

# Chapter 15

## MILITARY TRANSFUSION PRACTICE

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#### SUMMARY

#### GUIDELINES FOR INTERACTING WITH THE BLOOD-DISTRIBUTION SYSTEM

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## INTRODUCTION

Transfusion support of resuscitation and surgery in the combat zone is a cornerstone of military medicine.<sup>1-8</sup> Military doctrine includes planning for blood products and the provision of blood components in the combat zone, but it does not include implementation of patient care. This chapter describes a safe and effective transfusion service for the combat zone. It covers clinical, technical, and military aspects of planning and training, including blood component therapy, the variety of transfusion practices in the four echelons of care, the special requirements for women, and the possible impact of research on military blood programs.

Military doctrine for health service support and blood management in a theater of operations is outlined in manuals such as U.S. Army Field Manual 8-55, *Planning for Health Service Support* (FM 8-55).<sup>9</sup> The principles for transfusion practice by echelon are shown in Table 15-1. Doctrine for

availability of blood components in theater and for planning factors for blood products is shown in Tables 15-2 and 15-3, respectively. The material in this chapter outlines the implementation of doctrine.

The definition of echelons of care varies according to military service and mission; it is best viewed as a continuum of care rather than as care delivered within rigid, fixed boundaries.<sup>10</sup> In general, second-echelon units (constituted by the medical company/battalion and its organic units) support battalion aid stations, casualty collection points, and other first-echelon of care units. In the army and marines, “second-echelon” corresponds to “division-level” units (eg, clearing stations) that support the medical platoons of maneuver battalions, and the terms are sometimes used interchangeably. Second-echelon units, which are authorized to transfuse only universal-donor (ie, blood group O packed

**TABLE 15-1**  
**BLOOD TRANSFUSION PRACTICES BY ECHELON**

Echelon/ MMS	Blood Product	ABO and Rh Group	Transfusion Service Procedures	Storage Capacity	Blood Resupply
First	none	—	—	—	—
Second	PRBCs	O, Rh +/-	ABO group donor RBCs <sup>†</sup>	50 units RBC per field medical refrigerator	Third-echelon BSU
Third					
D304*	PRBCs	O, A, B, Rh +/-	ABO and Rh-group patient and donor RBCs <sup>†</sup> Major side, immediate spin cross-match	480 units liquid RBCs	Third-echelon BSU
D404*	PRBCs	O, A, B, Rh +/-	Same as D404	Same as D304, plus 475 units frozen	Third-echelon BSU
	FFP	A, B, AB, Rh +/-	None	20 units	Third-echelon BSU
	PLT	O, A, Rh +/-	None	5 units <sup>‡</sup>	Third-echelon BSU or MTF
Fourth	Same as D404	Same as D404	Same as D404	Same as D404	Fourth-echelon BSU

\*Capability to collect and perform the ABO and Rh group determination on 180 units of whole blood for extreme emergencies. D304 is liquid-only DEPMEDS module. D404 is hybrid liquid-frozen DEPMEDS module. D405 is a frozen-blood augmentation set that converts the D304 to D404 capability.

<sup>†</sup>Not necessary if Armed Services Whole Blood Processing Laboratory has verified the ABO group.

<sup>‡</sup>One unit = one 6-pack

BSU: blood supply unit; DEPMEDS: Deployable Medical Systems; FFP: fresh frozen plasma; MMS: medical material set; MTF: medical treatment facility; PLT: platelet concentrate; PRBCs: packed red blood cells

Adapted from US Department of the Army. *Planning for Health Service Support*. Washington, DC: Headquarters, DA; approved final draft January 1994. Field Manual 8-55: 8-6-8-7.

**TABLE 15-2**  
**BLOOD PRODUCTS AVAILABLE TO THE THEATER**

Product	Unit of Issue	Storage	Shelf Life for Transfusion	Echelon Availability	Blood Group Availability			
					O +/-	A +/-	B +/-	AB +/-
Liquid PRBCs	~ 250 mL	35 d	35 d	Second & third (MASH)	100%	—	—	—
				Third (CSH) & fourth	50%	40%	10%	—
Frozen/deglycerolized RBCs	~ 250 mL	10 y	3 d (postwash)	Third & fourth	100%	—	—	—
FFP	~ 250 mL	1 y	24 h (postthaw)	Third & fourth	—	50%	25%	25%
Platelet concentrate	~ 60 mL	5 d	5 d	Third & fourth	50%	50%	—*	—*

\*Will be provided by blood bank platoon and medical treatment facilities by in-theater blood collections  
 CSH: combat support hospital; FFP: fresh frozen plasma; MASH: mobile army surgical hospital; PRBCs: packed red blood cells; RBCs: red blood cells  
 Adapted from US Department of the Army. *Planning for Health Service Support*. Washington, DC: Headquarters, DA; approved final draft January 1994. Field Manual 8-55: 8-6.

red blood cells ([PRBCs]), have limited patient-holding, laboratory, and radiological capabilities. Located forward of hospitals and lacking surgical capability unless augmented by a forward surgical team, second-echelon units are strategically situated for triage, resuscitation, and stabilization of casualties before they are medically evacuated to higher echelons of care.

Third-echelon facilities (mobile army surgical hospitals [MASHs] and combat support hospitals [CSHs]) provide resuscitative and definitive surgery and have much more extensive laboratory, radiological, patient holding, and nursing support than second-echelon units. As presently configured, the MASH provides liquid group O red blood

cells, but not platelets or fresh frozen plasma (FFP). Platelets and FFP are available at CSHs as well as at the fourth echelon. MASHs, CSHs, and fourth-echelon facilities are all authorized for *emergency* collection of limited units of whole blood. Fourth-echelon facilities, such as field hospitals (FH) and general hospitals (GH), have blood banking support similar to that found in a civilian medical center.

Military transfusion therapy is directed to best meet the clinical needs of the casualty within the operational constraints of the tactical situation. The current concept of medical support within a theater of operations is being revised, and units such as MASH, CSH, GH and FH are being reconfigured.

**TABLE 15-3**  
**BLOOD PLANNING FACTORS**

Blood Component	Planning Factor
Red blood cells	4 units for each WIA and each NBI casualty initially admitted to a hospital*
Fresh frozen plasma	0.08 units for each hospitalized WIA or NBI casualty
Platelet concentrate	0.04 units for each hospitalized WIA or NBI casualty

\*For blood-planning purposes, only count the WIA or NBI once in the system, not each time the patient is seen or admitted  
 NBI: nonbattle injury; WIA: wounded in action  
 Reprinted from US Department of the Army. *Planning for Health Service Support*. Washington, DC: Headquarters, DA; approved final draft January 1994. Field Manual 8-55: 8-11.

For purposes of this chapter, *second-echelon transfusion capability* refers to the use of group O PRBCs to support resuscitation, and *third-echelon transfusion capability* refers to support of resuscitative surgery without benefit of a full, tertiary care, blood banking capability. In practice, these arbitrary guidelines blur. Resuscitation with blood remains an

integral component of surgery at any echelon, and forward surgical treatment squads may be assigned to augment a division clearing station. Conversely, a medical clearing company may augment a CSH, a MASH, or a GH to provide resuscitation and second-echelon medical support in the corps support zone or the communication zone.

## BLOOD TRANSFUSION AT THE SECOND ECHELON

Second-echelon medical units are authorized liquid group O PRBCs for initial resuscitation and stabilization. These units thus bring blood the farthest forward on the battlefield and the closest to the casualties. This approach is not new. During World War II, the need for whole blood was recognized and was at least occasionally available at clearing stations (Figure 15-1). The ideal, of course, is to provide blood as close as possible to the location where the casualty was injured, but logistical considerations make this difficult.

Second-echelon blood transfusion conforms with two principles taught in the American College of Surgeons' Advanced Trauma Life Support (ATLS) course<sup>11</sup>:

1. Resuscitation begins as soon as possible (ie, the civilian "Golden Hour", but in military medicine this critical time is much shorter; see Chapter 1, Combat Trauma Overview).
2. Resuscitation with blood is given for hemorrhage of more than 25% to 30% of a casualty's blood volume (Figure 15-2). Casualties with this degree of hemorrhage need the restoration of oxygen-carrying capability that only red blood cells provide; volume expansion with plasma, crystalloid solutions, or albumin will not be sufficient to treat hypovolemic shock.

### Transfusion Experience From Previous Wars

The transfusion of red blood cells, either for stabilization prior to medical evacuation or perioperatively, is an essential element of military medical therapy in forward locations. The experiences that follow, of U.S. Army medical officers during World War II, the Korean War, the Vietnam War, and the Persian Gulf War, all (a) describe the use of blood at the second echelon and (b) further the rationale for the use of blood in forward areas.



**Fig. 15-1.** Whole blood is being administered on 21 April 1945 to a casualty at a clearing station of the 102nd Medical Battalion during the savage Okinawa Campaign. Historically, the emphasis has been on giving blood at the surgical level; this photograph reminds us that blood can be given far forward, near the point where casualties are injured. In fact, during the D-day invasion in June 1944, U.S. Navy assault surgeons who landed with U.S. Army troops on Normandy beachheads each carried units of whole blood packed in ice, intending to administer it at the first echelon. Sources: (1) Ben Eiseman, MD, Rear Admiral, Medical Corps, US Navy Reserve (ret), Denver, Colo. Personal communication, June 1995. (2) Photograph: Reprinted from Flick JB, Raine F, Robertson RC. Pacific Ocean areas. In: Carter NB, ed. *Activities of Surgical Consultants*. Vol 2. In: Coates JB Jr, ed. *Surgery in World War II*. Washington, DC: US Army Medical Department, Office of The Surgeon General; 1964: 680.

### World War II

[T]ransfusions...were not ordinarily given in battalion aid stations or in collecting and clearing stations, though occasionally as during the rapid advance at Anzio, these installations were so far ahead of field hospitals that blood was sent to them.<sup>12(p406)</sup>

....

[I]f hemorrhage had occurred, only whole blood could meet the situation. Blood had been used extensively as far forward as battalion aid stations. Given over a 24-hour period, 5,000 cc. could completely change the appearance and outlook of a critically wounded casualty.<sup>12(p635)</sup>

....

When whole blood was immediately available as far forward as clearing companies and portable surgical hospitals, it became the practice to use plasma only when blood was not at hand.

By March of 1945, it was routine for invasion forces to carry blood ashore with them, and it was not uncommon, on reading a casualty's Emergency Medical Tag in a rear hospital, to find that he had

received 1 or more pints of bank blood at a clearing company. Some casualties received as much as 6 pints in an hour.<sup>12(p634)</sup>

....

Colonel Churchill had himself supervised the development of the program from his arrival in North Africa in March 1943. His first recommendations were the result of his personal verification of the need for whole blood by his own examination of wounded casualties in clearing stations and forward hospitals.<sup>12(p443)</sup>

### Korea

Our military surgeons have become increasingly bold in the use of blood for resuscitation of casualties.<sup>3(p439)</sup>

....

[T]he use of universal blood in the combat zone is a valuable military expedient.... Small but effective banks of blood can be established at the forward aid stations.<sup>3(p455)</sup>

....



**Fig. 15-2.** The flasks that this man and woman hold contain fluid representing approximately 25% of their blood volume, based on their gender and weight. Casualties who lose more than this amount of blood require transfusion support with red blood cells to prevent shock.

In Korea—a stable situation—we sent group O blood forward to the aid stations, where it was stored in wet ice boxes.<sup>13</sup>

### **Vietnam**

As the troop strength built up, so did the number of medical units receiving blood, ranging from front-line clearing companies to 400-bed evacuation hospitals. By February of 1966 there were 26 separate medical units receiving blood, including 15 medical clearing companies, 3 surgical hospitals etc....<sup>5(p1478)</sup>

. . . .

During the Plei Me battle, one clearing company of the 1st Air Cavalry Division handled most of the patients, giving 154 units to 94 patients, including 15 units to one soldier with wounds of the arm and throat.<sup>5(p1479)</sup>

### **Persian Gulf War**

[T]he entire concept and technical details of [administering] blood at the division clearing station have largely been ignored.... [S]ince most patients in the Vietnam war overflow clearing stations and went directly to corps-level hospitals, the institutional memory and clinical art of division blood management suffered a nearly 40-year lapse.<sup>14</sup>

### **Case Presentation**

During Operation Desert Shield of the Persian Gulf War, a 7-year-old boy stepped on a land mine near Al Nasiryah, Iraq, and suffered a near total amputation of his left leg. He was taken by his father to the aid station of 1st Battalion, 504th Parachute Infantry Regiment, 82nd Airborne Division, where bleeding was controlled and intravenous crystalloid solution administered. Despite this initial resuscitation, the child remained in shock. Air evacuation was not available, and he was transported as an emergency via ground ambulance to the medical clearing station in direct support of the brigade.

On arrival at the medical clearing station, the patient remained pale and lethargic. The pulse was more than 150 beats per minute and barely palpable at the femoral artery. The skin was cool and clammy. There was no bleeding from the wound, which was properly bandaged and splinted; two intravenous lines were open, and normal saline was being administered.

One unit of group O PRBCs was administered. The patient's mental status improved and his pink color returned. The pulse became stronger and slowed toward the normal range. A second unit of group O blood was administered and the patient transferred to a holding tent to await routine evacuation.

