed driven by the aspiration to increase the operational reach of remote damage control resuscitation through the use of LTOWB. The four deployment phases were to regional HEMS bases, a large metropolitan ground EMS agency, then suburban, rural, and frontier ground EMS agencies, and lastly, rural Level IV trauma centers.

The program capitalized on a robust and mature STRAC trauma system network architecture to incorporate whole blood transfusion capabilities into the regional EMS agencies and trauma centers’ resuscitation strategies. This plan allows for complete regional trauma system geographic coverage and prioritizes the LTOWB resource distribution to locations most likely to use it.

A regional whole blood stakeholder committee, also known as The San Antonio Whole Blood Consortium (SAWBC), was formed to guide and oversee the blood deployment strategy and the implementation and maintenance of the program (Fig. 2). The SAWBC comprises constituent regional air and ground EMS agencies, rural and urban trauma hospitals, the Southwest Texas Blood & Tissue Center (STBTC), and STRAC. Prehospital air and ground EMS participants included medics and nurses, administrators, medical directors, EMS supervisors, and operations staff.

The STBTC representation included operations, logistics, marketing, and medical director. Hospital participants included hospital administrators, trauma surgeons, emergency medicine physicians, hospital blood bank and lab personnel, trauma coordinators, and trauma registrars. The STRAC, as the regional trauma systems convener, provided research staff, and a medical communications (MEDCOM) and operations center that operate 24 hours daily. The STRAC MEDCOM has no association or affiliation with the United States Army Medical Command.

The genesis of the SAWBC arose from the necessity to cultivate a consensus-driven forum to manage and guide the program. The group is also charged with identifying areas of process improvement to optimize patient safety, improve resource efficiency, and advance the program’s goals. All organizations involved in the Regional Whole Blood program voluntarily committed to following the established guidelines and protocols through a memorandum of understanding that was signed by each organization’s leadership.

Low-Titer O-Positive Whole Blood Donor Sources, Processing, and Product Availability
The regional blood product supplier, using modified donor collection and testing protocols developed by the Army Blood Program, established and publicized a donor recruitment program called “Brothers in Arms” (BIA). The BIA program identifies men with a low anti-A/anti-B agglutination titer level of <1:256. The blood is processed with no leukocyte reduction and is collected in a bag containing the preservative citrate-phosphate-dextrose-adenine (CPD-A), which has a 35-day lifespan. The use of LTOWB containing CPD-A

FIGURE 2. Regional whole blood stakeholder committee.
mitigates prehospital concerns about logistical management and financial impact compared to programs that use component therapy (red blood cells, plasma, and platelets) or LTOWB with a 21-day lifecycle.

The regional blood program relies on the careful management of donors to maintain a constant and appropriate LTOWB supply level within a complex system often faced with unpredictable patient flow patterns. The availability of a steady state of BIA donors ultimately drives how fast and how wide the regional program can expand. Additionally, the number of units that a rotation center can manage in their inventory also impacts program growth. Consideration was also given to developing contingency plans to support the LTOWB supply at STBTC in the event of a mass casualty incident.

The SAWBC fostered a philosophy that LTOWB should be a capability that is consistently available at the point of injury, and crews can be rapidly restocked after an administration.

**Rotation System**

Low-Titer O-Positive Whole Blood management used the concept of a “rotation site” and “rotation center” (Fig. 3). A rotation site is defined as an EMS agency or trauma center with relatively low product utilization. Rotation sites were provided with 1 to 2 units of LTOWB. They receive the LTOWB during the first 14 days of its 35-day lifecycle. A rotation center, a trauma center with higher utilization rates of blood, receives LTOWB from the rotation sites for days 14 to 35.

Blood issued to the rotation site has return privileges to STBTC. The return privileges of a blood product are a practice already found within the blood production industry; this is merely extending that same philosophy outside of the hospital setting. If the product is not used and stays within transport temperature guidelines, it is returned to STBTC, inspected, and then reissued to a rotation center. If a rotation site uses the product or does not maintain the temperature requirements, they are charged for that unit of blood. In contrast, a rotation center does not have return privileges to STBTC. Blood is either transfused or expires at the rotation center.

This process has multiple benefits, including keeping costs down for EMS agencies since they are currently unable to charge patients for LTOWB transfusion as an intervention consistently. The rotation center has a higher likelihood of utilizing LTOWB as part of an enhanced resuscitation strategy and, as such, supports the entire system of care, from the point of injury until arrival at definitive care, thereby making LTOWB feasible in the prehospital setting.

