Army Air Ambulance Blood Product Program in the Combat Zone and Challenges to Best Practices

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BACKGROUND: Identify challenges and best practices in the development of an austere air ambulance transfusion program.

METHODS: A search of PubMed using combinations of the key terms 'prehospital,' 'blood product,' 'red blood cells,' 'damage control resuscitation,' 'transfusion,' 'air ambulance,' 'medical evacuation,' and 'medevac' yielded 196 articles for further analysis, with 14 articles suitable for addressing the background of prehospital transfusion within a helicopter. Retrospective analysis of unclassified briefs, after action reports, and procedures was also undertaken along with interview of subject matter experts. The initial series of 15 transfusions were discussed telephonically among flight crew, trauma surgeons, and lab specialists. Review of Joint Theater System data was readily available for 84 U.S. Army air ambulance transfusions between May-December 2012, with December marking the redeployment of the 25th Combat Aviation Brigade.

RESULTS: Standardized implementation enabled safe blood product administration for 84 causalities from May-December 2012 without blood product shortage, expiration, or transfusion reaction. Challenges included developing transfusion competency, achieving high quality blood support, countering the potential for anti-U.S. sentiment, and diversity in coalition transfusion practices.

DISCUSSION: Blood product administration aboard the air ambulance is logistically complex, requiring blood bank integration. Repetitive training enabled emergency medical technicians (EMTs) with basic medical training to safely perform transfusion in accordance with clinical operating guidelines. In the austere environment, logistic factors are significant challenges and political sensitivities are important considerations. Best practices may facilitate new en route transfusion programs.

KEYWORDS: blood, transfusion, medevac, pre-hospital, resuscitation.

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Immediate medical care and rapid transportation to a surgical facility are key to survival in austere settings.[9] Military leaders are aware that resuscitation capabilities of medical evacuation helicopters are just as critical as the evacuation time (BG Frank W. Tate, Pentagon G8; personal communication; October 10, 2012). The use of en-route blood products can be lifesaving and has been safely delivered by medics since WWII.[8] Transfusion in helicopters did not routinely occur until after the advent of Golden Hour® Container technology in 2004.[3,7,12] Transfusion capability of medical evacuation helicopters is associated with improved hemodynamic outcomes in critically injured casualties.[1,2,10] The UK's Medical Emergency Response Team, established in 2012, was composed of four advanced medical providers who administered multiple units of blood products in conjunction with other advanced procedures.[2] Two advanced medical providers from Air Force Special Operations Command (AFSOC) worked as a pair to conduct transfusions.[2] Both these evacuation teams were co-located with combat support hospitals in Afghanistan.[9] U.S. Army flight medics, often operating alone in austere areas with limited medical certification, began transfusing after significant initiatives. Using a clinical operating guideline, U.S. Army flight medics safely transfused 84 severely wounded causalities from

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May-December 2012 without medical evacuation (medevac)-related wastage or spoilage of blood products. Understanding the experiences, challenges, and cost benefit of air ambulance transfusion will enable decision makers to field this service under appropriate conditions.

METHODS

This analysis is a literature review of published literature and unpublished sources; it was reviewed by the Joint Combat Casualty Research Team review board and determined to be exempt from IRB review. Challenges and strategies were ascertained through unclassified information/decision briefs, after action reports, and training/implementation standard operating procedures. As transfusions took place, outcomes, including the presence of any complications or logistical hurdles, were reported to higher command levels. After action reports were generated on the conclusion of each of the first 15 transfusions. These after action reviews were conducted telephonically among flight medics, pilots, trauma surgeons, laboratory specialists, and flight surgeons in order to ascertain best practices and any complications surrounding the transfusion process itself. Interviews with subject matter experts involved in these prehospital transfusions further collaborated logistical challenges, best practices, and potential barriers toward implementation at new locations. Background information surrounding prehospital transfusion was obtained through an extensive Pub Med review of the forward damage control resuscitation and air ambulance literature. Search words included 'prehospital,' 'blood product,' 'red blood cells,' 'damage control resuscitation,' 'transfusion,' 'air ambulance,' 'medical evacuation,' and 'medevac.' Of 196 articles founds using combinations of these search terms, 14 were pertinent to prehospital transfusion aboard helicopters. The Clinical Operating Guidelines (COGs) referenced throughout the manuscript reflect the transfusion indications for 82% of the casualties, with an update of indications, including presence of proximal amputation added after the first series of 15 transfusions. There were 84 total transfused causalities identified for the time in which the assigned medevac units were deployed to the combat zone.

