Supplying blood to the battlefront has been an ever-growing challenge since its inception in the First World War, when blood collection and transfusions came of age. During the early phases of Operation Iraqi Freedom, blood supplies were difficult to acquire and maintain because of the dynamic and austere environment of the battlefield. To ensure adequate supplies to meet patients’ needs during emergency situations, some units collected and transfused whole blood.

During the initial phases of Operation Iraqi Freedom (Spring 2003), our forward surgical team (FST) received our first call that medical evacuation helicopters were bringing in several severely wounded casualties. Unknown to us at that time, this experience would also be our first time of collecting whole blood.

The FST Concept
The fall of the Berlin Wall brought many changes, including the way the US Army would fight future battles. For many years, the Cold War had provided the US Armed Forces a single enemy, and only a linear concept of fighting a war. Military planners soon realized that the post–Cold War battlefield would be characterized by quick-moving military operations in which mobility, flexibility, and geographically extended lines of communication would be key elements to success. In order to support the changing battlefield, the FST concept was developed in 1987, leading to a significant change in how the Army Medical Corps delivers wartime health care. The concept of the FST is based on research from earlier conflicts that indicated that

PRIME POINTS

• Hemorrhage is the leading preventable cause of morbidity and mortality on the modern battlefield.
• For patients with hemorrhage, whole blood transfusion is a practical option to counter the lack of supply and lack of clotting factors.
• Walking blood banks require no refrigeration and can provide a wide variety of blood types.
• Fresh whole blood can reverse the effects of hypothermia, acidosis, and coagulopathy.

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Hemorrhage was the most common cause of preventable mortality. The earlier experiences showed that the faster a casualty was treated and stabilized, the more mortality and long-term morbidity were reduced. Operation Iraqi Freedom is the first large-scale test of the Army’s new concept of placing surgical assets close to the fighting and potentially right in the heat of battle.

An FST consists of a 20-person team that can provide around-the-clock surgical and postoperative care for up to 30 patients in a 72-hour period without resupply (Figure 1). Typical surgical candidates for a FST include patients with major chest or abdominal wounds, uncontrolled or continuous hemorrhage, severe shock, airway compromise, and closed head injuries with progressively deteriorating levels of consciousness. The section breakdown and team organization are described in more detail in the Table.

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### Blood Capabilities of an FST

Mobility is critical to the success of an FST, so limitations must be set on supplies, blood, and equipment. Increasing the weight of an item or the space it requires will directly increase the overall size of the FST and slow the team’s movement. The time frame for FST operations (48-72...
unstable, and coagulopathy developed. The patient was rushed back to the operating room to ensure that no injuries had been missed and that the graft from the previous surgical repair had not failed. During the second surgery, the patient experienced ventricular fibrillation, which the surgeon attributed to continued fluid depletion. Defibrillation was successful, but the patient continued to have pulseless ventricular fibrillation. No surgical evidence was found for the patient’s continued unstable hemodynamic status, and the coagulopathy further complicated the resuscitation because bleeding from the surgical incision, gunshot wound, intravenous catheter sites, nares, and rectum occurred.

Being in an austere environment, the FST carried only PRBCs and had no blood components to treat the coagulopathy. Because of the desperate need for coagulation components to potentially save the patient’s life, the decision was made to use transfusions of whole blood. The call for donors went out, and volunteers began donating almost immediately. Despite vasoactive medication, continued volume replacement, and transfusion of whole blood, the patient continued to experience marked periods of hypotension and bradycardia. The patient ultimately died 12 hours after arrival, after receiving more than 10 units of type-non-specific PRBCs and 8 units of whole blood.

hours) and the limitation in supplies demand efficiency and frequent resupply. Blood storage is confined to a compact portable refrigerator (Figure 2). The refrigerator can hold approximately 50 units of PRBCs, an amount that is adequate for our 72-hour mission but leaves little room for multiple mass transfusions. Therapy with blood components is often not possible, and an FST cannot afford the extra room to carry platelets, fresh-frozen plasma, or cryoprecipitate. Managing storage limitations, maintaining blood at required temperatures (outdoor day-time temperatures often exceed 49°C [120°F]), ensuring shelf life, and coordinating resupply caused major difficulties for our blood bank in addition to the normal complications associated with maintaining stored blood.

