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Review article

Evolution of the role of army transfusion services in the management of trauma patients and battle casualties with massive hemorrhage

Brig R.S. Sarkar^{a,*}, Col J. Philip^b, Lt Col S. Kumar^c, Pramod Yadav^d

^a Commandant, 151 Base Hospital, C/o 99 APO

^b Associate Professor, Dept of Transfusion Medicine, AFMC, Pune 40, India

^c Classified Specialist (Transfusion Medicine), INHS Asvini, Mumbai, India

^d Resident, Dept of Transfusion Medicine, AFMC, Pune 40, India

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ABSTRACT

Providing blood at the times of national emergencies and war-like scenarios is a challenge to the blood transfusion services. The dictum should be adequate bleeding, minimum storage time, quick transportation and maximum utilization of blood as soon as possible. For the successful implementation of its role, forward transfusion services should be fully mobile with integral transportation and communication systems. Supplementation of blood supplies has to be prompt, & for this adequate air transport facilities will have to be established. A rational approach to using blood products in patients with bleeding, requires an understanding of the principles of managing hemorrhagic shock. The main priorities are controlling hemorrhage and restoring adequate oxygen delivery to the tissues. Surgical control and treatment of coagulopathy are required to stop hemorrhage in these patients. Resuscitation with fluids and red cells are necessary to improve perfusion and oxygen delivery to tissues. Once patients are resuscitated and further bleeding is stopped, use of conservative transfusion triggers is recommended to avoid excessive transfusion and adverse outcomes. A host of new technologies are being developed that have the potential of reducing blood loss. These will help in reducing the transfusion requirements in trauma patients with massive hemorrhage.

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Introduction

The evolution of blood transfusion services was one of the most important of medical advances derived from World War I.¹ The benefits of whole blood transfusion for traumatic hemorrhagic shock became apparent during World War II.² The success in World War II by the British Army was partly

attributed to the Army Transfusion Service.³ American physicians and surgeons used plasma to resuscitate their soldiers whereas British physicians established the infrastructure for safe and efficient blood transfusion service before the start of World War II, & used whole blood for transfusion.⁴ Whole blood was the chief replacement fluid used by the USSR in World War II. When Russia entered

* Corresponding author.

E-mail address: eoj_in@yahoo.com (R.S. Sarkar).

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World War II, this programme, lead by female donors, became, virtually a system of factories for collecting, preserving and delivering blood to the battlefield.⁵ In the current conflicts in Iraq and Afghanistan, soldiers with severe injuries caused by high-velocity weapons and explosive devices presented in large numbers to military hospitals. As a result, military physicians are seeing patients who require massive transfusion at four to five times the frequency seen in civilian practice.⁶ In the Gulf War 82,000 units of RBC were sent to Iraq during a period of 8 months.⁷

Transfusion services in Armed Forces

Hemorrhagic shock is the leading cause of death in trauma patients. The transfusion service has a major role to play in the war and mass casualty scenario. The Army Transfusion Service also provides support for civilian emergencies, natural disasters and blood support to populations in remote and inaccessible areas.

A well organized Blood Transfusion Service (BTS) is a vital component of any health care delivery system. For quality, safety and efficacy of blood and blood products, well-equipped blood centers with adequate infrastructure and trained manpower are an essential requirement. Success of Blood Transfusion Services in War or CI Ops depends on adequacy of planning, training, preparedness prior to occurrence of hostilities and mobility of facility to the point of requirement. The pre-war logistic planning should be based on provision of better infrastructure, blood and component supply and involvement of latest technology. Transfusion Services should be located close to the area of probable greatest need, without being concentrated in areas likely to become targets for enemy attacks. Most of the blood and blood components are collected, processed, tested and stored at tertiary care military hospitals and regional blood centers, and must be delivered to the field hospitals before transfusion. During emergency *just in time* delivery system is the need of the hour. This requires a close coordination between blood center and hospital, with developed communication and information system, transportation and logistic support and critical utilities like fuel and power to ensure that blood can be transported and stored at required temperature. On a mass and individual level of patient care during war hostilities, the role of triage is extremely important. Triage means to determine the priority of patients treatment based on the severity of their condition by marking the victims with different color codes to determine their priority for medical care. The various color coding approved internationally are as follows:

Out of these, the transfusion service has to provide life support mainly to the priority-1 and 2 patients, mainly in the form of blood and blood components. Mass casualties in wars which require transfusion support rely primarily on the local blood inventories for the initial treatment. Blood being transported from the peripheries and distant areas would take 12–24 h to reach the site of casualties treatment. In such circumstances the field hospitals near the war site must maintain adequate blood supplies for 5–7 days for the victims. Therefore effort should be made to establish the true medical need for blood during a mass casualty and to effectively communicate this need to the national transfusion service, blood donors and to the blood donating citizens of our country through clear and consistent messaging strategies. Vast experiences on wars show that relatively few units of blood are actually consumed than what is demanded in these situations. Sudden increase in unexpected unwanted blood donations can disrupt both local and national blood supplies. Therefore blood donations should be controlled diligently and deliberately.

