Conducting fresh whole blood transfusion training

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ABSTRACT: Fresh whole blood is the optimal resuscitation fluid for casualties in hemorrhagic shock according to the Committee on Tactical Combat Casualty Care and has demonstrated to improve outcomes in severely wounded patients. Like all medical interventions, fresh whole blood transfusions are not without risks, but similarly can be mitigated through increased training to develop provider knowledge and proficiency. To date, no literature has been published regarding the proper technique to conduct fresh whole blood transfusion training. This article provides a structured foundation to establish a standardized fresh whole blood transfusion training program to increase skill and preparedness for fresh whole blood protocol implementation. Using these techniques in a training environment, providers will be able to provide optimal resuscitation in hemorrhagic shock in austere environments. (*J Trauma Acute Care Surg.* 2019;87: S184–S190. Copyright © 2019 Wolters Kluwer Health, Inc. All rights reserved.)

KEY WORDS: Fresh whole blood; transfusion; resuscitation; hemorrhagic shock; prehospital.

In 2014, the Committee on Tactical Combat Casualty Care (CoTCCC) published changes to their fluid resuscitation guidelines.[1] The revisions moved blood products to the forefront of care for those in hemorrhagic shock. Specifically, whole blood should be used "as far-forward as feasible, including evacuation platforms and some selected Tactical Field Care locations."[1] This change in the hemorrhagic shock treatment algorithm was revolutionary and made blood transfusions a prioritization over the previously championed Hextend.[1] More importantly, the declaration of whole blood as the optimal fluid for hemorrhagic shock resuscitation essentially gave endorsement to its use by medical personnel in the conventional forces. Previously, the use of blood products prior to arrival at fixed facilities was largely confined to medical evacuation platforms and special operations forces whose medics had significantly advanced medical training.[2] In stating whole blood was the optimal resuscitative fluid in hemorrhagic shock, the new CoTCCC recommendations, therefore, indirectly supported the application of fresh whole blood (FWB) at the far forward areas. These far forward areas include the point of injury (POI) in combat and the medical support facilities capable of providing triage and immediate life-saving measures termed Role 1 care. By current doctrine, stored blood component therapy is absent at these locations.

The procedure to administer blood products in the prehospital setting came with the assumption of increased responsibility for unit training and proficiency. However, despite 4 years passing since the CoTCCC changes, very few units have successfully implemented a FWB program. This may be due to not only logistical concerns but also apprehension by medical decision makers over perceived difficulty and risk of FWB transfusions. This is most apparent in the fact that few FWB transfusions have been performed by conventional forces personnel at POI or Role 1 facilities.[3] Given anticipated logistical difficulties in austere environments, the consistent access to prepackaged blood products, such as cold stored-low titer group O whole blood (CS-LTOWB), red blood cells and fresh frozen plasma is difficult at best. Freeze dried (lyophilized) plasma only recently became available to the Department of Defense (DoD), but this has limitations of providing coagulation factors and volume resuscitation only. With minimal logistical support and a simple but comprehensive training plan, units can rapidly and safely implement a whole blood program. Prehospital providers should focus on development and sustainment of whole blood programs for optimal outcomes in a resource-limited environment in accordance with the 2014 CoTCCC recommendations. This article provides a structured foundation for training programs to increase provider knowledge and proficiency regarding FWB transfusions.

MILITARY RELEVANCE

Like most aspects of advanced medical care, proficiency in FWB transfusions requires repeated exposure and training. Repetition breeds confidence, skill refinement, and improved execution. Effective training requires not only proper planning and material resource support at the unit level, but as importantly, command support to consistently devote resources, time, and personnel. Unfortunately, recent literature has discovered an uneven focus on medical training by conventional military units, which may contribute to potentially survivable death when compared to units that consistently incorporate medical training into standard military training.[4–6] Recent research also points to poor Tactical Combat Casualty Care (TCCC) guideline adherence in other areas of prehospital care, including antibiotic administration, provision of analgesia, and tranexamic acid administration,

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again implying a lack of command focus and support for medical training.[7–9] This may also indicate barriers between combat medics or corpsman and the supervising providers. Recent survey data demonstrate a significant gap in TCCC-based knowledge and that a surprising proportion of military medical providers have little-to-no awareness of the TCCC model.[10] Overall, these findings create significant concern for creation of successful FWB programs in many DoD units.