**Regionally Approved Equipment List**

The vision of a program is to keep the highest standards and promote interoperability within the region to include the equipment used. To maintain program integrity, all equipment must be Food and Drug Administration approved. A list of required equipment has been established to include a validated transportable blood cooler, continuous temperature monitoring devices in the cooler, and blood warmers.

The selected blood cooler (Credo Promed Series, Pelican BioThermal, Plymouth, MN) was similar to those used by the military in their prehospital blood program (Golden Hour, Medic Thermal Blood Transfer Container, Pelican BioThermal, Plymouth, MN). The cooler underwent extensive independent testing to ensure it could withstand the high temperatures found in South Texas during the summer and not unintentionally raise to a temperature too high or drop the temperature below the recommended ranges.

Rotation sites are required to use a continuous temperature monitoring device inside the blood cooler to monitor for temperature changes closely.

In addition to a commercially available continuous temperature monitoring device, STBTC opted to place a non-reversible, American Association of Blood Bankers compliant, Safe-T-Vue 10, (Temptime Corporation, Morris Plains, NJ) on the blood bag to offer another verification method that the blood has stayed in the correct temperature ranges from processing until the final disposition at the rotation center. Using one make and model of a blood cooler and continuous temperature monitoring offers assurances and data to STBTC, rotation sites, and rotation centers that the blood is being appropriately managed while in the prehospital setting.

The use of standardized equipment allows for agencies to better support the patient when moving through the continuum of care, or in cases where interagency mutual aid and assistance is being rendered, or in the event of a mass casualty
FIGURE 3. Regional rotation guideline.
incident requiring multiple agencies to respond with LTOWB to the scene.

**Regional Prehospital Clinical Documentation and Patient Safety**

Although the use of an electronic healthcare record (EHR) has tremendous value, it does not provide a real-time communication tool between prehospital agencies and receiving facilities that are not on the same system. There are at least six different EHR platforms in use in the regional prehospital system and none that actively connect or communicate with the county or military Level I trauma centers or other area hospital’s EHR. A low technology communication tool using tripclicate/carbon-less copy paper was developed. The Prehospital Blood Product Transfusion Record was adopted and implemented to facilitate real-time communication between the transporting agency, receiving ED/trauma team, and the receiving hospital blood bank/transfusion services (Fig. 4).

The SAWBC members recognized the importance of ensuring the receiving hospital’s transfusion service was made aware of the use of uncrossed unmatched whole blood. The top copy of the Prehospital Blood Product Transfusion Record stays with the transporting agency. The second copy is given to the receiving hospital ED/trauma team. The third copy is sent by the ED/trauma team to the hospital transfusion services/blood bank. In addition to the Prehospital Blood Product Transfusion Record, the transporting crew leaves the empty blood bag with segments intact. The receiving hospital transfusion service has the opportunity to perform post-transfusion compatibility testing and document the blood unit identification number in the patient’s hospital record. After the Prehospital Blood Product Transfusion Record is completed, it is sent to STRAC MEDCOM where it is entered into a Health Insurance Portability and Accountability Act compliant whole blood database for regional process improvement and research.

**Communication**

When devising a systematic deployment of any capability, effective and timely communication is essential. The regional whole blood program developed several layers of communication. At the regional level, all participants meet quarterly as a multi-institutional, multidisciplinary group to track usage, discuss process improvement, update research studies, and offer a presentation relevant to LTOWB implementation such as perinatal use of LTOWB. LTOWB was placed on two medical special operations units (MSOU) covering 24 hours a day, 7 days a week. The MSOU, in addition to 9-1-1 responses, have a mission to assist authorities during high operational tempo events, have a mission to assist authorities during high operational tempo events. The MSOU, in addition to 9-1-1 responses, have a mission to assist authorities during high operational tempo events.

**RESULTS**

The regional deployment of LTOWB to the frontier, rural, and urban HEMS bases began in January 2018 and was completed in August 2018. Eighteen helicopters, from four different air medical companies, carried two units of LTOWB on-board. Since the initial rollout, several air medical companies closed bases and redistributed their assets for a current total of 11 HEMS bases in the region.

The Bexar County Level I trauma center (University Hospital) served as the first rotation center and began receiving the rotating units 14 days after the HEMS deployment. Brooke Army Medical Center (BAMC), the military Level I trauma center, began using LTOWB in September 2017. As a result of logistical and contract constraints, as well as receiving its blood supply directly from the Armed Forces Blood Program, BAMC is not able to participate as a regional rotation center.