Blood will be collected and dispatched in the ratio of 1:2:3:4 for blood groups AB, A, B and O. As per the mass casualty management data the infusion of fresh whole blood to the trauma victim is considered to be the best transfusion therapy. In an emergency where type-specific blood is not available or where blood grouping cannot be done due to shortage of time or resources the following guidelines will be followed:

- (a) For whole blood or PRBC: O–ve group of blood will be issued.
- (b) For FFP: AB–ve Plasma will be issued.
- (c) For platelet: AB–ve group of platelets will be issued

The proper storage of blood products and their transportation are of immense importance and the maintenance of cold chain should be ensured. Fresh blood can be stored at forward surgical centers (FSC) and field hospitals at 2–6 °C in blood storage cabinets with 24 × 7 power backup. The use of blood transport boxes with dry ice and inbuilt thermo stabilizers is very handy these days. Long distance transport of blood must be done in refrigerated trucks with inbuilt generators and thermostats.

Storage capacity exists at military hospitals at the peripheral military hospitals & Base Hospitals, and the same can be augmented under medical authorities of Corps/Command. Transport of blood to Field Hospitals/FSC constitutes a major problem in war/counter insurgency (CI) Ops. There are two modalities of transport, road and air transport. The logistic support including blood transport boxes required is readily available at hand in majority of field medical units at Corps

S. no.	Priority	Color code	Time required to initiate treatment	Requirement for transfusion support
1.	I	Red	Immediate or within 1 h	+
2.	II	Yellow	Delayed or within 6 h	+
3.	III	Green	Within 24 h	–
4.	IV	Black	Treated with low chances of recovery (last priority)	+/-

level and Forward Medical Store Depot (FMSD). Blood component therapy is usually not feasible in scenario of War or CI Ops area due to problems in storage of components and high prevalence of volume depleted patients. Patients are usually managed with whole blood transfusion and subsequently evacuated to rear for further management. According to a study 80% of the acute trauma patients received RBCs and sustained an overall mortality of 27%. In these patients 62% of RBCs were given in first 24 h of care.⁸

The Gazette of India (Extraordinary) dated 04 Jan 2001 makes provision for exemption of license for whole blood collected and transfused by centers run by AFMS in border areas, small mid-zonal hospitals, field hospitals, mobile medical units and other field medical units including blood supply units in border, and field areas.⁹

Acute management of hemorrhagic shock in massive hemorrhage

'He, who would be a surgeon, must take up his tools and follow the army' – Hippocrates.

General principles

Hemorrhagic shock is the leading cause of death in trauma patients. The accepted principles of managing hemorrhagic shock are suggested by the advanced trauma life support (ATLS) guidelines.¹⁰ Airway and breathing issues have priority over bleeding because of their acuity.

Volume resuscitation

In adult hypotensive patients, ATLS calls for a rapid infusion of 2 L of an isotonic crystalloid solution. A second bolus is appropriate if there is no response or if there is only a transient response. Red cell transfusions are recommended for transient or initial nonresponders.¹⁰

The norm is to transfuse crossmatched blood if the patient's clinical status permits the 35–45 min wait for the full crossmatching process. Even if the situation is emergent, use group-specific blood where possible, to avoid depleting type O stock. Transfusing type-specific blood has been shown to be safe in trauma situations and avoids the transfusion of significant anti-A and anti-B antibodies from the residual plasma in packed red cell units.^{11,12} As a last resort, use type O– blood in young women and type O+ in all other patients, when uncrossmatched blood is required.

Red cell salvage (autotransfusion) is another strategy developed to reduce exposure to allogeneic blood and refers to when the patient's own lost blood is collected and then reinfused. A systematic review of the literature suggests that autotransfusion reduces transfusion in elective surgery; however, there is no evidence to support its use in trauma.¹³

End points of resuscitation

ATLS cautions against using hemoglobin level as a guide for resuscitation. Hemoglobin level is known to be inaccurate while active hemorrhage is still occurring, because it might

have not yet equilibrated with the total circulating plasma volume. We must try to keep a minimum hemoglobin level of above 7 g/dL during this resuscitative phase. The primary goal of transfusing red cells is to enhance tissue perfusion and oxygen delivery.¹⁰ Therefore, during active hemorrhage, red cell transfusions should primarily be guided by the rate of ongoing bleeding and by signs and symptoms of inadequate tissue perfusion. Several different laboratory measures of persistent metabolic acidosis like base deficit, bicarbonate, and lactate help to detect the compensated shock state, after hemodynamic parameters are normalized and bleeding is controlled. The basis for these tests is the observation that the body compensates for inadequate tissue oxygenation with anaerobic glycolysis.⁴

Control of hemorrhage

Massive hemorrhage after traumatic injury is frequently a combination of *surgical and coagulopathic bleeding*. Surgical bleeds originate from lacerated vessels at the site of injury. In contrast, coagulopathy results from a complex, multifactorial process and commonly develops after severe injury. Prompt control of hemorrhage to avoid massive transfusion is the sine qua non of treatment for hemorrhagic shock.