At the POI, choosing the blood product to be used should be planned before the mission and donor identification should be established (Table 1). The CoTCCC has recommended that the use of CS-LTOWB be used first if these resources are readily available.[11] This is because CS-LTOWB is well established for universal donation, is Food and Drug Administration (FDA)-approved and transfusion-transmitted disease (TTD) testing has been completed. Steps have been taken to expand resourcing units with CS-LTOWB, but as of this writing, it is not available at POI and Role 1 facilities in conventional forces. The next recommendation is to use fresh LTOWB. Fresh LTOWB is superior to CS-LTOWB because it maintains all its hemostatic and oxygen carrying potential. However, it generally takes over 15 minutes of time to collect the donation. If low titer donors are not available, then it is recommended to use untitered group O whole blood. If this is unavailable, group-specific FWB is recommended. Group-specific FWB is a safe and effective method of whole blood transfusion, but takes the longest to test and collect the donation. Group-specific FWB also carries an increased risk of administration error (either through Eldon card misread or inaccurate blood group recording) leading to potential ABO mismatch and hemolytic transfusion reaction (HTR).

Units can better prepare to conduct FWB transfusions in the deployed or austere setting by titer testing group O service members along with TTD testing. This may be completed with the assistance of the Armed Services Blood Program and creates a large pool of universal whole blood donors. If titer testing is not possible, creating rosters of service members, their blood group, and TTD status could help facilitate the FWB transfusion process. Here, only FWB transfusions are reviewed, though portions could be applied to CS-LTOWB transfusions.

TECHNIQUE

Fresh whole blood transfusions performed in an austere environment can be considered in the following four steps, each with specific procedural considerations:

1. Venous access
2. Blood collection
3. Preparing for transfusion
4. Initiating and monitoring the transfusion

TABLE 1. Whole Blood Products in Order of Preference

CoTCCC Recommended Whole Blood	Notes
1. CS-LTOWB	FDA-approved and TTD testing has been completed.
2. Fresh low titer group O whole blood	Requires a walking blood bank.
3. Fresh untitered group O whole blood	
4. Fresh group-specific whole blood	

In training, before gaining venous access, it is important to remember that the donor is also the patient. The training utilizes autologous blood transfusions. To mitigate the chance of a nonautologous blood transfusion, the donor/patient should initial and sign the blood donation bag. This is not required in combat, but may be considered if multiple donations are occurring at once. Other methods to mitigate risks include writing a unique mark (letter of the alphabet or number) on the donor arm and the bag. In combat, the label should be filled in with the donor's name and battle roster number or unique unit identification.

STEP 1: VENOUS ACCESS

Commercial blood collection bags come preequipped with a 16-gauge intravenous (IV) needle without a catheter and lack a confirmation chamber, better known as a "flash." These features are unique to blood collection bags when compared to the standard IV setup that many are used to for fluid infusions. The large needle gauge and lack of confirmation in these collection bags necessitate several considerations in conducting a whole blood donation in the field environment. The primary consideration in blood draw is vessel site selection for donation. No studies have been conducted to demonstrate the proficiency of combat medics, advanced medics, or other medical providers for success rates at phlebotomy with a 16-gauge blood collection bag straight needle. However, phlebotomy using larger needle gauges reasonably demonstrates inverse success rates of vascular access with decreasing needle size.[12] Similarly, studies have used a needle for initial venous access, but these procedures have been performed in combination with a needle-angiocatheter assembly commonly used for IV fluid infusion, unlike the single needle without angiocatheter system that is found in blood collection bags. Therefore, even more so than usual, the process of obtaining venous access must be a deliberate and precise process.