RESULTS

From May-December 2012, 84 casualties were transfused without blood product shortage, expiration, or transfusion reaction. Transfusions occurred in a minority of all U.S. Army helicopter evacuations, likely in part due to short evacuation times with an average evacuation time less than 1 h in well over 95% of all evacuations. Despite the relative infrequency of transfusion, this practice affords important presurgical resuscitation for severely injured causalities. The first challenge of initiating a new program was gaining leadership support. Briefs outlining the air ambulance transfusion program were presented to theater leadership for approval at multiple levels. Importantly, ongoing performance improvement and monitoring of the program was built into the program. Transfusion training, clinical operating guidelines, and logistic and political considerations are important issues. Best practices in transfusion and blood support operations are specifically highlighted.

Army laboratory technicians are required to undergo 52 wk of advanced training in laboratory procedures.[4] Those supporting the U.S. Army air ambulance transfusion program received additional training specific to preparation and storage of blood products. Until recently, Army flight medics were only trained to the level of a basic emergency medical technician, with Advanced Cardiac Life Support certification and 6 wk of aviation medicine training.[14] Although medics in WWII delivered blood products without advanced certifications, transfusion is not currently within the scope of practice for basic EMTs. Most basic EMTs in the blood program received over 200 h of additional trauma, intubation, and Advanced Cardiac Life Support training prior to deployment. All medics certified for transfusion received at least an additional 20 h of transfusion training and underwent daily to weekly sustainment training. Given this additional training, all EMTs from this program were approved to become qualified for transfusion.

Emergency critical care nurses served as trainers with a physician assistant designated as the lead trainer. A residency-trained, board-eligible emergency medicine physician served as medical director. The subject matter expertise of local air ambulance services helped to refine implementation and training protocols. Local trauma center surgeons and emergency medicine physicians also provided training support. Flight medics were required to pass a written exam with a minimum score of 90% as well as day and night skill tests to become certified for transfusions.

Prior to implementation of the blood product mission at a new location, a rehearsal was conducted among aircrew, laboratory, blood bank, and surgical personnel. Trauma specialists ensured incorporation of evolving knowledge and practices into the program. The original COGs were directly transferred from existing AFSOC guidelines based on Advanced Trauma and Life Support parameters for class 3 to 4 blood loss; 30–40% and over 40% of total blood volume, respectively. The transfusion COG (**Table I**) and transfusion reaction management COG (**Table II**) were further refined by using lessons learned from other air ambulance services. Before implementation, the U.S. Army Medical Center and School and Army Institute of Surgical Research reviewed the finalized comprehensive COGs.

Once maximal hemorrhage control was established, casualties in shock were candidates for blood product administration. Indications included persistent tachycardia 120 bpm or higher, systolic blood pressure less than 90 mmHg, or clinical evidence of shock, including absent radial pulse and/or altered mental status in the absence of head injury. Initially, hypoxia with a pulse-oximeter reading less than 90% despite oxygen administration was a separate indication for transfusion in the setting of traumatic injury, but this was removed within the first 15 transfusions following an instance of an unrecognized

Table I. Transfusion Clinical Operating Guidelines.