Indications for the use of fresh whole blood (FWB) have been reported. Jevtic et al described using autotransfusion to supplement limited blood supply for treatment of massive hemothorax during high-intensity combat in the territories of the former Yugoslavia during 1991 and 1992. During the war in Croatia in the early 1990s, Horzic et al noted the importance of transfusion services during wartime to ensure that adequate amounts of whole blood are readily available. FWB has been used within the military community during significant

Figure 1 Deployable rapid assembly shelter tents set up on the outskirts of Karbala.
conflicts when subcomponents such as platelets and frozen components were not available.7 In Somalia, FWB was used after the entire supply of PRBCs was used,8 and in the first Gulf War, FWB was used when platelet supplies were exhausted.7

During combat operations, limitations and restrictions in blood products affect the decision of when to use blood and/or how much blood to use for the situation at hand. Each medical unit must decide how to augment its blood supply in crisis situations when immediate resupply is not an option. Use of FWB is a practical option in these extreme situations, and each soldier deployed is a source of whole blood.

Establishing a Walking Blood Bank

Recognized shortfalls of blood and/or blood components have been a wartime reality, and health care providers have needed to adapt. The principle of walking blood banks is not new; it has been documented in the literature and is an effective alternative to stored blood.4 Medical units have typed and screened assigned personnel before deployment to further augment the units’ own organic blood supply. The screening process used by the FST for this emergency blood requirement relies on donors’ answers to screening questions and the predeployment processing system. Predeployment processing is a screening evaluation completed on all military personnel before they are deployed to ensure that they are healthy enough to deploy, have received all required vaccinations, are free from communicable diseases, and have proper blood-typing documentation. For example, the screening

Table  Organization of the forward surgical team: responsibilities, capabilities, and staffing

<table>
<thead>
<tr>
<th>Section</th>
<th>Responsibilities</th>
<th>Capabilities</th>
<th>Staffing</th>
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<tbody>
<tr>
<td>Triage section</td>
<td>Triage, resuscitation, and stabilization</td>
<td>Treatment beds</td>
<td>General surgeon</td>
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<tr>
<td></td>
<td></td>
<td>Rapid infusion pump</td>
<td>Nurse</td>
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<td>Defibrillator</td>
<td>Medic</td>
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<td>Hemodynamic monitors</td>
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<tr>
<td>Operating room</td>
<td>Damage-control surgery</td>
<td>Operating tables</td>
<td>General surgeon</td>
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<tr>
<td></td>
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<td>Rapid infusion pump</td>
<td>Orthopedic surgeon</td>
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<td>Tourniquet machine</td>
<td>Certified registered nurse anesthetist</td>
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<td>Draw-over anesthesia device</td>
<td>Operating room nurse</td>
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<td>Portable suction device</td>
<td>Operating room technician</td>
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<td></td>
<td></td>
<td>Hemodynamic monitor</td>
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<tr>
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<td>Postoperative recovery</td>
<td>Treatment beds</td>
<td>Intensive care unit nurse</td>
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<td>Stabilization and preparation for transport</td>
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<td>Portable suction devices</td>
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<td>Hemodynamic monitors</td>
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<tr>
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<td>Security, medical resupply</td>
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<td>Patient tracking and evacuation</td>
<td>Communication equipment</td>
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<td>Computer interface</td>
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<td>Generator and tents</td>
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Figure 2 Portable blood refrigerator typically used by forward surgical teams.
 prevents deployment of soldiers who have a positive test for infection with human immunodeficiency virus or have other communicable diseases. Hepatitis vaccinations are a requirement for all medical personnel. Prescreening before FWB donation confirmed each donor’s general state of health, verified blood type, and completion of all required immunizations.