An alternative to using the blood collection bag needle is to start a standard saline lock by using a 14-gauge to 16-gauge angiocatheter assembly and attaching a needle port at the end once access is secured. The 16-gauge blood collection bag needle may then be used to tap the needle port, thus facilitating blood collection (Fig. 1). This method allows for familiarity and consistency with prior IV training, as well may increase the number of available sites in patients with difficult vascular access. Furthermore, in the military or other field environment, the use of a needle port allows the medic to halt the donation and remove the 16-gauge needle and replace as necessary. This is most evident in the combat environment, where units and troops may be required to move without notice. However, this may also slow down the donation process. Another advantage of this method is that it eliminates the need to hold the needle still and in perfect position throughout the draw as the IV catheter is secured in the vessel.

A constricting band or elastic tourniquet can be used to create venous congestion and facilitate easier vein identification. Always place the blood collection bag on the ground or lower than the patient's heart when collecting blood from a donor. In general, the lower the bag from the patient's heart, the faster the flow. Some commercially available kits come with a plastic clamp that is used to occlude the tubing near the needle. As an alternate, a hemostat can be used (Fig. 2) or the tubing can be

Figure 1. A 16-gauge saline lock can be used for donation.

held in a kinked position until inserted into the vein. Once the cap is removed from the needle, if no clamp or kink is placed, air can enter the tubing or the anticoagulant can flow out of the bag and onto the ground. Before inserting the needle, the site should be prepped with a chlorhexidine swab. The needle can be inserted bevel up or down, though most teach and recommend bevel up.[13] Once the vein has been cannulated, the hemostat can be taken off. Blood should freely flow into to the collection bag.

STEP 2: BLOOD COLLECTION

During the blood collection process, the most important considerations are to maintain proper collection bag filling and intermittent bag agitation. The anticoagulants citrate phosphate dextrose or citrate phosphate dextrose adenine-1 in the collection bag prevent coagulation of donated blood by binding calcium, thereby minimizing risk of blood clotting in the collection bag. If there is too much blood added into the bag, the citrate-based anticoagulant will be exhausted, and the risk of blood clotting in vitro increases. Conversely, an insufficient amount of blood in the collection bag will then cause flow of the excess citrate directly into the blood transfusion recipient. This citrate will then bind calcium in the recipient, which can lead to complications ranging from benign paresthesia to hypotension and cardiac dysrhythmias. Therefore, a proper balance of donor blood and citrate must be ensured for best outcomes.

The optimal way to properly measure a blood collection bag is through the use of a digital scale, where the current blood bank recommendations is a full 450-mL collection bag weight of 585 g +/− 10%.[14] There has been little research into field-expedient means for measuring blood collection bag volumes. Most commercial FWB transfusion kits come with a 9 ½- to 11-inch piece of military parachute cord (Fig. 3). The Emergency War Surgery, fifth Edition states that when a piece of 10-inch parachute cord is wrapped around the bag and the ends touch that is a full blood bag.[15] Other methods that have been examined include the use of a restrictive 6.5-inch beaded cable tie or similar being placed around the midsection of the collection bag (Fig. 4) as it fills or folding the top of the bag over by 1.25 inches and securing it with a hemostatic clamp.[16] Each of these methods has been demonstrated to be within the 585 g +/− 10% fill volume that is optimal for donation and transfusion. The same study demonstrated that guessing by trained medics can also be accurate, but had about 25% overfilled rate. If left

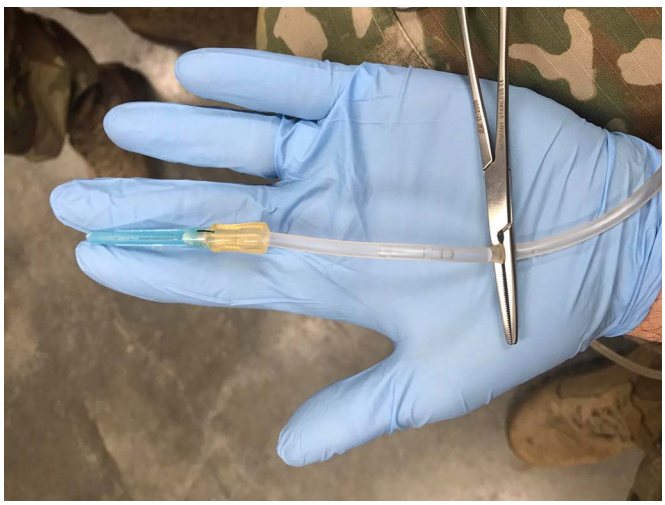

Figure 2. A hemostat may be used to occlude the donation bag line.