Preflight
Verify GHC content with lab (AB pos plasma/O neg PRBC)
Ensure checklist and medical documentation available in GHC
In Flight
Patient stabilization; hemorrhage control, airway, IV/IO access and monitor
Confirm transfusion indication(s)
Pre-transfusion quality assurance cross checks
Access site (18G IV or IO)
Line preparation (prime Y tube line with 0.9% normal saline, place warmer)
Transfusion: monitor vitals q 5 min × 3, then q 30 min/monitor for signs/symptoms of reaction
Postflight
Record post-transfusion vitals
Complete documentation
Transport all blood product bags with patient
Dispose of all contaminated supplies/tubing

GHC: Golden Hour Container; PRBC: packed red blood cells; IV: intravenous; IO: intraosseous.

pneumothorax in a patient with a low pulse-oximeter reading. The additional indication of two or more amputations was also added as an independent criteria given near universal preoperative blood product requirement in these causalities; however, it is not known if this update significantly increased the overall number of transfusions. In order to ensure comprehensive quality assurance and efficient rotation of blood products, an Army medevac transfusion algorithm was developed (**Fig. 1**).

A fresh Golden Hour® Container (GHC) was prepared by the laboratory and picked up by the flight medic at the start of every shift (24 h). If a single unit was chosen for use, a secured radio communication was made to ensure a freshly charged GHC at the time of patient transfer. During the transfusion process, a series of cross checks were undertaken by the flight crew. Standardization of this process enabled simultaneous blood support operations in over 10 areas of U.S. Army air ambulance coverage by July 2012 without a single instance of air ambulance related blood wastage.[11] Blood not used for helicopter transfusion was used instead by surgical teams.

Table II. Transfusion Reaction Management Clinical Operating Guidelines.

Allergic Reaction (bronchospasm, urticarial, itching, erythema, anaphylaxis)
Discontinue transfusion
Diphenhydramine 50 mg IV
Epinephrine
IM: (1:1000) 0.3 ml to 0.5 ml in the thigh (preferred) or deltoid q 5-15 min for adults. If thigh and deltoid not available, epinephrine may be given subcutaneously. Repeat up to three times for moderate bronchospasm, facial and laryngeal edema.
IV: (1:100,000) 0.1 mg (0.1 ml of 1:1000) in 10 ml normal saline over 10 min.
If mild rash only which resolves with diphenhydramine, may re-initiate transfusion.
Acute Hemolytic Reaction (fevers, chills, breathlessness, lower back/flank pain, burning sensation at IV site, hypotension)
Discontinue transfusion
Hydrate to maintain diuresis (at least 100 ml/h)
Infuse normal saline 1000 cc over 2 h
Time permitting, place Foley catheter to monitor urine output
Diphenhydramine 50 mg IVP
Febrile Non-Hemolytic Reaction (chills, fever, unexpected temperature elevation 1°C-2°C)
Discontinue transfusion
Treat symptoms appropriately

IV: intravenous; IM: intramuscular.

Best practices were identified through an after action review (AAR) following each of the first 15 missions as well as through weekly AARs. The AAR was attended by the flight crew, the senior blood support officer, and one or more U.S. Army flight surgeons who had received "lessons learned" briefings and operations orientations from Medical Emergency Response Team and AFSOC medical aircrew. Best practices for laboratory aspects of transfusion were also garnered through an orientation to the United Kingdom's in-theater blood service. Transfusion techniques, quality assurance measures, and overall blood support operations are captured in **Table III**.

Best practices were also shared by all medical evacuation services during bimonthly trauma conferences. An important best practice is flight medic recommendation for the use of two or more medical personnel for the transfusion procedure. Lab integration and oversight on transfusion-related equipment is essential to ensure safe operations. Transfusion components used by the U.S. Army medical evacuation helicopter crews are delineated in **Fig. 2**.