The management of this casualty illustrates the important role played by maintaining a blood transfusion capability in a second-echelon facility. Clinically, the child was in severe hemorrhagic shock and responded only to replacement of lost blood volume with circulating red blood cells. Large-volume resuscitation with normal saline failed to reverse shock. Plasma, albumin, or other colloid may raise blood pressure and provide temporary improvement, but fail to control shock without red blood cell replacement.<sup>6,11</sup> Logistically, after resuscitation with blood and stabilization, the patient required only routine evacuation, thus reducing the burden on aeromedical evacuation when it resumed.

### **Field Administration of Group O Packed Red Blood Cells**

Basic technical details such as supply and storage requirements; inspection, record-keeping, and inventory procedures; and clinical principles such as technique and patient evaluation must be considered when group O PRBCs are to be administered in the field (Exhibit 15-1 and Figure 15-3). The critical importance of training is discussed later in this chapter.

### **Technical Factors**

Technical factors involve maintaining appropriate transfusion supplies as well as the storage and record keeping required to maintain 30 to 60 units of blood available for transfusion. Infusion sets, normal saline, and group O blood stored in a small thermostabilizer constitute all the supplies necessary to maintain a second-echelon transfusion capability (Figure 15-4). Units of PRBCs can also be safely stored in rigid polystyrene plastic chests containing wet ice. Since all supplies can be stored in the equivalent space of two small chests, a second-echelon transfusion program is entirely consistent with the mobility of a light infantry or airborne unit. The transfusion log is essential; in it, records are kept of unit numbers, blood types, inspections, temperatures, expiration dates, and information about the recipient (Figure 15-5). However, log books are not available for field use—especially at the second echelon—and must be adapted by hand from standard-issue notebooks.

The temperature of the blood must be maintained between 1°C and 6°C—this must be ensured with daily inspections of blood stored in refrig-

**EXHIBIT 15-1****FIELD ADMINISTRATION OF GROUP O PACKED RED BLOOD CELLS****Technical Factors**

- *Required Supplies.* Infusion sets (eg, from the Blood Chest Packing List of the 307th Medical Battalion [Airborne] Sets, Kits, and Outfits Components Listing, the Chest Med Inst & Supply No. 5, National Stock Number [NSN] 6545-00-914-3500, and Blood Recipient Set Y-Type, NSN 6515-01-128-1407), normal saline, blood log books, blood refrigerator, and group O packed red blood cells (PRBCs) are required.
- *Storage.* Maintain temperature between 1°C and 6°C. Shelf life is 35 days after collection for citrate phosphate dextrose adenine (CPDA-1) PRBCs. Blood will be safe if it remains with wet ice. Consider putting blood in plastic bags to protect label legibility.
- *Inspection.* Inspect daily for temperature and for evidence of hemolysis, package breakdown, or infection.
- *Records.* For all units, record dates, unit numbers, ABO group and Rh type, expiration date, and results of daily inspection. When a unit is infused, record unit information as above, along with the date of transfusion and the casualty's name, service number, and military unit.
- *Inventory.* Maintain 30 to 60 units for a clearing station, 500 or more units at higher echelons. *Coordinate closely with the blood supplier.* Determine how quickly inventory can be reconstituted.
- *Reports.* Report information on inventory, numbers of blood groups, and expiration dates of units on hand. Figure 15-3 is sample blood report.

**Clinical Factors**

- *Technique.* Infuse intravenously using an infusion set and normal saline.
  - When group O PRBCs are used, it is not necessary to check the casualty's ABO blood group.
  - If the casualty is a woman, make sure Rh factor is correctly matched. Transfuse with Rh-negative blood if Rh factor is unknown.
- *Annotation.* Record the transfusion in the transfusion log and on the casualty's field aid card. Consider pinning the empty unit package to the casualty's clothing for transfer with the casualty to the next echelon of care.
- *Transfusion Volume.* *Follow clinical, not laboratory, criteria for response.* Look for return of pink color and blood pressure higher than 80 mm Hg systolic. Do not use field laboratory tests to guide transfusion. Consider whether the casualty is likely to be bleeding internally. Avoid excessive transfusion both to conserve blood and to possibly reduce blood loss.

ated or thermostabilized containers, or by keeping blood stored with wet ice. If placed with wet ice, the units may be first placed in a plastic bag to protect against water damage. The expiration date for PRBCs collected in citrate-phosphate-dextrose-adenine (CPDA-1) solution shall not exceed 35 days after phlebotomy. Units must be inspected daily for evidence of hemolysis and package integrity. It is crucial that the number, type, and expiration dates of all units be recorded in the daily log. The recipient's patient identification number, name, military unit, and the date should also be recorded when a unit is transfused. It is imperative that each unit received have a final record of disposition (eg, the unit was transfused, destroyed, shipped to an-

other facility, etc) and that the record be maintained indefinitely. In prior conflicts, some physicians have stored blood for up to 10 days past expiration when daily inspections remained normal for use as a last resort in a mass casualty situation. Personnel must quickly determine the frequency and format of desired reports and procedures for resupply with the blood-supply program (these are discussed later in this chapter under Planning and Training).

**Clinical Factors**

Since the major cause of transfusion reactions is the inadvertent administration of correctly typed and cross-matched blood to *the wrong patient*, it is

\_\_\_\_\_ This is \_\_\_\_\_ Blood Report Over  
 (Addressee) (Originator)

Addressee answers, then originator responds: This is \_\_\_\_\_

**FLASH**      **IMMEDIATE**      **PRIORITY**      **ROUTINE**      (Underline and transmit the precedence of this message.)  
**TOP SECRET**      **SECRET**      **CONFIDENTIAL**      **UNCLASSIFIED**      (Underline and transmit the security classification of this message.)

**BLOOD REPORT**

Line 1 (or as of) \_\_\_\_\_ (Day-time-zone of this report. Use Zulu time!)  
 Line 2 (or unit) \_\_\_\_\_ (Reporting unit's name or designator code.)  
 Line 3 (or activity) \_\_\_\_\_ (Reporting unit's activity brevity code letter.)

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Line 4 (or location) \_\_\_\_\_ (Unit location in LAT/LONG, UTM, or place name.)  
 Line 5 (or rendezvous) \_\_\_\_\_ (NAVAL VESSELS ONLY: Projected location in LAT/LONG or place name for delivery of blood products.)  
 Line 6 (or arrival) \_\_\_\_\_ (NAVAL VESSELS ONLY: Estimated time of arrival [day, time, time zone, month, year] at the projected location.)

**Lines 7–12 may be repeated as a group when more than one activity must be reported in a message.**

Line 7 (or status of) \_\_\_\_\_ (Name or designator code of the unit of activity reporting status of blood supplies if other than message originator.)  
 Line 8 (or activity) \_\_\_\_\_ (Reporting unit's activity brevity code letter if other than message originator.)  
 Line 9 (or on hand) \_\_\_\_\_ (Number and code of each blood product on hand.)  
 Line 10 (or needed) \_\_\_\_\_ (Number and code of each blood product requested.)  
 Line 11 (or expiration) \_\_\_\_\_ (Estimate of total number of blood products by group and of those that will expire in the next 7 days.)  
 Line 12 (or resupply) \_\_\_\_\_ (Estimate of total number of blood products by group and type required for resupply in the next 7 days.)  
 Line 13 (or narrative) \_\_\_\_\_  
 \_\_\_\_\_

Line 14 (or time) \_\_\_\_\_ (Message hour-minute-zone when required. Use Zulu Time!)  
 Line 15 (or authentication is) \_\_\_\_\_ (Message authentication IAW JTF procedures.)

MESSAGE MODIFIERS

- |                     |  |                |                                  |
|---------------------|--|----------------|----------------------------------|
| Management Offices: | A Joint Blood Program Office                       | Blood Groups:  | O To Be Determined               |
|                     | B Area Joint Blood Program Office                  |                | P To Be Determined               |
| Facilities:         | C Armed Services Whole Blood Processing Laboratory |                | Q Random Group and Types O, A, B |
|                     | D Blood Donor Center                               |                | R Random Group and Types O, A    |
|                     | E Blood Products Depot                             |                | S Group O                        |
|                     | F Blood Transshipment Center                       |                | T Group A                        |
|                     | G Blood Supply Unit                                |                | U Group B                        |
|                     | H Medical Treatment Facility                       |                | V Group AB                       |
|                     | I Naval Vessel                                     | Time Frame:    | W Required Within 12 Hours       |
| Blood Products:     | J Red Blood Cells (Packed)                         |                | X Required Within 24 Hours       |
|                     | K Whole Blood                                      |                | Y Required Within 48 Hours       |
|                     | L Frozen Red Blood Cells                           | Miscellaneous: | Z Not Applicable, or See Remarks |
|                     | M Fresh Frozen Plasma                              |                |                                  |
|                     | N Frozen Platelets                                 |                |                                  |

Fig. 15-3. Sample Blood Report used by the 655th Medical Company (–), USAREUR Blood Bank, Operation Desert Shield, Fall, 1990.





**Fig. 15-4.** Blood supplies and refrigerator (thermostabilizer, also called the blood box) for field transfusion of packed red blood cells (PRBCs). (a) Infusion set needed to administer blood, which should be infused with normal saline through a simple intravenous catheter. (b) Normal saline; blood should not be transfused through the same catheter with hypotonic fluid or lactated Ringer's solution. (c) The thermostabilizer is manufactured by ThermoPol, Inc, Chicago, Ill; weight: 83 lb; dimensions: 25 in. (w) x 21 in. (l) x 22.5 in. (h). This chest can be connected to either generator power or the direct current of a vehicle battery. These items, the transfusion log book and reports seen in Figure 15-5, and group O PRBCs constitute all the supplies required to run an effective second-echelon transfusion program.

imperative to use only group O PRBCs obtained through established blood program channels at second-echelon facilities. The appropriate connections between patient, infusion set, and donor unit should be mastered and practiced in advance in mock situations with simulated patients before being used on casualties.

Normal saline is the only crystalloid fluid to be infused with blood during a transfusion. Hypotonic solutions such as dextrose in water or half-normal saline can cause hemolysis. Calcium in lactated Ringer's solution will complex citrate and may cause coagulation.<sup>15</sup> The American Association of Blood Banks' *Technical Manual* recommends that lactated Ringer's solution not be infused with blood.<sup>16</sup>

The volume of blood required for transfusion is determined *clinically* and should be an amount that restores mentation, circulatory stability, pink color, and a systolic blood pressure of about 80 mm Hg to the patient. Continued infusion after these criteria have been met can promote further bleeding in patients with internal injuries, and waste limited supplies of blood.<sup>2</sup> Recent studies suggest that immediate, full-volume resuscitation may not be optimal for patients with penetrating chest injuries,<sup>17</sup> and the proper timing and amount of fluid

resuscitation is not yet known with certainty.<sup>18</sup> Laboratory tests such as measuring the hematocrit are not appropriate measures of response to transfusion in trauma patients in a field setting.

After transfusion, the unit's number and blood type should be noted on the casualty's field aid card (ie, the emergency medical tag); the empty unit should be pinned to the patient's clothing while the patient is being transported. Knowledge of the number and type of previously transfused units may be useful in guiding therapy for possible subsequent transfusions at higher echelons.

### Field Management of Transfusion Reactions

The signs and symptoms of a transfusion reaction can be subtle.<sup>19</sup> The diagnosis may be especially difficult in a field setting and in casualties with internal injuries and dirty wounds. However, abrupt fever, chills, hypotension, hemoglobinuria, hemoglobinemia (in plasma), or shortness of breath in the appropriate setting may provide sufficient evidence of hemolysis to initiate therapy (Exhibit 15-2). Infusion of the unit of blood should be stopped while the intravenous catheter remains in place infusing normal saline. Every attempt should be made to maintain blood pressure and urinary out-

### Blood Inventory Tracking Operation

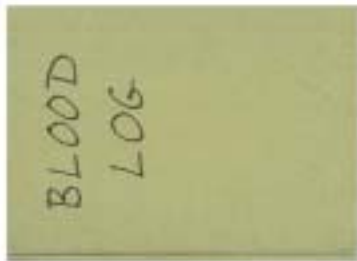
\_\_\_\_\_  
Name of Medical Care Facility

1. Unit Number	2. Expiration Date	3. Product Type	4. Cryovial Location	5. BSU	6. Medical Unit	7. Date Issued	8. Disposition Date	9. Reason	10. Method	11. Location	12. Report to JBPO

1. Input number of unit of blood
2. Input the expiration date of unit of blood
3. Input ABO/Rh of unit
4. If frozen units are deglycerolized, indicate the location of the cryovial if known
5. Indicate the name of the BSU that supplied the unit of blood
6. Medical care facility dispositioning the blood
7. Date blood was issued by the BSU, or received by the medical facility
8. Date blood was disposed or shipped
9. Indicate the reason that the blood was dispositioned (ie, expired, shipped)
10. Means of disposal (ie, incinerated, autoclaved)
11. Where the blood was dispositioned (ie, afloat)
12. JBPO will indicate date when report is received

Frequency of transmission of reports will be determined by the JBPO.

At the least, the disposition of units must be submitted on redeployment of the MTF.



### Blood Inventory Tracking Operation

\_\_\_\_\_  
Transfused Units

1. Unit Number	2. Expiration Date	3. Product Type	4. Cryovial Location	5. BSU	6. Medical Unit	7. Date Transfused	8. Patient's Name	9. Patient's SSN	10. Note	11. Report to JBPO

1. Input number of blood unit transfused
2. Input the expiration date of the blood unit transfused
3. Input ABO/Rh of unit transfused
4. If deglycerolized red cells are transfused, indicate the location of the cryovial if known
5. Input name of BSU supplying blood; if unknown, leave blank
6. Medical care facility transfusing the blood
7. Date of blood transfusion
8. If unknown, indicate nationality or branch or service (ie, Haitian 1)
9. If unknown, indicate patient's nationality (ie, Haitian)
10. Indicate the reason for the transfusion (ie, gunshot wound)
11. JBPO will indicate date when report is received

Frequency of submission of reports will be determined by the JBPO.