After the completion of the HEMS bases, a system-wide expansion began in October 2018, starting with a large metropolitan ground EMS agency. Covering a city of 1.5 million people with 55 ambulances on-duty at any given time, the ability for individual ambulances to carry LTOWB was not feasible or sustainable because of concerns regarding unnecessary waste as a result of expiration and placing a strenuous demand on the donor supply. Providing one agency with 55 units would likely preclude or severely limit the ability to support future LTOWB placement to rural and frontier EMS agencies throughout the region.

To best support the metropolitan EMS system, one unit of LTOWB was placed on two medical special operations units (MSOU) ambulances and six Medical Officers’ (MOF) supervisor vehicles. The MOFs are senior paramedics with many years of experience and cover 6 zones in the metropolitan area 24 hours a day, 7 days a week. The MSOU, in addition to 9-1-1 responses, has a mission to assist authorities during
## FIGURE 4. Regional Prehospital Blood Product Transfusion Record.

![Image of Prehospital Blood Product Transfusion Record](https://example.com/image.png)

### Prehospital Blood Product Transfusion Record

<table>
<thead>
<tr>
<th>Patient Name:</th>
<th>Transporting Agency Run / Case #:</th>
<th>Receiving Facility Medical Record #:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Product Unit Number (Affix sticker below, or write unit number)</th>
<th>Product Type (Check One)</th>
<th>Transfusion Date &amp; Start Time</th>
<th>Transfusion Complete* (Check One)</th>
<th>Transfusion Reaction** (Check One)</th>
<th>Transporting Medic/RN Initials</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Affix Sticker Here or Write Unit #</td>
<td>PRBC Plasma LTOWB</td>
<td></td>
<td>Yes Ongoing</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>2. Affix Sticker Here orWrite Unit #</td>
<td>PRBC Plasma LTOWB</td>
<td></td>
<td>Yes Ongoing</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>3. Affix Sticker Here or Write Unit #</td>
<td>PRBC Plasma LTOWB</td>
<td></td>
<td>Yes Ongoing</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>4. Affix Sticker Here or Write Unit #</td>
<td>PRBC Plasma LTOWB</td>
<td></td>
<td>Yes Ongoing</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Name of Air Medical or Ground Agency:  
- Receiving Facility (Check One):  
  - University Hospital  
  - Brooke Army Med Center  
  - Other: ________________  

Type of Call (Check One):  
- Scene Call  
- Interfacility Transfer

Aircraft ID / Medic Unit #:  
Comments: ________________

*If blood product transfusion is ongoing at time of patient transfer to hospital, document “Ongoing.”*  
**Document actions taken in ‘Comments’ Section at the time of patient drop-off at receiving hospital.**

### Mandatory Blood Product & Blood Form Tracking:

Transporting crew keep **White Copy**; give the yellow and pink copies AND the blood bag to the Emergency/Trama Team.

Emergency Department keep **Yellow Copy**; give the Pink Copy AND the blood bag to the Blood Bank/Transfusion Services.

Blood Bag & Form given to: __________________________ PRINTED NAME
_________________________ SIGNATURE

Actions to take for suspected transfusion reaction:  
- STOP TRANSFUSION
- Disconnect tubing from infusion site; flush site with normal saline
- Keep line open with normal saline
- Re-initiate new transfusion if deemed clinically essential
- Document actions taken in ‘Comments’ section

Transferring Crew: Please send a copy to MEDCOM via text image (210) 417-7016, or email MEDCOM@strac.org or FAX: (210) 233-5825

Version July 2019; FINAL
high-risk tactical scenarios. The MOF and MSOU are dispatched through 9-1-1 to predefined calls and scenarios likely requiring LTOWB. Agencies have modified 9-1-1 dispatch protocols to ensure the MOFs and MSOU arrive on-scene as early as possible to assist EMS units as needed.

Since January 2019, an additional 12 suburban, rural, and frontier ground EMS agencies have been added. Ground EMS vehicles each carry one unit of LTOWB.

One rural Level IV facility was an early adopter and brought LTOWB into their facility when they realized the clinical and fiscal benefits. Before LTOWB, the hospital only maintained a small stock of frozen plasma and no platelets. Often plasma was not used in the resuscitation strategy because of the time it takes to thaw. The thaw time exceeds the hospital’s timelines’ ability to get the patient moved to a higher level of care through local air transport (which all carry LTOWB). Low-Titer O-Positive Whole Blood has been used twice at the facility—both times for patients experiencing nontrauma-related major hemorrhage, one for a gastrointestinal bleed, and the other an esophageal varix rupture during a routine outpatient esophagogastroduodenoscopy. Both patients were hemodynamically stabilized and transported to a higher level of care for further management.