The GHC houses a removable thermal isolation chamber system (TIC) which contains six vacuum-insulated panels. Each panel contains a liquid phase change material capable of thermal regulation from deep freeze to the solid state. GHCs, manufactured by Minnesota Thermal Science, LLC (Baxter, MN), are available for platelets (pink colored containers) and plasma/packed red blood cells (black colored containers). However, no 'platelets only' or 'red blood cells/plasma only' labels or warnings appear on any of the containers. The TIC also has a different expiration date than the GHC in which it is housed. Although GHCs can maintain red blood cells and plasma at an acceptable temperature for 72 h in the extreme desert environment, a daily exchange policy was developed to err on the side of safety, with subsequent lengthening of the exchange to 48 h without any instances of temperature excursion. Laboratory space and cold storage requirements for an in-flight transfusion program are appreciable. Freezers capable of maintaining −18°C or colder must also be large enough to store GHCs for daily exchange as well as one for use during patient hand off. As thawed plasma and packed red blood cells require storage between 1°C to 6°C, refrigerators as well as freezers were required within the lab. Refrigerators validated for appropriate temperature controls are bulky and must be maintained in space constrained forward surgical areas. The need to have temperature-monitoring devices and/or freezers and refrigerators frequently assessed for acceptable temperatures represents an important quality control requirement as well as an additional logistical burden. Lastly, fresh frozen plasma must be thawed in a regulated fashion; plasma thawing