Figure 3. Parachute cord is often used to determine a full blood donation bag.

Figure 4. Volumetric restriction can allow for a more accurate means to determine a full blood donation bag.

with guessing, without measure, a full blood bag has some dimpling at the edges and when held, the blood should be above the corners, with an air fluid level present (Fig. 5).

Consistent agitation of the blood collection bag is also needed to ensure an equal distribution of blood-to-citrate throughout the bag as it fills. Agitation does not need to be constant, as can often be found in formal blood donation centers, but can instead be intermittent, without significantly increasing the risks of hemolysis or other damage to the donated blood.[15] Therefore, gentle agitation with side-to-side motions at regular intervals during the blood donation process should be sufficient to adequately disperse citrate throughout the donated blood for optimal effect.

Ensure careful attention is given to the donor during this process. Vasovagal reactions with nausea and vomiting may occur with needle insertion, still others may become lightheaded and have syncopal episodes during the donation. Reactions, like an allergic response to donation materials (primarily latex), are possible,[17] but unlikely and have not been documented in previous FWB donation literature. During training, it is recommended that the transfusion be immediately stopped for any side effect or adverse event. During collection of FWB in combat settings at the POI or Role I, weigh the risk versus benefit for your casualty and donor pool. Risks include further deterioration of the donor based on the severity of reaction, while benefits are the continued donation of resuscitative fluids that will facilitate

Figure 5. Slight dimpling on the edges and an air fluid level above the corners can be used to determine a full blood donation bag.

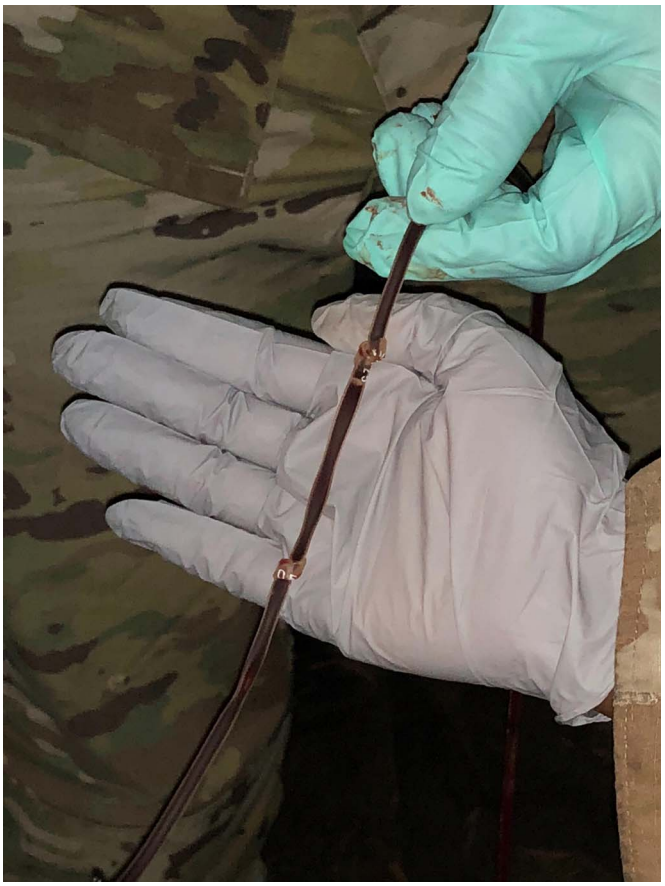

Figure 6. Ensure two overhand knots are tied when preparing the blood donation bag.

tissue oxygenation and clotting in the hemorrhagic shock patient. This decision must be made in the setting of the overall clinical picture of donor and recipient, projected evacuation time, and medical resources available, to include the availability of other compatible donors.