At the least, the disposition of transfused units must be submitted on redeployment of the MTF.

**Fig. 15-5.** Blood Inventory tracking operation reports. Blood log is a standard-issue notebook adapted for use with hand-drawn labels and report sheets. Blood Inventory Tracking Operation reports adapted from US Department of the Army. *Planning for Health Service Support*. Washington, DC: Headquarters, DA; approved final draft January 1994. Field Manual 8-55: Chap 8, Section V.

**EXHIBIT 15-2**

**FIELD MANAGEMENT OF A TRANSFUSION REACTION**

- Stop the infusion of blood. Continue to infuse normal saline through the intravenous line.
- Examine the urine for hemoglobinuria. Examine plasma for hemoglobinemia.
- Maintain blood pressure and urinary output with saline. Consider administering mannitol or furosemide after volume repletion if the patient is oliguric.
- Reexamine the donor unit for seal integrity, evidence of hemolysis or infection, and recheck the transfusion log for clerical error.
- Annotate the field medical card with a description of the suspected reaction and the therapy provided. Transfer the unit suspected of causing the reaction to the next echelon of care with the casualty.

put with continued saline infusion; if urinary output decreases, then furosemide or mannitol may improve renal function. Benadryl (diphenhydramine hydrochloride, manufactured by Parke-Davis, Morris Plains, N.J.) may be useful for treating hives and itching.

The donor unit should be reexamined for compatibility with the blood type of the recipient as

well as for evidence of infection, loss of package integrity, hemolysis, and, in winter, freezing, which can cause hemolysis. The suspected reaction and its management should be annotated both on the casualty's field aid card and in the transfusion log; if possible, the unit of blood should be transferred with the casualty during evacuation to the next echelon of care.

**TRANSFUSION SUPPORT AT THE THIRD AND FOURTH ECHELONS**

Because blood transfusion is an integral part of surgery, third- and fourth-echelon facilities perform all aspects of transfusion therapy with PRBCs described for second-echelon facilities. Third- and fourth-echelon facilities have improved laboratory and blood banking capability, and are responsible for more complex transfusion practices (Table 15-4). Some third-echelon, and all fourth-echelon facilities may be required to support surgery with random-mix instead of universal-donor group O PRBCs (see Tables 15-1 and 15-2). Compared with the use of group O universal-donor PRBCs, the use of random-mix blood greatly increases the risk of transfusion reactions and requires testing of the recipient's blood group—with attendant delays in therapy as well as increasing the requirement for laboratory testing. Random-mix blood must only be used with trained and tested personnel in authorized laboratories. Some experienced military clinicians<sup>13</sup> argue strongly that only group O universal-donor PRBCs should be available within the entire combat zone; this, however, is not present doctrine. Support with frozen blood and other blood products such as platelets and FFP may also be authorized. Finally, third- and fourth-echelon units are authorized by doctrine to perform emergency col-

lection and transfusion of blood that is collected in the field when blood products are unavailable through regular channels.

**Logistical Aspects**

The requirements for liquid PRBCs have already been described. Additional blood banking capa-

**TABLE 15-4**  
**MEDICAL LABORATORY PROCEDURES, BLOOD BANK**

Description	MASH	CSH	FH	GH
Perform blood group and type (ABO, Rh)	x	x	x	x
Perform blood cross-matches		x	x	x
Thaw fresh frozen plasma		x	x	x
Issue platelet concentrate		x	x	x

Reprinted from US Department of the Army. *Planning for Health Service Support*. Washington, DC: Headquarters, DA; approved final draft January 1994. Field Manual 8-55: 7-5.

bility for military medical facilities in the Department of Defense's Deployable Medical Systems (DEPMEDS) configurations is determined by the blood bank section. The Liquid Blood Bank Medical Material Set (MMS) D304 can store 500 units of PRBCs, and can perform ABO grouping, Rh typing, and a single-tube (major-side saline, immediate spin) cross-match on each patient. The Liquid/Frozen Blood Bank MMS D404 has the same capacity for liquid PRBCs as the MMS D304, but can also store 485 units of frozen PRBCs, 10 units of FFP, and 5 units of platelets (each unit of platelets contains six platelet packs). The MMS D404, when fully staffed and supplied, should be capable of reconstituting 180 units of frozen PRBCs in 24 hours. Both blood bank sections should be able to issue up to 250 units of banked PRBCs in 24 hours, and are authorized to collect and type 180 units of fresh whole blood for extreme emergencies.<sup>10</sup> (See Chapter 6, Deployable Hospitals, for a more complete discussion of MMSs and their use in DEPMEDS-equipped hospitals.)

The use of frozen red blood cells allows large amounts of universal-donor blood to be prepositioned at military medical facilities outside the continental United States (OCONUS), which has the theoretical potential to minimize long supply lines from CONUS. However, frozen red blood cells require storage in  $-80^{\circ}\text{C}$  freezers, as well as large volumes of sterile crystalloid, special processing equipment, trained personnel, and, after being thawed, at least 1 hour per unit to process for deglycerolization. After they are thawed, frozen red blood cells have a shelf life of only 24 hours; however, this time may be extended under emergency military conditions to 72 hours.<sup>20</sup> Although future research may improve the utility of frozen blood, at present these factors may limit its use in forward locations.<sup>20,21</sup> Frozen blood remains an integral part of doctrine. Medical officers assigned to areas that utilize frozen blood resources should be especially careful to start early, hands-on planning and realistic training to determine the system's clinical utility.

Platelets require storage at  $20^{\circ}\text{C}$  to  $24^{\circ}\text{C}$  with continuous gentle agitation, and have a 5-day viable shelf life after collection. One unit of FFP contains one unit of all clotting factors per milliliter, and must be stored at  $-18^{\circ}\text{C}$  or colder. FFP has a shelf life of 12 months when stored at this temperature and must be administered within 24 hours after being thawed. Given these constraints, the availability of FFP and, especially, platelets may be limited in the combat zone.<sup>9</sup>

## Effect of Massive Transfusion

Resuscitation and surgery of the severely wounded casualty may require large amounts of blood. Massive, large-volume transfusions can rapidly reduce a medical treatment facility's blood supplies. This may also lead to subsequent difficulties in patient management, including dilutional coagulopathy and selection of appropriate blood group for further transfusion. The management of a dilutional coagulopathy is described in Chapter 14, Transfusion Therapy.

The *subsequent* transfusion management of the patient who survives surgery with massive transfusion requires that attention be paid to both the patient's ABO blood group and the blood group of the units previously transfused.<sup>22</sup> Patients with A, B, or AB blood groups who have received more than 4 units of group O whole blood, or 8 units of group O PRBCs, should be transfused with group O blood if further transfusions are needed for at least 2 weeks or until their serum is compatible with the donor blood type as determined by a full compatibility test.<sup>22,23</sup>

## Emergency Collection and Transfusion of Whole Blood Donated in the Field

Collection and transfusion of fresh, whole blood in the field (authorized by doctrine at third- and fourth-echelon facilities *under emergency conditions only*) is a source of platelets, plasma, and red blood cells. Because whole blood contains plasma with antibodies to the antigens not present on the donor's red blood cells, it is necessary to do full ABO group determination on both the donor's and the recipient's blood. The principles involved in performing an emergency collection of whole blood in the field are outlined in Exhibit 15-3.

When performing an emergency collection, a key factor is the potential risk of infection. Infections may be caused by viruses (such as the human immunodeficiency virus, parvovirus, or hepatitis) or other organisms (such as those that cause malaria or syphilis) transmitted via the donor's blood, or bacterial skin flora contracted by the use of improper sterile technique. Sterility is best ensured by using (a) Betadine Solution (povidone-iodine, 10%, manufactured by Purdue Frederick, Norwalk, Conn.) to scrub the donor's arm and (b) the appropriate collection technique. Blood must be collected into a sterile, closed, blood-collecting and -dispensing bag. Because blood is a fertile culture medium, small amounts of contaminating bacteria may grow rap-

**EXHIBIT 15-3****EMERGENCY COLLECTION AND TRANSFUSION OF BLOOD DONATED IN THE FIELD**

This collection and transfusion technique should be used in extreme emergencies after all efforts to obtain adequate supplies of blood collected by blood banks have failed. Emergency collection should *never* be performed in lieu of securing blood through normal channels. Although the following information is provided so that the technique can be performed as safely as possible in this contingency, the emphasis should be on careful planning to obtain an adequate supply of blood-bank-procured blood.

**Donor Factors**

Lab tests for transmissible infection may not be available in the field. Careful screening of a donor's *risk* for infection is thus essential. Strongly consider recruiting volunteers who were active blood bank donors prior to deployment—their blood and their risk for infection will have been checked repeatedly during that period. Recognize that military units may place pressure on their members to donate; give a donor a chance to decline in private in case he or she is unwilling to admit to potentially risky behavior. Donations may be obtained every 6 to 8 weeks from healthy male donors. After donating, the donor should be given oral fluid replenishment and, if possible, light duty for 12 to 24 hours. Donors screened in the field should be questioned regarding the following topics:

- history of intravenous drug use,
- history of hepatitis,
- history of high-risk sexual behavior,
- exposure to malaria, dengue fever, or recent febrile illness,
- prior blood transfusion, and
- prior or current pregnancy.

**Collection Factors**

Scrupulously scrub the donor's vein with Betadine Solution (povidone-iodine, 10%, manufactured by Purdue Frederick, Norwalk, Conn.). The collecting unit is a closed system, with a measured amount of sterile anticoagulant and preservative already in place. A volume of 450 to 500 mL should be collected. The unit of whole blood should be cooled immediately and used as soon as possible. Assign the collected unit an identification number, and enter the number in the blood log. A tube of serum from the donor should be saved indefinitely for future testing and tracking. The appropriate supplies, listed below, must be available in advance:

- blood collection sets;
- Betadine swabs to sterilize the collection site;
- appropriate markers to label and identify the collected unit;
- typing sera for groups A and B blood, which must be kept cool with blood in the refrigerator;
- glass slides, mixing swabs, wax pencils, and lab slips;
- purple-top blood tube (containing ethylenediaminetetraacetic acid [EDTA] anticoagulant); and
- red-top tube for serum sample.

**Transfusion Factors**

Transfusion of whole blood must be fully ABO specific because the plasma in the donor's blood may have high levels of antibodies to the recipient's antigens. (Universal-donor group O whole blood, as used in the Korean and Vietnam wars, was checked to ensure that the antibody titer was not elevated prior to shipment to a combat zone.) Full blood typing, with determination of Rh, and cross-matching should be performed on both the donor unit and the recipient.

idly, especially if the unit is warm and not used immediately. Thus, scrupulous sterile technique is essential, and the collected unit should be labeled, cooled, and used as soon as possible. The collected

unit should (a) be given a unique unit-identification number (eg, the social security number of the donor) and (b) be added to the blood inventory and disposition records.

Currently, laboratory tests to screen the donor unit for infectious diseases are not available in the field setting, although some may be developed in the near future. *Questions to determine the donor's potential risk for transmissible infections* (eg, a history of drug use, high-risk sexual behavior, hepatitis, or recent febrile illness) are thus *critical to selection of the safest donor in a field environment*. Current policy mandates that a sample tube of serum from the donor be retained and stored for future testing and tracking if necessary. The physician should also consider a potential donor's time in country and possible exposure to endemic disease such as malaria.

The individuals who can most safely donate are those who give a negative response to these questions and who have been successfully screened and used as regular blood donors prior to deployment. Although there will be heavy peer pressure on potential donors to provide blood for their wounded comrades, they should be given a chance to decline in private, according to procedures established in civilian blood banks. Again, the technique of emergency collection and transfusion of whole blood should only be used under dire circumstances when there is absolutely no other source of blood and when the casualty would die without transfusion.

### MILITARILY UNIQUE CONSIDERATIONS

The administration of group-specific blood, proper use of identity tags, and clinical relevance of the Rh blood group for female casualties pose challenges for military physicians in the combat zone. Research is active and the development of new products and technology can be anticipated. Integration of these factors into appropriate planning and training exercises is critical to successful military transfusion practice.

#### Group-Specific Transfusion and Random-Mix Blood

Universal-donor group O PRBCs are the optimal resuscitation fluid for a combat casualty; however, the supply may be limited in a combat zone. Liquid group O PRBCs comprise only 50% of blood collected and shipped to a combat zone. Because second-echelon units are authorized by doctrine to receive only group O PRBCs, the supply of universal-donor group O PRBCs may be more limited at third- and fourth-echelon units, and may become limited at second-echelon facilities during peak demand for blood.

Group-specific transfusion refers to blood that is matched on the basis of the donor's and the recipient's ABO groups alone. Random-mix blood refers to a supply of PRBCs that has been collected from donors of all blood groups. Administration of group-specific, random-mix blood requires correct determination of the recipient's ABO blood group *and* the correct administration of the appropriate unit to the recipient. In contrast, group O PRBCs may be transfused in an emergency without regard for either testing the recipient<sup>24,25</sup> or matching the appropriate unit with the recipient.