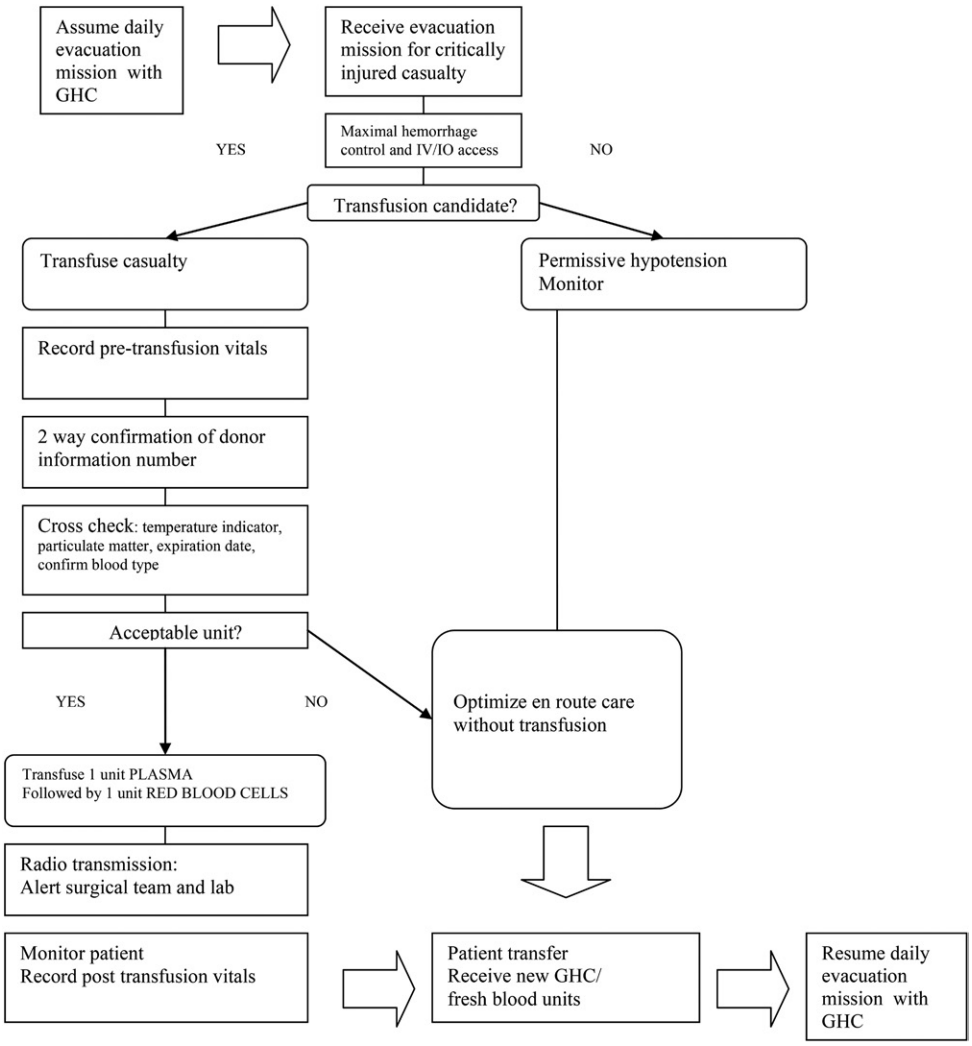

Fig. 1. Transfusion algorithm. GHC: Golden Hour Container.

devices are expensive, relatively bulky, and not readily available in theater. Plasma was discontinued at several locations due to the complexity of its use.

Administrative items such as paper, ink, and printers are challenging to obtain and use in remote areas. Intraosseous training devices were also extremely important for skill sustainment. All battery operated and electronic medical equipment used in theater requires inspection and maintenance, which present additional logistical complexities. Table III summarizes equipment considerations and best practices.

Given a limited blood supply, air ambulance transfusion programs may divert blood products away from locations where it is most urgently needed. Rotation of unused products into the combat support hospital and use of the U.S. air ambulance transfusion algorithm (Fig. 1) ensured zero instances of wastage due to expiration or spoilage. Likewise, regional blood shortages were prevented by designating blood support leaders who have comprehensive knowledge of usage, along with authority for urgent resupply. The potential for contingency use of O+ packed red blood cells and A+ plasma also enabled the air ambulance blood program to coexist with forward surgical teams, who took priority for O− and AB+ plasma during surge operations.

Important considerations exist for humanitarian transfusion missions in the combat environment, and broad standards for donor screening and post-transfusion documentation exist internationally. Infections from donated blood can be a source of anti-U.S. sentiment and poor documentation of blood donor information may limit comprehensive quality oversight. Potential negative implications of any humanitarian program were especially relevant after covert immunization programs in Pakistan compromised trust in humanitarian assistance.[13] Suspicions of malicious intent were allayed by early and transparent involvement of the Afghan blood bank. With regard to documentation of donor information, the use of a single name by many Afghans and a lack of strong local clinic record keeping procedures make notification of any infectious exposure exceptionally challenging. For this reason, as well as for concerns for Creutzfeldt-Jakob disease, only prescreened U.S. blood products were used. This 'U.S. blood only' policy was a source of some tension, given the strong desire of many British and Afghans to donate blood in support of combat operations.

All trauma victims remaining in shock, despite maximal hemorrhage control, were candidates for transfusion, regardless of country of origin or combatant status. Indeed, several casualties receiving U.S. air ambulance blood products were enemy combatants.

DISCUSSION

Basic EMT certification is adequate for transfusion when followed by specific advanced training and a tightly regulated protocol. EMTs with basic certification underwent over 20 h of transfusion-related training and over 200 h of advanced level trauma training. A lack of a specific certification should not preclude transfusion, but specific, advanced training is important in ensuring safe procedures. The use of an additional medical attendant was strongly identified as a best practice and

Table III. Equipment Considerations and Best Practices.