STEP 3: PREPARING FOR TRANSFUSION

Once the blood collection bag has been adequately filled by one of the methods described above, the donation should be terminated. After clamping the line, the medic can then remove the needle from the arm or needle port as with any other procedure. A bandage with slight compression should be placed over the site where the needle was placed to ensure hemostasis. The bag assembly should be labeled and hung vertically by the line with the collection bag closest to the ground, and the clamp should be removed to allow any remaining blood to flow down the line and into the bag. Once this is complete, the line should be clamped. Two simple, overhand knots should be tied approximately 1 to 2 inches apart, with one being within 1 to 2 inches from the collection bag itself (Fig. 6). Once both knots are secure, the medical operator can cut between the two knots, as the donation line is now secure and will not leak blood.

It is important that only blood transfusion administration sets be used for infusion. These administration sets use 170 to 210 micron filters, which provide a risk mitigation measure against blood clots and microemboli. Most are Y-tubing, consisting of two input tubes into a single drip chamber. There are several means to approach this; the recommended method is to not use the second input and to allow the blood to prime the tubing (Fig. 7). Second, use a crystalloid, such as 0.9% sodium chloride (normal saline [NS]) or Plasma-Lyte A (Baxter International Inc., Deerfield, IL), to prime the tubing and eliminate any air bubbles. Concerns of creating microemboli when using lactated Ringer's (LR) in place of NS or Plasma-Lyte A exist due to the calcium content of LR. This is not recommended because whole blood does not require a crystalloid for administration. The Joint Trauma System guidelines maintain only NS and Plasma-Lyte A are compatible fluids for FWB transfusions at the time of publishing.[18]

STEP 4: INITIATING AND MONITORING THE TRANSFUSION

Prior to initiating the autologous transfusion, medical supplies to treat an allergic reaction and HTR should be readily available. These include (at a minimum): epinephrine,

Figure 7. The FWB can be used to prime the blood administration set.

diphenhydramine and/or ranitidine, crystalloid fluid, and supplies for administration.

Transfusions can be performed through an IV or intraosseous (IO) access. Ideal initial access, as taught throughout military medical training, entails large-bore (18-gauge or greater) IV placement in the antecubital fossa. A lack of IV access, due to body habitus, extremity trauma, or vascular collapse secondary to hypotension, necessitates an IO approach. Studies have compared flow rates between IV and IO with crystalloid and blood, while IV rates tend to be faster, the ease of insertion and reliability of the IO should be considered.[19,20]

It is recommended that infusions be initiated quickly based on the hemodynamic instability of the recipient. Nevertheless, medical personnel must ensure close observation of the recipient response for possible hemolytic and/or anaphylactic reactions throughout the duration of the transfusion, and most especially in the first few minutes (Table 2). The first corrective action to take when a reaction is expected is to stop the transfusion, reassess the patient, and provide additional medical interventions, as appropriate. While unlikely, the possibility of delayed HTRs is possible, which expand the window of acute reactions to up to 24 hours after the transfusion has been initiated. Posttransfusion observation is not recommended during training.

END POINTS OF RESUSCITATION

The 2014 CoTCCC update used lack of radial pulse and altered mental status for indications for blood products.[1] As much, the return of radial pulses or a systolic blood pressure of 80 mm Hg to 90 mm Hg and improved mental status were indications to cease active resuscitation efforts. The CoTCCC guidelines used the same end points from guidelines that previously recommended crystalloids and colloids. The latest Advanced Resuscitative Care guidelines from CoTCCC recommend a systolic blood pressure less than 90 mm Hg as an indication for resuscitation.[11] Eastridge et al. surmised that there is increased mortality with a systolic blood pressure below 100 mm Hg.[21] Fisher et al.[22] recognized that FWB may allow for a higher blood pressure for an end point. Therefore, the endpoints of whole blood resuscitation should be the resolution of its indications, namely, attaining a systolic blood pressure at or above 100 mm Hg, heart rate less than 100 bpm, and improved mentation. If these endpoints are not met after the transfusion of the first unit of blood, additional units may be administered until they are met, or the recipient is successfully evacuated to more definitive care. Additional parameters to evaluate are decreasing pulse rate, increasing mental status, decreasing lactate, and improvement of clinical picture.