The determination of the recipient's blood group and the safe transfusion of random-mix blood un-

der combat or mass casualty conditions, even with the laboratory capability of a fourth-echelon tertiary facility, require extensive, careful planning and training. The potential risks and logistical problems may be understood by considering the nature of the ABO blood groups.

The ABO blood groups are named for the antigen or antigens that are present on the surface of red blood cells (Figure 15-6).<sup>26</sup> Shortly after birth, we develop immunoglobulin (Ig) M antibodies directed against the antigen or antigens that are not present on our own red blood cells. Thus, individuals with group O blood have neither the A or the B antigen present on their red blood cells, but have antibodies against both A and B antigens in their plasma. Individuals with group A blood have only the A antigen present on the red cells, and have antibodies to the B antigen in the plasma. These IgM antibodies are present shortly after birth and efficiently activate complement when combined with antigen. An ABO-mismatched transfusion is immediately life-threatening and may cause hemolysis, hemoglobinuria, hypotension, renal failure, and death.<sup>19</sup>

Group O PRBCs, which comprise approximately 40% to 50% of the blood supply, can safely be infused into casualties of any ABO blood group regardless of the recipient's blood group. Group O *whole* blood, which was used as universal-donor blood during World War II and the Korean and Vietnam wars, can also be safely infused if special laboratory techniques demonstrate that the donor plasma (which is infused with the unit of whole blood) does not have high-titer anti-A or anti-B antibodies.<sup>5,12</sup> However, transfusion of whole blood or PRBCs of the A, B, and AB blood groups can only be given to casualties who have these same blood antigens present on their red cells. Thus, transfusion of PRBCs of any blood group other than O

**ABO Frequency and Compatibility**

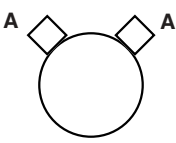
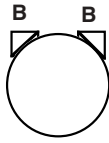
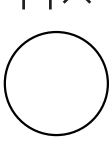
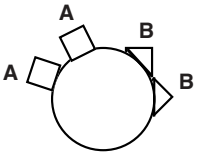
Blood Type	<b>A</b>	<b>B</b>	<b>O</b>	<b>AB</b>
Frequency in Population	45%	10%	40%	5%
<u>Antibodies</u> IgM Present from Infancy	Anti-B	Anti-A	Anti-B and Anti-A	No Antibodies
Red Cell Antigens				
Can Donate Packed Cells to:	A, AB	B, AB	Universal Donor (A, B, AB, O)	AB
Can Receive from Transfusion:	A, O	B, O	O	Universal Recipient (A, B, O, AB)

Fig. 15-6. The nature of blood and the ABO blood groups.

requires knowledge and confirmation of both the recipient's and the donor's blood groups.

**Identification Tags**

Determination of blood groups for identification tags (ie, dog tags) is not done in medical laboratories, and there may be a 3% to 6% error rate in either the ABO or the Rh blood groups,<sup>27</sup> although a recent study<sup>28</sup> indicates that the risk may be lower. During World War II, however,

when blood had to be given in emergencies in forward hospitals and tests for compatibility were impractical, the blood group of the recipient had to be accepted on the basis of his identification tag, in which the known error was from 5 to 25 percent.<sup>12(p429)</sup>

Previously, these percentages of error had been acknowledged in the context that dog tags were designed only to identify *potential* donors and were not designed to be used for transfusions on individual patients.<sup>12,27</sup> However, even contemporary medical officers who are unfamiliar with this philosophy may assume that identity tags are provided to guide transfusions without confirmatory testing, as World War II-era medical officers did:

Circular Letter No. 170, Office of The Surgeon General, War Department, Services of Supply. In this letter [dated 2 December 1942], it was pointed out that the policy of blood grouping of military per-

sonnel and its purpose seems to have been misunderstood by some medical officers.... [T]he assumption that the first [dog tag or identification tag] typing test would be the only one performed was based on a false premise. To correct the misconception it was pointed out again that the purpose of the program was to simplify assembling donors whose blood would probably crossmatch with that of intended recipients.<sup>12(p235)</sup>

....

Our physicians were amazed to learn, well into development of our blood program, that the error rate in dog tags was as high as 5–10%, and that dog tags were not designed to be a field expedient means to transfuse random mix blood. We also found that we did not know the blood type for civilian casualties.<sup>29</sup>

In addition, civilian casualties will not have identity tags, which further illustrates the inappropriateness of using identity tags for type-specific blood transfusion.

Finally, identity tags may be used in the future in second-echelon facilities, which use universal-donor group O PRBCs, to match the Rh group of the casualty with that of the donor unit (this subject is discussed in greater detail later in this chapter). Priority for Rh-negative blood will be given to female casualties.<sup>30</sup> This strategy would (a) decrease exposure and sensitization of Rh-negative female casualties to Rh-positive blood, (b) represent a significant change in the doctrinal use of identity tags,

and (c) require improved testing capability and further education and training.

### Female Casualties and Rh Blood Groups

Military medical officers must carefully consider the relevance of the Rh blood group system and the different clinical implications of Rh-mismatched blood transfusions when administered to male or to female combat casualties. The Rh blood groups and antibodies differ clinically from those in the ABO system; they were not identified until more than 30 years after discovery of the ABO blood groups, when they were determined to be the major cause of hemolytic disease of the newborn. Approximately 85% of the population is Rh positive; 15% is Rh negative.<sup>31</sup> Acute intravascular hemolytic reactions in Rh-mismatched transfusions are rare, because antibodies formed against Rh antigens are IgG, and unlike IgM-ABO antibodies, do not activate complement efficiently. Additionally, these IgG antibodies appear in Rh-negative patients only after exposure (ie, sensitization) to Rh-positive blood and are not present from birth like the antibodies to ABO antigens. Sensitization occurs most frequently in Rh-negative women after exposure to the blood of an Rh-positive fetus at childbirth. Rh-mismatched transfusion reactions are thus usually not immedi-

ately life threatening, and are manifest by chronic, extravascular hemolysis that appears several weeks after exposure to Rh-positive blood. However, unlike ABO antibodies, these IgG antibodies do cross the placenta, and, in the Rh-positive fetus of an Rh-negative, previously sensitized mother, will cause chronic extravascular hemolysis or hemolytic disease of the newborn (Figure 15-7).

Thousands of Rh-negative male combat casualties have been transfused with Rh-positive blood without clinically significant consequences.<sup>5,12</sup> There is a much smaller experience with transfusion of Rh-mismatched blood to female civilian trauma casualties,<sup>32,33</sup> including cases that have resulted in legal action.<sup>34</sup> In the future, medical officers will likely care for more female casualties in combat. Some major clinical factors that should be considered are discussed in Exhibit 15-4.

### Active Research Efforts

A major goal of military research is to develop blood products for field use, thus providing essential support for resuscitation of the wounded soldier immediately or within the first few hours after the injury is sustained. The research and development for such products is being conducted in universities, by the American Red Cross, and in



**Fig. 15-7.** The consequences of administering Rh-positive blood to Rh-negative women are not immediately apparent but neither are they benign. This third-trimester fetus died of chronic hemolytic disease of the newborn, which occurs in Rh incompatibility when an Rh-positive fetus is conceived in an Rh-negative, but sensitized, mother. The immunoglobulin G antibodies in the mother's blood cross the placenta and cause chronic hemolysis with hyperbilirubinemia and enlargement of the fetus' blood-forming organs. Antibodies to Rh groups form only after an Rh-negative individual is exposed to Rh-positive blood. This occurs most commonly in women after they give birth to an Rh-positive child. *Sensitization and antibody formation will also occur in Rh-negative battlefield casualties who receive transfusions of Rh-positive blood.* Owing to the relative frequency of Rh-negative individuals in the general population, Rh-mismatched blood transfusions have been given widely in prior wars; however, the casualties were male. In both men and sensitized women, the immediate consequences of an Rh-mismatched transfusion are clinically mild and at the time of future surgery can be managed routinely with modern blood banking techniques. However, women who are sensitized will be at risk for severe complications of pregnancy in an Rh-positive fetus. Photograph: Courtesy of Colonel John Pierce, MD, Medical Corps, US Army; Chief of Pediatrics, Walter Reed Army Medical Center, Washington, DC.



**EXHIBIT 15-4****TRANSFUSION SUPPORT OF FEMALE COMBAT CASUALTIES: CLINICAL IMPORTANCE OF THE R<sub>H</sub> BLOOD GROUP****Universal-donor blood is used for resuscitation in the field.**

Blood typing and cross-matching are not feasible in forward combat mass casualty situations. Universal-donor transfusions, defined as group O without Rh specificity, have been safe and effective when administered to male casualties in prior conflicts. During World War II, experience with multiple Rh-incompatible transfusions demonstrated that serious reactions to Rh-incompatible blood were rare in men, although the survival of incompatible red cells was poor.<sup>1</sup> In Vietnam, over 100,000 universal-donor transfusions were given without a single fatal reaction.<sup>2</sup>

**Rh-positive blood is used in universal donor transfusions.**

All group O units shipped to Korea were Rh positive.<sup>1</sup> Group O, Rh-negative blood was distributed to fixed hospitals in Japan. This policy was developed to maintain Rh-negative blood at facilities with the capability to identify Rh-negative individuals and to prevent further transfusions with Rh-incompatible units. Current doctrine does not discriminate between Rh-positive and Rh-negative group O units distributed for universal transfusion at forward units. Thus, 85% of all units transfused in these areas will be Rh positive.

**Women deployed to forward combat units who require transfusion may therefore receive Rh-incompatible blood.**

Using manpower data from the Persian Gulf War<sup>3</sup> and current military doctrine,<sup>4,5</sup> up to 10% of universal donor transfusions given to female casualties are predicted to be Rh incompatible (ie, Rh-positive blood is transfused into an Rh-negative recipient).

**Rh-incompatible transfusions in women can be less efficacious and cause anti-Rh antibodies that compromise future pregnancies.**

Approximately 35% of deployed women have been pregnant.<sup>3</sup> If sensitized, Rh-incompatible cells will survive poorly in these women and cause a delayed transfusion reaction. Virtually any Rh-negative patient transfused with Rh-positive blood develops anti-Rh antibodies. IgG anti-Rh antibodies can cross the placenta during future pregnancies and cause severe, fatal consequences to the fetus.

**The risk of transfusing Rh-incompatible blood to women can be minimized.**

Based on the supply of O-negative blood and the number of expected female casualties, adequate stocks of O-negative blood should be available to transfuse most female casualties who receive universal-donor transfusions. In the future, development of hemoglobin-based oxygen carriers, enzymatic removal of Rh antigen from stored liquid red cells, or improved logistical aspects of frozen group O, Rh-negative blood may decrease the incidence of Rh-incompatible blood transfusion. At present, in situations where a casualty's Rh blood group cannot be determined, reserving Rh-negative units whenever possible for transfusion to women will not expose men to any more danger than in prior wars but will limit the dangers involved to women. Department of Defense policy is now being revised to call for using identity tags to match the blood type and Rh factor of the donor unit and the recipient in forward mass casualty situations where universal-donor group O blood is used.<sup>6</sup> NOTE: identity tags should *never* be used to match the ABO blood group of donor and recipient.

(1) Kendrick DD. *Blood Program in World War II*. Washington, DC: Department of the Army, Medical Department, Office of the Surgeon General; 1964: 748. (2) Camp FR, Conte NF, Brewer JR. Military blood banking 1941–1973: Lessons Learned Applicable to Civil Disasters and Other Considerations. Fort Knox, Ky: US Army Medical Research Laboratory; 1973. (3) Schefflen KC. Defense Manpower Data Center, Monterey, Calif. Personal communication, 21 April 1990. (4) Scotti MJ, chairman. Defense Medical Standardization Board. *DEPMEDS Policies/Guidelines: Treatment Briefs*. Fort Detrick, Frederick, Md: Defense Medical Standardization Board; 1990. (5) Rosenblatt MS, Hirsch EF, Valeri RC. Frozen red blood cells in combat casualty care: Clinical and logistical considerations. *Milit Med*. 1994;159:392–397. (6) Joseph SC, Assistant Secretary of Defense (Health Affairs). *Policy for the Use of ID Tags and ID Cards for Emergency Transfusion at the Second Echelon of Medical Care and the Validation of Those Parameters*. Washington, DC: Department of Defense. Memorandum for Secretaries of the Military Departments, Chairman of the Joint Chiefs of Staff, 21 April 1995.

Exhibit prepared for this textbook by Janiine Babcock, MD, Major, Medical Corps, US Army; Blood Research Detachment, Walter Reed Army Institute of Research, Washington, DC 20307-5100.

the commercial sector, as well as through research programs in the U.S. Army and the U.S. Navy. An essential ingredient for the rapid success of these efforts is close communication among these organizations so that appropriate information can be shared and duplication of effort does not occur.

Current efforts are mainly directed toward improving the shelf life and storage properties of PRBCs or developing a blood substitute to simplify

the use of blood on the battlefield. Other efforts are directed toward improving early hemostasis and improving access to platelets and other blood products at third- and fourth-echelon areas (Exhibit 15-5). Some of these goals may be met without developing new technology by adapting existing technology to the field environment. One method could be the use of portable blood pheresis units to produce platelets and FFP without removal of the donor's red blood cells (Figure 15-8 and Exhibit 15-6).