EQUIPMENT	RATIONALE	CONSIDERATION	BEST PRACTICES
Golden Hour Container (GHC)	Validated to maintain plasma and PRBCs to 1–10°C for up to 72 h in extreme weather conditions	Thermal Isolation Container (TIC) must be frozen, then 'conditioned' to slightly cooler temperature prior to use. Each of two components has a different expiration date.	One set of TICs always in freezer and one in the back of the aircraft for each line of medevac coverage supported by each lab
Cooler	Maintain plasma and PRBCs at 1–6°C for duration of shelf life in the room temperature environment	Bulky and requires temperature monitoring	Larger, temperature alarmed cooler (UK) (Cost prohibitive)
Freezer	Maintain −18°C or colder for GHC and fresh frozen plasma storage	Bulky and requires temperature monitoring	Larger, temperature alarmed freezer (UK) (Cost prohibitive)
Plasma Thawing Device	Thaw plasma in a controlled, standardized fashion	Expensive, relatively difficult to procure. Veterinary equipment available, but not able to substitute	
Temperature Indicator Stickers	Validate blood product temperature is maintained 1–10°C	Normally used for large scale, overseas blood transportation. Difficult to visualize color using night vision goggles.	Affix to each unit of blood product
Filtered transfusion tubing (i.e., Y tubing)	Prevent aggregation of particulate matter	Cannot be substituted with non-filtered tubing	Maintain a transfusion bag with all critical items and prime with normal saline as soon as mission likely
Intraosseous devices, largest possible size	10 has clear superiority to IV for rapid administration with less clotting	Musculature in athletic men often demands large bore if IO placed in humeral head location	Simultaneous bilateral humeral head placement enables concurrent blood product delivery
Large syringe and three way stopcock	Allows an additional crewmember to push blood product	Overly loose fit arrangement can cause seepage/wastage	Most rapid route of administration and non-medical crewmember can push product
IV fluid warming device	Prevent hypothermia and secondary arrhythmia	En Flow and Angel Warmer are approved for flight. Warms cooled products rapidly.	All in theater services mandated use. No known hypothermic reaction to blood in any casualty.

PRBCs: packed red blood cells; IO: intraosseous.

should be seriously considered as an air ambulance standard. Interdisciplinary exchanges enabled extensive knowledge sharing. Centralized training facilities in the United States were able to contribute subject matter expert review to this program while simultaneously gaining experience from the program.

The U.S. Army air ambulance COGs and transfusion algorithm best serve as living documents. Comprehensive AARs for each of the initial 15 transfusions, followed by weekly AARs, enabled timely and relevant updates. Participants in this evaluation included flight medics, crew chiefs, pilots, trauma surgeons, operational flight surgeons, emergency critical care personnel, blood bank specialists, and lab technicians, resulting in comprehensive and unified procedures. Stakeholder integration into COG development ensured standardized operations across multiple areas of blood support. Successful en route transfusion programs must have tight integration of laboratory and flight medical services from implementation to quality assurance oversight. Given the extensive cold chain requirements for blood products in high/cold temperature environments, significant