Walking blood banks require no refrigeration and can provide a wide variety of blood types. When the need arises for additional blood, this prearranged walking blood bank offers ready access to FWB; prescreened donors require only a rapid recertification before blood is donated. However, this type of walking blood bank has a major drawback for the FST. Donation of blood can affect some donors physically, and these donors would require time to recover, a luxury an FST cannot afford with limited personnel and 24-hour operations.

Urgent Need for Blood

Upon receiving word from the primary general surgeon that FWB was needed, we notified personnel in the base camp that a soldier was in urgent need of blood. Within minutes, a line of nearly a dozen soldiers had formed. Our blood donation collection system consisted of a primary container with 63 mL of a solution of the anticoagulant citrate phosphate dextrose and a satellite container with 100 mL of Optisol brand preservative solution for red blood cells (Terumo Medical Corp, Tokyo, Japan). We did not use the satellite container, which is used for collecting plasma and cryoprecipitate. With the primary container, approximately 450 mL of blood can be collected. The collection system includes all the required tubing and needles for collection. Blood was collected from an antecubital vein, while the collection container was gently rocked, until the container was full. During this process, additional samples were collected for further testing of the blood for hepatitis B and C viruses, human immunodeficiency virus, syphilis, and human T-cell lymphotropic viruses I and II; a donor tracking system should be in place to locate donors if indicated. After collection, the blood was immediately given to the staff caring for the patient for immediate infusion. The blood was run through a rapid fluid infuser by using blood tubing, and each unit of blood was followed by 250 mL of normal saline intravenous solution. The time from questioning of the first donor soldier to bedside delivery of the first unit of FWB was less than 20 minutes.

Discussion

In the most severely injured casualties, preventing the lethal triad of hypothermia, acidosis, and coagulopathy is paramount. FWB can be a key component in the reversal of the effects of this triad. Treatment with FWB can reverse dilutional coagulopathy associated with transfusing large amounts of preserved red blood cells. Whole blood and PRBCs differ markedly. Type O whole blood has benefits in correcting coagulopathy that may offset the inherent risks of giving FWB. FWB is readily available, can increase both red cell mass and plasma volume, and contains clotting factors, which were critical for the patient described in the case study and are not otherwise available. Levels of coagulation factors II, V, VII, IX, X, XII, and XIII and fibrinogen are well preserved in stored whole blood. In total, 1 unit of PRBCs (335 mL) plus 1 unit of platelets (50 mL) plus 1 unit of fresh-frozen plasma (275 mL) provide 660 mL of fluid with a hematocrit of 0.29, 88,000 platelets, and 65% coagulation factor activity. In contrast, 1 unit of FWB (500 mL) has a hematocrit of 0.33 to 0.43, 130,000 to 350,000 platelets, and 86% coagulation factor activity.

Whole blood transfusions are a tried and proven concept. The systemic effects—improved intravascular volume, decreased or limited third spacing, enhanced oxygen carrying capacity, and replenishment of coagulation factors—all prove the effectiveness of this therapy. Replacement solely with crys
talloids and PRBCs may aggravate coagulopathy further. Experience in treating the severely wounded in Operation Iraqi Freedom has indicated that patients may already have coagulopathy upon admission to an FST. Anecdotal evidence from health care personnel who treated trauma patients in Iraq suggests that decreased crystalloid use in the first 24 hours results in less postoperative edema and may improve ventilation and decrease duration of mechanical ventilation. During the situation discussed in this article, treatment with FWB provided the only possible solution available at the time to reverse the coagulopathy experienced by the patient.
Summary

Whole blood transfusion should be considered as an option for treatment of patients with unresponsive hypovolemic shock or coagulopathy during war or during shortages of blood components in a domestic disaster. With planning, appropriate supplies, and access to a walking blood bank, whole blood transfusion can be a safe and rapid alternative in times of critical blood shortages. Use of whole blood has played an important role in the history of war and treating wounded soldiers; its use should still be considered relevant, especially for replacing clotting components that are not readily available in a combat theater of operations. CCN

Acknowledgment

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Financial Disclosures

None reported.

References

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