## EXHIBIT 15-5

### DEVELOPMENT OF BLOOD PRODUCTS FOR FUTURE FIELD USE

The following blood products and specific component therapies are being developed for field use:

#### Hemoglobin-Based Oxygen Carriers

A temporary replacement for red cells in the field may be hemoglobin-based oxygen carriers. These might be prepared in solutions of 10% virally inactivated hemoglobin that has been cross-linked to avoid the dissociation of the 64-kd tetrameric form into 32-kd dimers, which can induce renal failure. The hemoglobin can be purified from human red blood cells or produced in a recombinant form; hemoglobin that has undergone polymerization in addition to cross-linking (or that has been encapsulated in liposomes) appears to have a prolonged survival time in the circulation and to have reduced vasoactivity. Thus, multiple products or forms of hemoglobin may eventually be licensed. Such products, which are being produced by at least four companies, are in phase I or phase II clinical trials in the United States and abroad. Hemoglobin-based oxygen carriers could presumably be used in liquid form in the second echelon; perhaps, for ease of storage, they could also be prepared in lyophilized form as well.

#### Platelets

The short, 5-day dating period for platelets, as well as the requirement that they be maintained at 22°C with continuous gentle agitation, precludes their use in far-forward positions. The ideal platelet preparation would be one that could be virally inactivated and then (a) lyophilized under controlled conditions and (b) reconstituted and infused. Alternatively, platelet concentrates could be stored indefinitely in a frozen form utilizing nontoxic cryoprotectants; they could then be thawed and directly infused into recipients.

#### Fibrin Sealant

Fibrin sealant comprised of purified, virally inactivated human fibrinogen and human thrombin is now commercially available in Europe and Canada, although the product has not been approved for use in the United States by the U.S. Food and Drug Administration. Fibrin sealant could be used on the field, delivered on bandages to control massive bleeding from organs such as the liver or spleen or from open wounds. Such preparations in cruder form were actually used successfully during World War II. Once such preparations are licensed, their use will undoubtedly be extended to many types of surgical situations.

#### Plasma

Plasma that has undergone viral inactivation by pasteurization or by solvent detergent treatment is now available in other countries. Such plasma could be prepared in freeze-dried form and then reconstituted in the field for treatment of casualties.

#### Modifications in Red Blood Cell Storage

Efforts are being made to extend the survival of PRBCs up to 6 to 8 weeks after collection, thus allowing longer storage time after reaching their destination in the theater of operations. Additional research efforts include (a) prolonging the storage time of frozen cells that have undergone deglycerolization and (b) converting the Rh(D) antigen to produce Rh-negative cells.

Exhibit prepared for this textbook by Barbara Alving, MD, Colonel, Medical Corps, US Army; Chief, Department of Hematology and Vascular Biology, Walter Reed Army Institute of Research, Washington, DC 20307-5100.



**Fig. 15-8.** Collection of platelets with a portable pheresis unit from a volunteer donor in a Department of Defense Deployable Medical Systems (DEPMEDS) environment. Approximately 2 hours are required for the donation. The pheresis unit uses generator power and is the size of a medium-sized television set. A volume of platelets equivalent to a six-pack was collected from this single donor, but the red blood cells were returned. Platelets can be collected in this fashion every 2 weeks.

## EXHIBIT 15-6

### HEMOPHERESIS: A FUTURE SOURCE OF PLATELETS IN THE FIELD?

The need for platelets during contingencies is small; however, there are times when platelets are required to save lives. Because platelets have only a 5-day storage life, it is very difficult to transport them from the continental United States to other parts of the world within the time allowed. Current research is investigating ways to extend the shelf life of platelets to longer than 5 days (see Exhibit 15-5), although final development and licensure by the U.S. Food and Drug Administration may take years.

In the meantime, the only way to provide platelets in the field has been emergency donor collections of whole blood at field hospitals. This form of collection has increased risks due to the inability to pretest the donors for transfusion-transmitted diseases, and many donors must be available to provide enough platelets for even one casualty.

To minimize the need for this form of collection and to alleviate risks and reduce stress, the U.S. military is studying the possible use of portable plateletpheresis capabilities for use in the field. Today's technology has plateletpheresis machines that are very light (55 lb), durable, and easy to transport. One plateletpheresis donor unit has the equivalent of platelets obtained from six to eight regular whole-blood donors. This scheme has several advantages:

- Pretested donors can be ready to donate, allowing for a safer product.
- Fewer donors are required, as plateletpheresis donors can donate every 3 to 7 days, compared with 8 weeks for regular blood donors.
- A superior product is provided, virtually free from red blood cells and more concentrated, reducing possible inadvertent hypervolemia.

The disadvantages include the following:

- Laboratory technicians must be trained to do plateletpheresis, which is a time-consuming and expensive process.
- Approximately 1.5 to 2 hours per patient is required for each plateletpheresis donation.

A concept that may possibly be used in the future is having plateletpheresis capability on hospital ships and at army blood supply units. These units would then supply other third- and fourth-echelon hospitals with platelets when emergency situations require.

## PLANNING AND TRAINING

A successful military transfusion program must blend operational, clinical, and blood-distribution system factors (Figure 15-9), each of which requires consideration of these three critical elements:

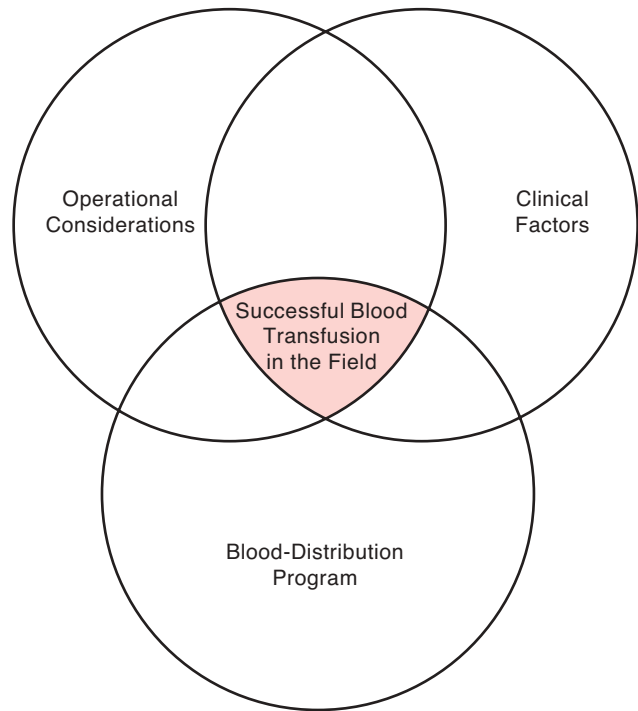
1. education of personnel, with hands-on, realistic training,
2. review of doctrine in FM 8-55 and other manuals, and
3. real-time interaction with the blood-distribution system before and during the deployment.

Detailed guidelines for interacting with the military blood-distribution program have been prepared for this textbook; these are included at the end of this chapter.

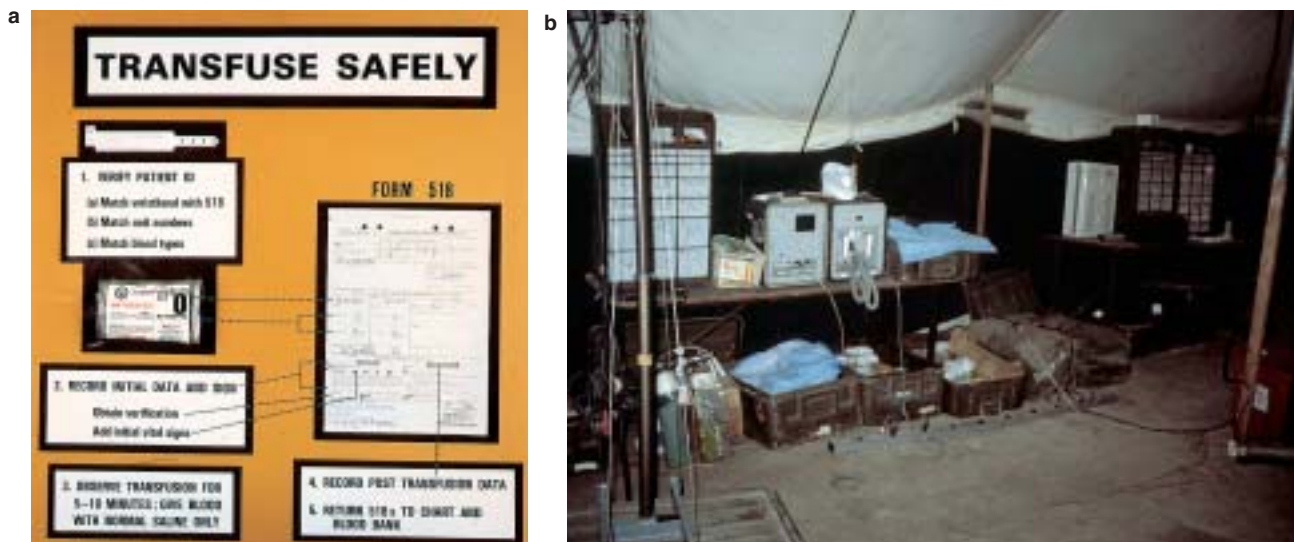
### Adjustments From Civilian Medicine

The needs and practices of military medicine require that medical officers make both a philosophical and a clinical adjustment (Figure 15-10). After they have been educated, leaders should review doctrine and incorporate blood product management into their training exercises.

Leaders from prior wars with experience in planning and training for a military blood transfusion



**Fig. 15-9.** Planning and training for a successful military transfusion program. Operational, clinical, and blood-distribution program factors must blend together smoothly and should be incorporated into all training exercises.



**Fig. 15-10.** Military hospital and field transfusion environments. (a) The poster describes safe transfusion practice in the hospital; after the medical officer orders the blood, the entire process is handled by other medical personnel such as nurses and laboratory workers. (b) In the resuscitation tent of a clearing station, the medical officer will not have access to the hospital personnel who routinely handle the blood (as indicated in the poster). When medical officers move from the hospital to the field, they must adjust not only to the changes in physical environment but also to the absence of these personnel.

program have described the philosophical and clinical readjustments they found necessary as they made the transition from civilian to military medicine:

Division clearing stations are not emergency rooms. Ambience is different, triage is different, problems are different. The rules must be different and the reasons for this must be part of the indoctrination of the medical officers in the combat zone and the pathologists who operate the blood supply.<sup>13</sup>

.....

[From World War II:] Intravenous therapy (transfusion therapy) is a medical specialty, training in which is not provided in a routine medical education.... [T]he civilian physician, if all goes smoothly, is completely unaware of the organization and painstaking control that make the use of parenteral fluids safe. When, however, he enters the Medical Corps, he is called upon to practice more intravenous therapy than he employed in civilian life.... Military medicine presents special problems in intravenous therapy as compared with civilian practice: the incidence of shock, hemorrhage, and burns is many times greater, as is their severity. In their treatment, the methods of civilian medicine must be modified by considerations of transport, equipment, and environment.... If a medical officer were to attempt to accumulate a store of whole blood, he would find that none of the methods in use in civilian practice could be applied directly to his military problem without modifications.<sup>12(p77)</sup>

.....

[From the Persian Gulf War:] Modern physicians

don't handle blood.... It has become so specialized that physicians (clinicians) have lost experience dealing with blood. The contemporary technical information available on blood management was focused largely on theater and corps hospital blood receipt and storage.<sup>14</sup>

### Hands-On Practice: Lessons Learned, Lost, and Learned Again

Hands-on training at the patient level is critical to the successful implementation of military transfusion practice (Figure 15-11). Medical personnel should walk through demonstrations that simulate transfusing blood to mock casualties in realistic training situations, including mass casualty exercises. Blood and the appropriate supplies should be taken to the field during training, and all daily inspections, inventories, and reports performed. The senior medical officer at the Second-Brigade Clearing Station during the Persian Gulf War (1990–1991) recalls:

We maintained a blood capability in our clearing station for a 3-month period before the ground war started. Our resupply of blood was frequently random-mix, with expiration dates only a few days from the date of our receipt. Our biggest advantage was having practiced a random-mix scheme at division level, and knowing that it was highly unsatisfactory; we therefore insisted on group O blood, often returning to the blood-supply unit several times to obtain it.

When I returned to the 82nd as Division Surgeon less than 3 years after the Persian Gulf War, medics



**Fig. 15-11.** Hands-on practice with second-echelon blood transfusion. Soldiers of B Company, 307th medical battalion, 82nd Airborne division, practice their division-level blood transfusion program. The “combat casualty” is simulated.

had already stopped practicing with blood because it was not "safe." During one exercise, I noted that the blood was in our forward (alpha) echelon; however, the infusion sets were in our second (bravo) echelon. The soldiers who had done the packing had never administered a unit of blood.