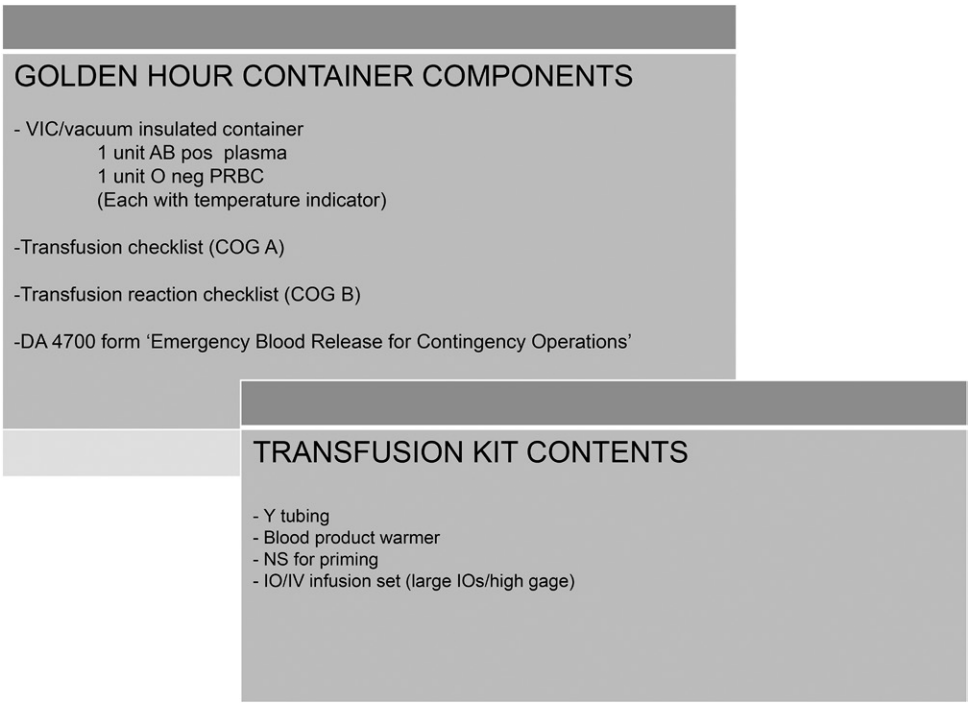

Fig. 2. Transfusion components.

planning must be undertaken. Subject matter experts in the blood support community and collaboration with other air ambulance services can ensure the identification of emerging technologies as well as best practices with respect to transfusion equipment.

Concerns for treating non-U.S. casualties include infections from donated blood and poor documentation of blood donor information, leading to anti-U.S. sentiment. Despite these concerns, limiting medical treatment to only U.S. and/or coalition casualties is unethical and contrary to established wartime conventions.[5,6] When a new air ambulance program is implemented in a host nation, early involvement of local medical personnel is essential for dispelling misconceptions. In regions lacking a robust medical record keeping system, it is imperative that medical documentation be available to local personnel and that only fully screened blood products are used.

The U.S. Army air ambulance community was fortuitous in its professional relationships with other air ambulance services—each participating in bimonthly trauma reviews with critical care specialists and readily sharing lessons learned with one another. All professional organizations involved in providing transfusions must be capable of honest self-examination, rigorous process improvement, and a willingness to learn from subject matter experts in a variety of professional arenas.

Despite the proven success of uncertified WWII ground medics, the lack of advanced medical certification in many U.S. Army flight medics threatened approval of this mission. The success of this program proved that quality assurance standards and rigorous training can surmount a lack of advanced training certification. However, considering the multiple critical injuries of casualties in Afghanistan and Iraq, the future training of Army medics will require certification to the level of Critical Care Flight Paramedic. It must be recognized that lifesaving battlefield transfusions cannot always occur under the direct supervision of or through a real-time written order by a physician. While this manuscript addresses challenges and strategies pertinent to the Afghanistan theater of operations from the first hand perspective of the U.S. military, limitations in universal applicability exist. Consideration must be given to the unique circumstances of every nation's training and logistical capabilities, as well as to the political considerations and environmental factors encountered. This manuscript also does not address the clinical outcomes of the 84 casualties undergoing transfusion, which is the focus of a future investigation.

The U.S. Army air ambulance transfusion program continues despite operational draw downs and fiscal limitations given the considerable political pressure to maintain the current standard of care. U.S. Army flight medics now receive paramedic certification commensurate with the clinical procedures they are expected to undertake and the program is evolving toward a joint standard across the entire U.S. military (LTC Edward Mandril, U.S. Army Medical Evacuation Proponency Directorate, Deputy Director; personal communication; October 29, 2014). Should fiscal or logistic constraints prevail, en route transfusion is best suited to remote areas in which casualty prediction estimates are high. The lessons learned in training, clinical operating guideline development, and logistic and political considerations may benefit new programs emerging in austere locations.

In conclusion, the development of blood product administration capabilities aboard the remotely stationed air ambulance is logistically complex. Rigorous temperature controls and attention to time sensitive qualities of blood product administration are important considerations. Structured, organized, and repetitive training enabled EMTs with basic certification to safely perform transfusions in accordance with a tightly regulated protocol. In the austere environment, equipment and maintenance costs as well as political considerations are important factors. Adoption of the strategies discussed previously can overcome the challenges of a new program in the austere setting. Further research must be conducted to determine survival benefit.

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