A reliable and loyal donor source is maintained through the BIA program. To date, there have been a total of 3,591 men screened for eligibility. Seventy-five percent (n = 2,748) are eligible for participation in BIA. Over 18 months, 1,286 have been consistently donating on an average of every 2 months. The average “show-rate” of a BIA donor is 80%, higher than the normal donor show-rate of 60%. The donors are managed through traditional scheduling, walk-in, or, during periods of high operational use, STBTC directly contacts them for assistance. BIA donors are not financially compensated for their donations. STBTC has developed a unique model to recruit and retain donors through active social media platforms and special events that bring together donors, first responders, and recipients of prehospital LTOWB. Once a year, donors can meet and interact with the crews and their platforms (air and ground) that carry the donated blood. This event has garnered the interest of the public-at-large to include city and county elected leaders. It is a unique opportunity to demonstrate to the BIA donors that their donated blood is appreciated and makes a direct impact on their community. The HEMS aircraft and ground ambulances they see in their community are carrying their gift of life.

STBTC developed a novel resupply process for prehospital crews. After delivering the patient to the hospital, the ground agencies go directly to the STBTC Operations and Processing area and pick up a new unit of LTOWB to minimize downtime and quickly get the crews back into service. STBTC has committed to keeping a designated par level on the shelves to meet this operational need. Resupply is available 24 hours a day, 7 days a week, 365 days a year. For aircrews, when they are bringing a patient to a facility, they contact STRAC MEDCOM during the inbound flight to assist with coordination with STBTC for resupply. The LTOWB is ready after the crew hands-off patient care to the receiving hospital. STBTC sends a courier to the receiving hospital (if a helipad is available) or coordinates to meet the helicopter crew at another nearby location for resupply. This process allows for the crews to procure a resupply and head back to base fully stocked. For rural or frontier ground agencies that do not come into San Antonio, STBTC dispatches a courier to deliver the LTOWB.

To date, over 425 patients have received prehospital LTOWB. Trauma, medical, and postsurgical hemorrhaging patients have received LTOWB with no reported transfusion-related complications. Pediatric patients, women of childbearing age, and pregnant women have received prehospital LTOWB for hemorrhagic shock. With a commitment to regional process improvement, the 11 receiving hospitals provide feedback and outcomes for patients.

Program wide, LTOWB wastage due to expiration is 1% to 2% per month. This has been achieved by the deliberate management of the blood par levels and the expansion of LTOWB usage to include pediatric, medical, and perinatal patients in the rotation center.

Over 1,500 units of LTOWB have been delivered to the prehospital agencies since January 2018, with only one single unit falling outside of the temperature guidelines because of the unintentional freezing of the product.

LIMITATIONS

We leveraged a highly functional and robust regional trauma system when developing the LTOWB program for Southwest Texas. There may be factors that would require customization to make it generalizable to other jurisdictions and geographical regions. One consideration is that Texas is a delegated practice state that provides the EMS medical director with authority to utilize this therapy in the prehospital environment. In the United States, some states have scope of practice laws that may limit the initiation of LTOWB or blood products by paramedics. As a result of the Southwest Texas experience, regions of the country like Northeast Georgia have successfully lobbied for ground ambulances to carry blood. Another advantage was the STRAC infrastructure to operate as the central point for system quality assurance, data flow, and logistics. If a state or region lacks a robust trauma system infrastructure, this program may not be easy to replicate.

CONCLUSION

This work demonstrates a novel civilian model for the development of a trauma system LTOWB program. Implementation and sustainment of the program, augmenting remote damage control resuscitation strategies, requires the integration and collaboration of a multidisciplinary stakeholder team to optimize efficiency, performance, and safety of the program. The SAWBC has shared all processes and outcome information with numerous interested organizations to facilitate
the development of other LTOWB programs in their catchment area to decrease mortality and morbidity associated with hemorrhage.

ACKNOWLEDGMENTS

We thank the Southwest Texas Regional Advisory Council (STRAC), the San Antonio Whole Blood Consortium hospitals (University Hospital, Brooke Army Medical Center, Frio Regional Medical Center), and EMS agencies (San Antonio Fire Department, Air Methods, Air Evac Lifeteam, Wilson County ESD 3, Karnes County, Canyon Lake, Bandera, Bulverde-Spring Branch, Bexar County ESD 2 & 7, New Braunfels, La Salle County, Schertz, and Acadian Ambulance). I have obtained written permission from all persons named in the Acknowledgement.

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REFERENCES