For our airfield seizure role at present, our planning is much simpler: we jump in with group O blood in ice and melted water in Styrofoam boxes. There is occasionally some difficulty obtaining blood prior to jumping, but not so much as during the Persian Gulf War because now we are the only game in town.<sup>35</sup>

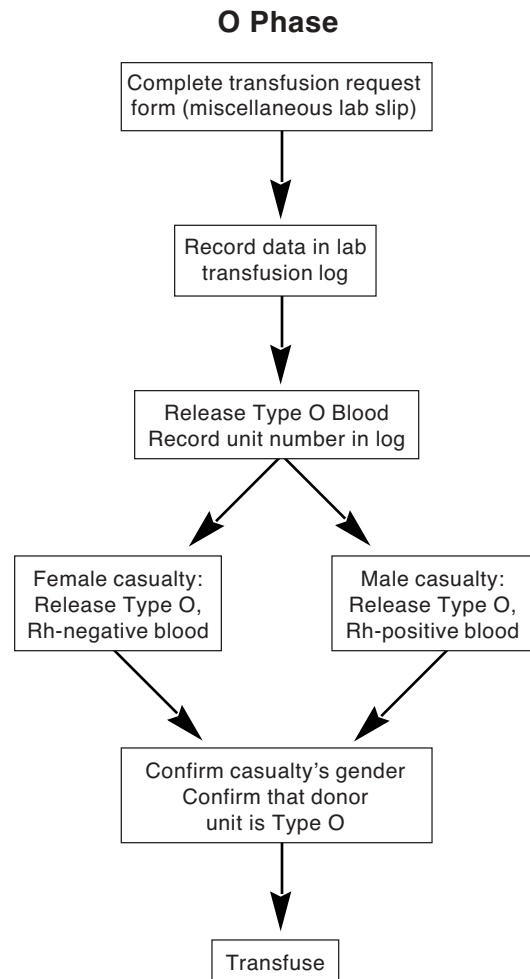
And during Operation Restore Hope in Somalia (1993), an emergency blood drive was performed to obtain plasma and platelets for a patient who was hurt in a vehicle accident. The 86th Evacuation Hospital laboratory personnel did an excellent job and saved a life. In their afteraction review, they stated that they were not as well trained as they

should have been but understood that it is difficult to train for specific emergency conditions. They also stated that trying to collect blood at a time of extreme emergency, with little time, is very difficult and stressful, especially when there also are increased demands placed elsewhere in the laboratory.<sup>36</sup>

### A Second-Echelon Transfusion Strategy

Figure 15-12 depicts a strategy that was developed for transfusion of blood for male and female casualties in the 82nd Airborne division during the Persian Gulf War.<sup>37</sup> At this time, division clearing stations were supported by the 307th medical battalion and could be augmented with a forward surgical support team. At the onset of deployment, group O PRBCs were in short supply, and division units frequently received random-mix blood. Initially, an A/O system, as had previously been used in Vietnam, was chosen, owing to a shortage of

**Fig. 15-12.** This second-echelon blood transfusion program was developed for men and women in the 82nd Airborne division during the Persian Gulf War. Group O packed red blood cells (PRBCs) were used. In this setting, no determination of the recipient blood group was necessary. Data were recorded and the unit transfused. Women were to receive Rh-negative blood and men Rh-positive blood. When universal-donor blood was not available in the early stages of the deployment, and only random-mix blood was available, an A/O phase was planned. After practicing the A/O system, division medical companies carried only group O blood and used the system illustrated here. The A/O system, which was intended to be reserved for use only in emergencies, was never actually used.



**EXHIBIT 15-7****NEW POLICY FOR USING IDENTIFICATION TAGS AND CARDS FOR EMERGENCY BLOOD TRANSFUSION AT THE SECOND ECHELON**

On 21 April 1995, the Assistant Secretary of Defense for Health Affairs issued a memorandum for the secretaries of the military departments and the chairman of the joint chiefs of staff to establish new Department of Defense policy for transfusing Rh-negative blood and for using identification tags and cards for second-echelon blood transfusions:

Effective immediately, during contingencies, the Services will provide Rh negative packed red cells to Rh negative male and female patients based on the Rh blood type on their ID tag or card at the second echelon of medical care. Third echelon and higher level of care medical treatment facilities have the capability and are expected to group, type and crossmatch blood with group specific Rh negative packed red cells selected for both Rh negative female and male patients prior to transfusion. Priority of Rh negative blood for transfusion should be given to Rh negative females if shortages of Rh negative blood arise. This new policy will also reduce the same sensitization to Rh negative males, although the impact of sensitization on males and the health care system is not as great.

With implementation of the above policy and as a result of acceptable high error rates of the ABO group and Rh type placed on ID cards and tags, it is imperative that the Services review their procedures for verifying and validating that the ABO group and Rh type on each service member's ID tags and cards matches laboratory testing results as documented in each service member's medical records. These procedures should also require that this verification be performed during the processing just prior to deployment.

The Services are to implement this policy immediately and provide their plans for verifying and validating service members' ID tags and cards concerning blood groups and types within 60 days of the date of this memorandum.

Reprinted from Joseph SC. Assistant Secretary of Defense (Health Affairs). *Policy for the Use of ID Tags and ID Cards for Emergency Transfusion at the Second Echelon of Medical Care and the Validation of Those Parameters*. Washington, DC: Department of Defense. Memorandum for Secretaries of the Military Departments, Chairman of the Joint Chiefs of Staff, 21 April 1995.

universal-donor PRBCs for use at the division level. We decided to transfuse female casualties with Rh-negative blood and to use Rh-positive blood in males, as had been practiced previously.

Since this deployment, new policy is being established to transfuse group O PRBCs to casualties at the second-echelon, according to the Rh group on their identity tags (Exhibit 15-7).<sup>30</sup>

The chief value of this system was that it *gave a structure for practice*. Although the A/O system appeared simple in theory, the added complexity of (a) performing a single slide test for the A antigen on the recipient's cells and (b) correctly assigning the result of the test to a casualty in a resuscitation tent greatly increased the risk of a transfusion reaction and slowed the pace of patient care—even when practiced under controlled training conditions. All units in the division, therefore, vigorously pursued a supply of group O PRBCs. The A/O system was reserved as an emer-

gency back-up system but was never used.

**Planning at the Third and Fourth Echelons**

Although third- and fourth-echelon facilities have improved blood banking capabilities, planning and training are just as critical to a successful transfusion policy in these facilities as they are at the second echelon. The clinical environment may vary considerably according to the location and operational situation where the hospital is deployed. Two personal experiences relate different blood banking procedures (Exhibits 15-8 and 15-9). The transfusion practice in each setting was successful because the clinical policies were tailored for the operational setting, and the personnel were familiar with policies because their preparation, planning, and training had been extensive.

**SUMMARY**

Treatment of battlefield injuries with blood transfusion in an operational environment is a cornerstone of military medicine. The practice has saved thousands of lives and gave rise to the civilian

blood banking industry shortly after World War II. Since then, transfusion medicine has become increasingly sophisticated and specialized, and physicians in peacetime medicine are no longer trained

## EXHIBIT 15-8

### PREPARING BLOOD BANKS FOR MASS CASUALTY INCIDENTS

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Fourth-echelon and other military general hospitals should be capable of providing blood bank services that are comparable to those of a civilian medical center. In a mass casualty incident, these services should include protocols for the selection of blood products for massive transfusions, positive blood-sample identification systems, a complete blood-component service, and procedures for the releasing of un-cross-matched universal-donor blood.

The following guidelines, based on previous military and civilian experiences,<sup>1-5</sup> are intended to provide a framework for addressing these issues.

#### Protocols for Managing Severe Blood Loss

Past experiences indicate that in mass casualty situations, physicians are likely to request the same quantities and types of blood products that they have become accustomed to using in the management of similar cases.<sup>1,2</sup> For this reason, protocols that are intended to be used during a mass casualty incident should be implemented in advance as part of routine operations. The concept of stockpiling special blood products, blood substitutes, or plasma expanders to be used only in a mass casualty incident introduces the risk of delays while clinicians accommodate themselves to unfamiliar clinical responses and reactions.

#### Separate Donor-Related and Casualty-Related Services

In a mass casualty incident, the blood bank staff should be unencumbered by blood-donor and -supply problems and should focus their efforts on providing safe, serologically compatible blood products in a timely manner. The current standard of practice in civilian and military hospitals requires all blood products intended for transfusion to be tested for multiple infectious disease markers, including anti-human immunodeficiency virus and hepatitis B surface antigen.<sup>6</sup> The former practice of collecting units of blood at the hospital and transfusing them as ABO-matched, but otherwise untested, warm blood is outdated and is not recommended.

Ideally, all blood donor-related functions should be conducted in a separate facility that is sufficiently distant from the hospital to allow a surge of blood donors to respond to the incident without congesting access to the hospital. The distinct functions of a hospital transfusion service (eg, cross-matching, blood typing) compared with a blood-donor service (eg, phlebotomy, infectious-disease testing, component preparation) should be recognized in the planning process. The optimal result would be a physical separation that would allow each service to conduct its specialized functions without competing for resources.

#### Positive Identification Systems

A system that positively identifies each casualty, blood sample, and blood product intended for transfusion is essential for safe management of a mass casualty incident. Wristband systems with uniquely numbered sticky labels are marketed commercially and have been used successfully by civilian transfusion services in a wide range of emergency situations.

#### Universal-Donor Blood and Abbreviated Cross-Matching

The blood bank should have a standing operating procedure that defines the requirements for releasing group O-positive (or O-negative) universal-donor blood without a cross-match. Criteria should also be specified for switching from the standard 60-minute cross-match to an abbreviated 5- to 15-minute cross-match. If group O whole blood or fresh frozen plasma is transfused to a group A or B recipient, then guidelines should be specified for safe reversion to ABO group-specific red blood cell transfusions.

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(1) Sandler SG, Sharon R, Hermoni D, Superstein E. Blood transfusion therapy in the rear hospital during the Yom Kippur War (October 1973). *Milit Med*. 1977;141:49, 52-53. (2) Sandler SG. Strategies for blood services in mass casualty incidents. In: Cowley RA, Edelstein S, Silverstein M, eds. *Mass Casualties: A Lesson Learned Approach. Accidents, Civil Disorders, Natural Disasters*. Washington, DC: US Department of Transportation. 1982: 229-233. DOT HS 806 302; October 1982. Proceedings, First International Assembly on Emergency Medical Services; June 1982. (3) Sandler SG. Blood utilization during the October 1973 (Yom Kippur) war. Presented at Combat Casualty Care Research Program; US Army Medical Research Development, Acquisition and Logistics Command (Provisional); 8-9 November 1993; Fort Detrick, Frederick, Md. (4) Camp FR, Conte NF, Brewer JR. *Military Blood Banking 1941-1973: Lessons Learned Applicable to Civil Disasters and Other Considerations*. Fort Knox, Ky: US Army Medical Research Laboratory; 1973. (5) Kendrick DD. *Blood Program in World War II*. Washington, DC: Department of the Army, Medical Department, Office of The Surgeon General; 1964. (6) Standard E5.000/Tests intended to prevent disease transmission. In: *Standards for Blood Banks and Transfusion Services*. 16th ed. Bethesda, Md: American Association of Blood Banks; 1994: 14.

Exhibit prepared for this textbook by S. Gerald Sandler, MD, Professor of Medicine and Pathology, and Director, Blood Bank and Blood Donor Service, Georgetown University Medical Center, Washington, DC 20007.



**EXHIBIT 15-9**

**BLOOD BANKING IN AN ISOLATED THEATER OF OPERATIONS: EXPERIENCE OF THE 46TH COMBAT SUPPORT HOSPITAL, MOGADISHU, SOMALIA, 1993**

**Background**

- Blood supply system: from Armed Services Whole Blood Processing Laboratory (ASWBPL), Maguire Air Force Base, New Jersey. Daily reports submitted. Routine shipments arrived weekly. About 72 hours from request to delivery of blood products.
- Available blood products:
  - random-mix packed red blood cells (liquid)
  - fresh frozen plasma; about one fourth to one half of bags cracked and unsuitable for use after rewarming
  - platelets not available
- Inventory: started with 50 units of packed red blood cells, increased to 200 units
- Blood banking personnel:
  - one M-4 blood bank–qualified technician
  - one laboratory officer
  - no pathologists or blood bank fellowship–trained officers
- Nearest civilian hospitals: Cairo, Egypt, and Nairobi, Kenya
- Emergency collection of whole blood: blood was drawn only when the demand was expected to increase. The donation and collection systems were kept separate from the dispensing function of the blood bank.

**Training and Preparation**

Civilian mass casualties were treated at least weekly. All aspects of trauma medicine were exercised, including the blood bank and the use of whole blood. After treatment, all aspects of trauma care, including the blood bank, were reviewed and improved if needed. The following amounts of blood were administered from 30 September through 4 October 1993:

<b>Date</b>	<b>Incident or Injury</b>	<b>Blood Products Administered</b>
30 September	Shark bite, one casualty	> 50 units of fresh frozen plasma and packed red blood cells; > 20 units of fresh whole blood, type O
2 October	Land mine exploded under a jeep; four casualties, including one woman	> 20 units of fresh whole blood, type O; Rh-negative blood used for the woman
3–4 October	Rangers pinned down after a failed raid in Mogadishu; > 20 casualties	> 70 units of fresh whole blood, type O

**Impressions**

The use of whole blood maintained a reserve inventory of ASWBPL blood products. Surgeons preferred whole blood to component therapy, especially as platelets were not available. Hemostasis was subjectively improved. All blood donors had been tested for antigens to the human immunodeficiency virus prior to deployment, but (a) identifying potential donors in advance of deployment and (b) having access to field test kits for blood-borne pathogens would have been useful.