DISCUSSION

The use of FWB transfusions for hemorrhagic shock patients has been proven beneficial in multiple studies conducted in combat settings.[2,23,24] A primary barrier to the implementation of such a program, however, is the lack of structured training that would hone the skills necessary to safely and quickly conduct donation and transfusion procedures. The ability to conduct FWB transfusions has already been established as a skill for the standard US Army combat medic, but as of this writing, no published standardized training exists to maintain this skill set across conventional forces. Therefore, units are left to try to piece together training when able, but this requires support and initiatives by unit commands and medical leadership. The previous referenced literature has established poor adherence to other CoTCCC recommendations for antibiotic, analgesia, and tranexamic acid administration in the combat environment, which brings into question the training and proficiency of units in these areas.

Although CS-LTOWB exists, like component therapy, the logistics required for its transport and storage for use at POI and Role 1 appear to be beyond most conventional force units at this time. As the primary resuscitative fluid for hemorrhagic shock according to the CoTCCC recommendations, FWB is logistically feasible, with a potential donor pool existing throughout the unit footprint in a combat setting. The improved outcomes with FWB transfusions in the military medical facilities capable of resuscitation and surgery support increased use of FWB in far forward and remote areas. Thus, an emphasis on predeployment training for units and medical personnel must be made to improve outcomes in potentially survivable deaths.[6]

This training strategy is limited by current knowledge of unit practices and individual provider and author experiences. To date, no studies have been conducted regarding the regularity or even prevalence of FWB transfusion training among

TABLE 2. Transfusion Reaction Characteristics

Reaction	Cause(s)	Characteristics	Intervention
Hemolytic	ABO mismatch, recipient blood responds to donor red blood cell antigens with systemic immune response; causes mass hemolysis of both donor and recipient blood	–Fever –Chills –Pain in arm (IV site), chest, back –Flushing –Dyspnea –Disseminated intravascular coagulopathy (DIC) –Sudden unexplained worsening hypotension	–Stop transfusion –Crystalloid fluid bolus –Vasopressors
Allergic	Recipient reaction to transfusion materials (preformed antibodies, latex, citrate, other preservatives)	–Hives –Itching –Local erythema Anaphylactic concerns: –Dyspnea –Chest pain –Abdominal cramping –Nausea, vomiting, diarrhea	–Stop transfusion –Epinephrine –Diphenhydramine –Ranitidine –Methylprednisolone –Crystalloid fluid bolus

conventional units. There is no DoD-wide structured evaluation for FWB transfusion proficiency. Furthermore, there has been no published data on the safety or adverse events associated with this training. Therefore, this training strategy is limited to the authors' best practice experiences with implementing FWB transfusion training among conventional and nonconventional forces.

CONCLUSION

To optimize provider knowledge and proficiency and patient outcomes, it is critical for units to prepare for combat environments by conducting FWB transfusion training. Lack of proper training not only makes it less likely that providers will use FWB, but also will likely increase procedural delays and error rates given a lack of proficiency. It is critical to document before, during and after the transfusion is completed. If FWB transfusion is completed at the POI, ensure the donor follows up at the local Medical Treatment Facility for additional testing for TTDs as required for all blood transfusions.

When properly trained and practiced, FWB transfusion is a simple and straightforward skill to perform in the TCCC setting. It is important that both unit command and medical leadership emphasize proper FWB transfusion training, but medical leadership ultimately holds responsibility to maintain the knowledge and enforce training standards. A current lack of knowledge and proficiency among leaders is likely preventing this skill from being implemented in the far forward areas. Units that have implemented the low titer group O whole blood programs have helped pave the way to bring lifesaving blood transfusion closer to the POI for all service members. This technique is demonstrated as feasible by the combat medic. Efforts to make this training available to all relevant medical personnel, including medics, nurses, physician assistants, and physicians, should continue.

AUTHORSHIP

A.D.F. developed the concept and technique, conducted literature review, and wrote the article. B.M.C. helped develop the technique, conducted literature review, and wrote the article, performed a critical review of the article. P.M.D. contributed to the writing and performed a critical review of the article. J.B.C. contributed to the writing and performed a critical review of the article. E.A.M. contributed to the writing and performed a critical review of the article. A.L.T. contributed to the writing and performed a critical review of the article.

DISCLOSURES

Opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Texas A&M College of Medicine, the Department of the Army, the Defense Health Agency, or the Department of Defense.
The authors declare no conflicts of interest.

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