Exhibit prepared for this textbook by (1) Denver Perkins, MD, Colonel, Medical Corps, US Army; Director for Clinical Services 46th Combat Support Hospital; Assistant Chief of Anesthesia, Walter Reed Army Medical Center. (2) David Elliot, MD, Lieutenant Colonel, Medical Corps, US Army; Chief of Surgery 46th Combat Support Hospital; Chief of Critical Care, Walter Reed Army Medical Center. (3) Hector Velasquez, Captain, Medical Service, US Army; Chief Laboratory Officer 46th Combat Support Hospital, Chief of Clinical Microscopy, Walter Reed Army Medical Center, Washington, DC 20307-5001.

in nor practice routine blood banking skills. The complex principles of transfusion support of civilian trauma patients in a fixed facility with a modern blood bank are detailed in Chapter 14, Transfusion Therapy. However, military casualties, wounded in a dangerous, austere environment, continue to suffer from injuries that require blood product therapy. There is increasing emphasis on moving resuscitation and surgery even farther forward on the battlefield with mobile surgical teams. In addition, military personnel continue to be deployed to isolated areas lacking access to fixed facilities with modern blood banking resources. Thus, the ability to bring these resources as safely as possible to forward and remote areas in an operational emergency military situation remains imperative.

This chapter describes the theory and practice of the unique aspects of military transfusion medicine. Emphasis is on planning and training, becoming familiar with military terms and doctrine, integrating operational and clinical factors with the blood-supply system, and making the adjustment from the civilian clinician's relative isolation from the laboratory and the blood bank. Medical officers must understand the availability of blood products according to doctrine and the echelons of care so they can anticipate the clinical needs of casualties—from resuscitation to definitive surgery and post-operative care. Technical factors related to the safe operation of a small emergency blood bank in the

field must be mastered by clinical personnel who may be unfamiliar with their peacetime use.

The frequency of the ABO and Rh blood groups in the general donor population acquire unique military significance, and the immediate and delayed effects of massive transfusion occur frequently. The treatment of female casualties in the field poses additional unique military considerations and is mandating further changes in doctrine, which include the proper use and interpretation of identity tags.

Blood products have a finite shelf life and require special storage, handling, and monitoring, which may limit their use in a rapidly evolving operational scenario. Thus, research is active in the areas of developing a blood substitute, controlling hemorrhage early on the battlefield with products such as fibrin glue, and providing platelet support.

Most importantly, successful military transfusion medicine requires practice and planning. The learning curve is steep and cannot be mastered for the first time on actual casualties. Leaders should use blood products as realistically as possible during training exercises. Early interaction with the blood-supply system is critical. Only when clinical, technical, and operational factors are recognized early and then practiced can medical officers safely provide blood products and meet what should be the standard of care for emergency treatment of men and women injured in battle.

#### Acknowledgments

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#### REFERENCES

1. Robertson LB. A contribution on blood transfusion in war surgery. *Lancet*. 1918;1:759–762.
2. Beecher HK. Preparation of battle casualties for surgery. *Ann Surg*. 1945;121:769–792.
3. Crosby WH, Howard JM. The hematologic response to wounding and to resuscitation accomplished by large transfusions of stored blood: A study of battle casualties in Korea. *Blood*. 1954;9:439–460.

4. Heaton LD. Foreword. In: Kendrick DD. *Blood Program in World War II*. Washington, DC: Department of the Army, Medical Department, Office of The Surgeon General; 1964.
5. Kiel F. Development of a blood program in Viet Nam. *Milit Med*. 1966;131:1469–1482.
6. Churchill ED. *Surgeon to Soldiers*. Philadelphia, Pa: JP Lippincott; Philadelphia, Pa: 1972: 36–58.
7. Frishberg DP. Historical review: Highlights in the development of combat transfusion programs. *Journal of Military Medical Laboratory Science*. 1989;18:41–44, 66–71.
8. Crosby WH. World War II's war within a war: What delayed the delivery of whole blood to overseas combat troops. *MD*. 1991;Dec:35–39.
9. US Department of the Army. *Planning for Health Service Support*. Washington, DC: Headquarters, DA; approved final draft January 1994. Field Manual 8–55.
10. Scotti MJ, chairman. Defense Medical Standardization Board. *DEPMEDS Policies/Guidelines: Treatment Briefs*. Fort Detrick, Frederick, Md: Defense Medical Standardization Board; 1990.
11. Committee on Trauma, American College of Surgeons. *Advanced Trauma Life Support Program for Physicians: Instructor Manual*. 5th ed. Chicago, Ill: American College of Surgeons; 1993.
12. Kendrick DD. *Blood Program in World War II*. Washington, DC: Department of the Army, Medical Department, Office of The Surgeon General; 1964: 406, 443, 634, 635.
13. Crosby WH. Colonel, Medical Corps, US Army (ret). Personal communication, September 1994.
14. Gerber FE. *Employment of the 307th Medical Battalion (Airborne) in Operations Desert Shield and Desert Storm: A Personal Experience*. Carlisle, Pa: US Army War College, Military Studies Program; May 1992. Monograph.
15. Ryden SE, Oberman HA. Compatibility of common intravenous solutions with CPD blood. *Transfusion*. 1975;15:250–255.
16. Walker RH, ed. Blood transfusion practice. In: *Technical Manual*. 11th ed. Bethesda, Md: American Association of Blood Banks; 1993: 421.
17. Bickell WH, Matthew MJ, Pepe PE, et al. Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. *N Engl J Med*. 1994;331:1105–1109.
18. Jacobs LM. Timing of fluid resuscitation in trauma. *N Engl J Med*. 1994;331:1153–1154. Editorial.
19. Walker RH, ed. Adverse effects of blood transfusion. In: *Technical Manual*. 11th ed. Bethesda, Md: American Association of Blood Banks; 1993: 471.
20. Rosenblatt MS, Hirsch EF, Valeri RC. Frozen red blood cells in combat casualty care: Clinical and logistical considerations. *Milit Med*. 1994;159:392–397.
21. Crosby WH. Frozen blood for military transfusion service. *Milit Med*. 1967;132:119–121.
22. Crosby WH, Akeroyd JH. Some immunohematologic results of large transfusions of group O blood in recipients of other blood groups: A study of battle casualties in Korea. *Blood*. 1954;9(2):103–116.
23. Barnes A, Allen TE. Transfusions subsequent to administration of universal donor blood in Vietnam. *JAMA*. 1968;204:695–697.
24. Walker RH, ed. Pretransfusion testing. In: *Technical Manual*. 11th ed. Bethesda, Md: American Association of Blood Banks; 1993: 312.

25. Walker RH, ed. Blood grouping and typing. In: *Technical Manual*. 11th ed. Bethesda, Md: American Association of Blood Banks; 1993: 621.
26. Walker RH, ed. ABO, H, and P blood groups. In: *Technical Manual*. 11th ed. Bethesda, Md: American Association of Blood Banks; 1993: 203–228.
27. Gaydos JC, Cowan DS, Polk AJ, et al. Blood typing errors on US Army identification cards and tags. *Milit Med*. 1988;153:618–620.
28. Ensign BG, Dougherty TH, Bowlus IN, Konecki EA. ABO and Rh blood type errors on Air Force identification cards. *Milit Med*. 1995;160(6):288–290.
29. Jaques D. Lieutenant Colonel, Medical Corps, US Army; Senior Medical Officer, 307th Medical Battalion, 82nd Airborne, Persian Gulf War; Chief of Surgery, Department of Surgery, Walter Reed Army Medical Center, Washington, DC. Personal communication, June 1994.
30. Joseph SC, Assistant Secretary of Defense (Health Affairs). *Policy for the Use of ID Tags and ID Cards for Emergency Transfusion at the Second Echelon of Medical Care and the Validation of Those Parameters*. Washington, DC: Department of Defense. Memorandum for Secretaries of the Military Departments, Chairman of the Joint Chiefs of Staff, 21 April 1995.
31. Mollison PL, Engelfriet CP, Contreras M, eds. The Rh blood group system. In: *Blood Transfusion in Clinical Medicine*. 9th ed. Boston, Mass: Blackwell Scientific Publications; 1992: 543–591.
32. Lefebvre J, McLellan BA, Coovadia AS. Seven years experience with group O unmatched packed red blood cells in a regional trauma unit. *Ann Emerg Med*. 1987;16:1344–1349.
33. Schmidt PJ, Leparac GF, Samia CT. Use of Rh positive blood in emergency situations. *Surg Gynecol Obstet*. 1988;167:229–233.
34. Engle HL. Medicolegal considerations in transfusion medicine. In: Petz LD, Swisher SN, eds. *Clinical Practice of Transfusion Medicine*. 2nd ed. New York, NY: Churchill Livingstone; 1989: 355–362.
35. Clark J. Major, Medical Corps, US Army. Senior Medical Officer, 2nd Brigade Clearing Station, 82nd Airborne Persian Gulf War. Division Surgeon 82nd Airborne. Personal communication, December 1994.
36. Kozar M. First Lieutenant, Medical Service, US Army. Laboratory officer, 86th Evacuation Hospital, Mogadishu, Somalia. Personal communication, May 1995.
37. Bolan CD, Strawder G. 82nd Airborne Division blood policy. In: Gerber FE. *Employment of the 307th Medical Battalion (Airborne) in Operations Desert Shield and Desert Storm: A Personal Experience*. Carlisle Pa: US Army War College, Military Studies Program; May 1992. Monograph.

## GUIDELINES FOR INTERACTING WITH THE BLOOD-DISTRIBUTION SYSTEM

Crossing the bridge between the medical officers who treat the casualties and the blood-distribution system that supports them takes planning, coordination, and teamwork. The successful blood product distributions that we have had recently in operations other than war and during combat operations are due largely to the foresight, hard work, and sacrifice of many people. They have read and understood the history of the use of blood products, have actually played a part in making the system work, have used blood products in battlefield conditions, and have seen the miracles that blood provides. Above all, we must teach from these lessons of history in order to train as a team, train as realistically as possible, and then train again so that we are always prepared.

All medical officers who work in a field environment where they will be transfusing blood products must understand the Armed Services Blood Program (ASBP) blood-distribution system (Guidelines Exhibit 1). Interestingly, the adoption of a permanent ASBP evolved from lessons learned from the Korean War, where

[n]o single medical item was more important than blood, and its supply was a specialized program stretching from the zone of the interior to the battlefield.<sup>1(p243)</sup>

At the end of World War II, well-founded, detailed recommendations for a transfusion service had been prepared and submitted through channels to the proper authorities. Time, manpower, effort, money, and lives could all have been spared in Korea if these recommendations had been utilized as a basis for postwar planning. As it was, the newly developed plans were not ready for implementation when the Korean combat began.<sup>2(p xiii)</sup>

The existence of an ASBP and its blood-distribution doctrine has since provided excellent support—from the Vietnam War, to the Persian Gulf War, to Operation Uphold Democracy (1994) in Haiti. Blood products were used in each of these operations. What has changed are the amounts and types of blood products as well as the transfusion procedures. This trend will also continue as new blood products and possible blood substitutes become licensed.

As important as support to the blood program, however, is the fact that the *who, what, where, when, and how* change for every operation and situation. Thus, prior planning and coordination as well as training are required to make things work as they should. The medical officer at the field medical treatment facility (MTF) or the forward medical company must be aware that blood products will not suddenly appear at their facility. For the system to work, the medical team must plan for and request blood products through the right communications and coordination channels.

### Who Should Medical Officers Talk to When Blood Products Are Required?

The chain of command is always the main communication channel for making things happen. Commanders are responsible for what happens in their units. Good commanders also realize that they are not expert in everything. They defer to lawyers on legal issues, to logisticians on logistical issues, and should also defer blood-distribution and technical blood issues to the blood expert.

Once he has coordinated the medical officer's requirements with the blood expert, the commander will usually allow the two to communicate directly, requiring status updates to keep himself informed.

At certain levels of command, the commander will have a Surgeon's staff. The commander will appoint or designate a person to be the blood program officer. For example, a Joint Blood Program Officer (JBPO) can be found at each Unified Command Surgeon's Office. JBPOs are usually laboratory officers who are specialists in blood banking and are well trained in the blood-distribution system. These blood program officers are directly involved with planning the blood-distribution system for operations within their unified command.

Depending on its size or based on the operation, the unified command may designate Area Joint Blood Program Officers (AJBP0s). These officers are used quite often with Joint Task Forces (JTFs) and work for the JTF Surgeon. They plan, coordinate, and communicate in much the same way as the JBPO but within a much more defined geographical area. They, too, are laboratory officers specialized in blood banking procedures. They are good assets for answering any blood-distribution questions that arise. Their main purposes are to

- monitor blood requirements from treatment facilities within their designated area,
- coordinate deliveries of blood products to those facilities, and
- report to the JBPO as well as their respective command element.

The AJBPO is responsible for making sure the blood-distribution system is working. The AJBPO is also responsible for monitoring blood-supply units (BSUs) and blood transshipment centers that provide storage of blood products for further shipment to MTFs.

BSUs are designated in the operations plans or orders. They can be an army blood platoon, a marine fluids platoon, a fixed MTF, a medical ship offshore, or a field MTF. They are designated specific missions depending on their capabilities. They will usually have a laboratory officer who may or may not be specialized in blood banking.

## GUIDELINES EXHIBIT 1

### ARMED SERVICES BLOOD-DISTRIBUTION SYSTEM: OPERATIONAL DESCRIPTION

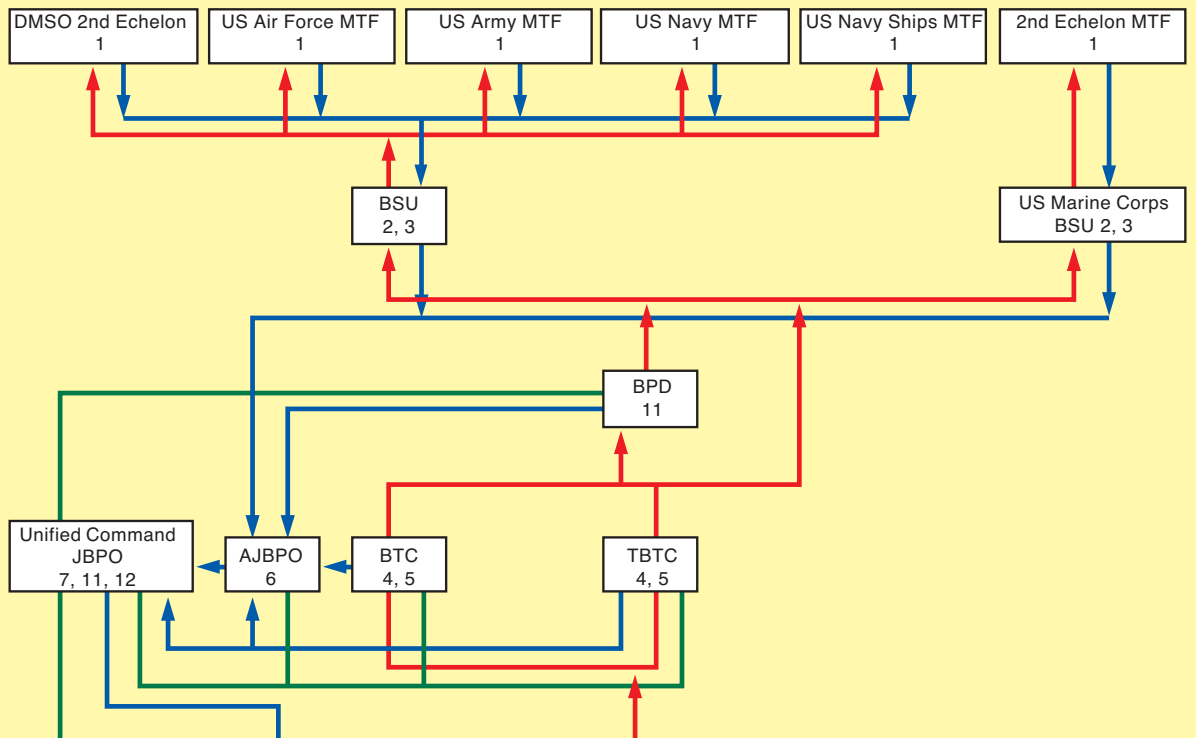
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Blood product requirements are preplanned and established in each unified command operations plan. The daily blood report (BLDREP), which includes a request for blood products and the status of the inventory, activates the execution of those plans. Information copies of the BLDREP and the blood shipment report (BLDSHIPREP) are provided in accordance with local command operational plans. The blood-distribution system is the standard doctrine. However, it is very flexible and, based on the situation, changes can be made with coordination with the Armed Services Blood Program Office (ASBPO). The numbers inside the boxes correspond to the numbered guidelines below.

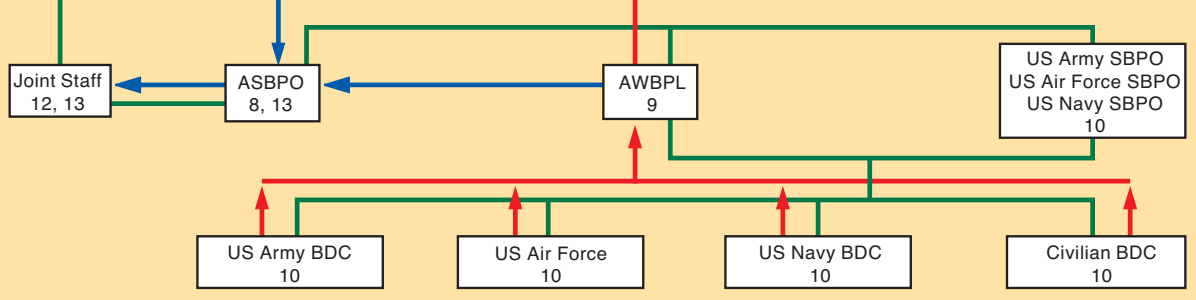
1. Each medical treatment facility (MTF) or element, including a naval vessel, that requires blood products submits a daily blood report (BLDREP) to a designated unified command component blood-supply unit (BSU). The MTF may be located in the second, third, or fourth echelon of medical support.
2. Each designated unified command component BSU issues blood products to the requesting MTFs. If directed, a BSU may serve MTFs of more than one service. The BSU may be located in the third or fourth echelon of medical support.
3. Each component BSU submits a daily BLDREP to a designated Area Joint Blood Program Office (AJBPO).
4. Each blood transshipment center (BTC) or transportable blood transshipment center (TBTC) issues blood products to each designated component BSU based on daily allocation guidelines established by the AJBPO or, if no AJBPO exists, the Joint Blood Program Office (JBPO).
5. Each BTC or TBTC submits a daily BLDREP to the designated AJBPO.
6. Each AJBPO manages blood products between component BSUs and submits a daily BLDREP to the JBPO.
7. The JBPO manages blood products between blood program areas in the unified command and submits a daily BLDREP to the Armed Services Blood Program Office (ASBPO).
8. The ASBPO directs the designated Armed Services Whole Blood Processing Laboratory (ASWBPL) to ship blood products, based on the ASWBPL situation report (ASWBPLSITREP).
9. Each ASWBPL ships blood products to designated unified command BTC or TBTC.
10. Military blood donor centers (BDCs) in the continental United States (CONUS) ship blood products to resupply designated ASWBPLs as directed by the respective Service Blood Program Office (SBPO). Defense Logistics Agency contracts with civilian blood agencies are activated when Armed Services Blood Program shortfalls are experienced.
11. Prepositioned frozen blood products stored in unified command armed services blood product depots (BPDs) are issued to BSUs as directed by the JBPO.
12. The JBPO provides, on a continuous basis, information on the status of the theater blood program to the unified command surgeon, who, in turn, coordinates with the Joint Staff.
13. The ASBPO is chartered to ensure implementation of the Armed Services Blood Program policies established by the Assistant Secretary of Defense for Health Affairs, and to coordinate the provision of blood products to the unified commands in concert with the Joint Staff. The U.S. Army is the Executive Agent for the ASBPO. An ASBPO situation report (ASBPOSITREP) is provided in accordance with mobilization plans.

Guidelines Exhibit 1 *continues*

THEATER OF OPERATIONS



SUPPORTING BASE



— Coordination     
 — Blood Flow     
 — Reports

- |               |  |        |  |
|---------------|--|--------|--|
| AJBPO:        | Area Joint Blood Program Office                  | BSU:   | blood supply unit                        |
| ASBP:         | Armed Services Blood Program                     | BTC:   | blood transshipment center               |
| ASBPO:        | Armed Services Blood Program Office              | CONUS: | continental United States                |
| ASBPOSITREP:  | ASBPO situation report                           | JBPO:  | Joint Blood Program Office               |
| ASWBPL:       | Armed Services Whole Blood Processing Laboratory | JTF:   | Joint Task Forces                        |
| ASWBPLSITREP: | ASWBPL situation report                          | MTF:   | medical treatment facility               |
| BDCs:         | blood donor centers                              | POC:   | point of contact                         |
| BLDREP:       | blood report                                     | SBPO:  | Service Blood Program Office             |
| BLDSHIPREP:   | blood shipment report                            | TBTC:  | transportable blood transshipment center |
| BPD:          | blood product depot                              |        |  |

However, they are trained to store and distribute blood products to MTFs. They are usually the MTF's and the medical officer's prime point of contact to the blood-distribution system.

So medical officers need to know that they will be supported by a BSU, who is monitored by an AJBPO, who reports to a JBPO within the unified command. These players in the blood-distribution system need to be able to communicate directly.

### **How Do Medical Officers Communicate With Their Points of Contact?**

Once medical officers know who their direct points of contact are, how do they communicate their blood requirements? The Department of Defense has standardized message formats so that each service can communicate with the other services. Two of these standardized messages are the blood report (BLDREP) and the blood shipment report (BLDSHIPREP).

Each MTF is required to submit a daily BLDREP to its supplier of blood products. This report can be sent by the fastest means of communication available. In some situations, this can be by courier. In other situations, telephones, radios, or satellite communications may be used. This report can also be sent by the message center nearest the MTF. The means by which the report is sent is dictated by the communications capabilities that exist within the MTF and within the supporting communications network.

A standard BLDREP will provide the facility's current blood inventory, the amount of blood products required within the next 12 to 48 hours, the amount of blood that will expire in the next 7 days, and the estimate of blood products required in the next 7 days. It may give the location of the MTF, and it has a narrative section to address any problems and to provide any other information required by higher commands. For example, transfusions may be addressed by stating the blood-unit donor number, matched to the patient transfused by the casualty's social security number.

A standard BLDSHIPREP will alert the receiver of blood products as to when a blood shipment will be arriving. It will also provide the number of blood products being shipped, by their ABO group and Rh type. If the shipment is arriving by air, it will usually have a mission number and a transportation control number to specify which plane the blood products will be arriving on. It will give the shipper's address and the point of contact.

Examples of BLDREPs and BLDSHIPREPs, with codes for using these reports, are explained in *Planning for Health Service Support*<sup>3</sup> and *Health Service Support Logistics in Joint Operations*.<sup>4</sup> It is imperative that medical officers who require blood products for their facilities make sure that their staffs are trained on the exact procedure to follow when submitting these reports.

### **How Do Medical Officers Receive Their Blood Products?**

The best part of the blood-distribution system is that it has at its service all the transportation capabilities that the Department of Defense has available. The problem is that these resources can become limited. Therefore, communication of requirements and coordination of transportation assets becomes very important.

Fortunately, this blood-distribution system is used daily for peacetime transportation of blood products around the world. Thus, personnel involved especially with the strategic lift capabilities are always ready to implement contingency blood-distribution procedures. Medical officers must realize that because strategic lift is limited, good coordination of blood requirements with sufficient advanced notice is also required.

Tactical transportation capabilities are also sufficiently flexible to meet requirements. Blood products can be shipped directly to the MTF (ie, unit distribution) or MTF personnel may have to go to a specific location to receive their blood products (ie, point distribution). In these routine instances, wheeled vehicles (assets organic to the unit) are used. Problems arise when distance, terrain, security, and time become factors.

When wheeled-vehicle transport is not useful, helicopters fill the void. Medical-evacuation helicopters have a secondary mission to ship blood products forward to MTFs. Helicopter support to ships that receive casualties needs to be coordinated. Helicopters can carry blood products via sling-load when more blood is required than can be held within the helicopter.

When helicopter capability is limited due to security, distance, and increased demands, tactical airlift via aircraft such as C-130s must be coordinated well. The JBPOs and AJBPOs should know these capabilities and be able to coordinate shipments as required. It is *their* responsibility to coordinate these capabilities for the MTFs.

### **When Can Medical Officers Get Blood From the Armed Services Blood Program?**

Each of the military's different types of operations is unique as to when the MTFs will require blood products. Medical officers may find themselves involved in a forward surgical element that is being deployed as part of the first wave of assault troops. In this case, the medical officer will need to deploy with blood products. In other cases, the medical officer may deploy with an MTF that will be deployed in a second iteration of troop movements and will not



have to take on casualties until days after entering the area of operations. In this case, it would not be reasonable to deploy with blood products; rather, they should be requested just before casualties are expected. In all cases, the medical officer needs to ask these questions: When is the blood required? and When can I get it?

The blood-distribution system can accommodate the treatment facilities as long as there has been coordination and advanced notice. For example, the Joint Task Force Surgeon for Operation Uphold Democracy was able to bring players together prior to the operation to plan all aspects of the medical support. Major Noel Webster, from the Armed Services Blood Program Office, was able to meet with the 82nd Airborne Division Surgeon, Lieutenant Colonel Jeffrey Clark, to coordinate some of the Division's unique requirements for blood support. Major Webster gave him some recommendations, and points of contact (POCs) were established to set up the distribution system. The POCs worked agreements among themselves, and Lieutenant Colonel Clark had the POCs train and exercise the distribution prior to deploying to make sure any problems were identified and resolved. When the 82nd Airborne Division was ready to deploy, all systems were go and the blood was ready and prepared without a hitch.

In other circumstances, the JBPO would be the POC coordinating the planning prior to and during an operation. For example, the U.S. Central Command (CENTCOM) Surgeon's JBPO, Commander Barbara Fieldman, was heavily involved in identifying BSUs for supporting medical treatment during the Persian Gulf War. In this operation, MTFs did not have to deploy with blood; instead, a blood-distribution infrastructure of BTCs and BSUs was in place to provide blood products for them. Commander Fieldman coordinated with the MTF commanders personally to make sure they were being supported.

## REFERENCES

1. Crowley AE. *The Medics' War: United States Army in the Korean War*. Washington, DC: Center of Military History, US Army; 1987: 243.
2. Kendrick DD. Preface. In: *Blood Program in World War II*. Washington, DC: Department of the Army, Medical Department, Office of The Surgeon General; 1964: xiii.
3. US Department of the Army. *Planning for Health Service Support*. Washington, DC: Headquarters, DA; approved final draft, January 1994. Field Manual 8-55.
4. Joint Chiefs of Staff. *Joint Tactics, Techniques, and Procedures for Health Service Support Logistics in Joint Operations*. Washington, DC: US Departments of the Army, Navy, Navy US Marine Corps, and Air Force; initial draft 15 August 1993. Joint Pub 4-20.1.