Surgical hemorrhage

In patients with hemorrhagic shock, the site of bleeding must be rapidly identified as part of the primary survey. Usually, surgical control involves ligation of the bleeding vessels and angiographic embolization.¹⁰

Coagulopathy

After transfusion of 6–12 units, coagulation factor decreases to the point to which PT and aPTT are raised more than 1.5 times the normal and the likelihood of coagulopathy is significantly increased.¹⁴ Coagulopathy develops in 44% of all seriously injured¹⁵ patients and accounts for most deaths that occur in the first 24 h of admission after trauma.¹⁶ The mechanism of coagulopathy is multifactorial. Postinjury, the predominant factor is core hypothermia. Hypothermia adversely affects platelet function, particularly when the core temperature falls below 34 °C.¹⁷ The direct loss of clotting factors through hemorrhage rapidly reduces the body's small and normal stores of 10 gm of fibrinogen and 15 ml of platelets.¹⁸ Other pathophysiological events include hyperfibrinolysis and consumption coagulopathy, although the associations are less clear.¹⁹ Therapy for coagulopathic patients requires the replacement of lost clotting components and correction of predisposing factors.

Platelets

Bleeding is unlikely to be aggravated by thrombocytopenia when the platelet count is greater than 50,000/μL. Maintaining a platelet count above 100,000/μL has been recommended if head injury is present.^{20–23}

Fresh frozen plasma (FFP)

Coagulation requires a minimum concentration of clotting factors that is 20%–30% of normal. Replacement of 1 blood

volume reduces the original concentration of clotting factors to one-third. Four units of FFP (10–15 mL/kg) is the calculated dose that will raise the concentration of blood clotting factors to 30% of normal.²²

Cryoprecipitate

Cryoprecipitate is used to replace fibrinogen and is indicated for levels less than 1.0 g/L. Cryoprecipitate administration results in high donor exposure, owing to the large number of donors per pool.²²

Despite these efforts, hemorrhage is still the leading cause of deaths during the first 24 h after admission.¹⁶ As a result, “damage control” surgical techniques have been advocated to reduce operative time and allow for early transport to the ICU. The 3 stages of damage control surgery are limited operation for control of hemorrhage and contamination, with packing of potential spaces; resuscitation in the ICU; and reoperation for definitive repairs and completion of gastrointestinal anastomoses.

Based mostly on the military experience emerging from the Iraq and Afghanistan wars but also from civilian clinical practice reviews and an International Consensus Conference, it has been proposed that coagulopathic trauma patients be primarily resuscitated with units of thawed FFP, red blood cells & platelets in a ratio of 1:1:1, virtually receiving “reconstituted whole blood”.²⁴

Emerging trends in transfusion services in AFMS

Evidence-based recommendations have emerged to help guide war surgeons to rationalize transfusion in trauma patients with bleeding.²⁵ Forward Transfusion Services should be fully mobile with integral transportation and communication systems.

A slew of newer, novel products and procedures have been introduced of late to deal with the problem of ongoing hemorrhage and dilutional coagulopathy in polytrauma and elective surgery.

There should be *better end point indicators to guide transfusion processes* and one potential method for reducing blood transfusion is *thromboelastography (TEG)*. TEG rapidly assesses the coagulation cascade, starting from the initial platelet–fibrin interaction through to clot lysis. Both FFP and platelet use was diminished with the use of TEG, with no adverse effects on blood loss or on rates of reoperations for bleeding.^{17,26}

Fibrin sealants mix thrombin and fibrinogen as a means of accelerating the formation of the fibrin clot. A systematic review of trials found that fibrin sealants reduce surgical blood loss and the need for blood transfusion in elective surgery.²⁷

The use of *Fibrin Bandage* to check hemorrhage and promote early wound healing is gaining more and more importance these days.⁴

Antifibrinolytic agents are widely used in major surgery to prevent fibrinolysis and reduce surgical blood loss. Based on their positive results in elective surgery, antifibrinolytics are attractive drugs for treating coagulopathy in trauma patients to be explored prospectively.²⁸

Recombinant activated factor VIIa (rFVIIa) has been approved for hemophilia patients with inhibitors. Recently, it has been used off-label as a hemostatic agent in trauma patients with massive bleeding. It is advocated that rFVIIa should be used as an adjunct to surgical control of hemorrhage in patients with massive bleeding, after 8 units of red cells have been transfused and if there is still evidence of marked, ongoing bleeding.⁴

Investigators have developed *cell-free hemoglobin solutions*, where red cell membranes are removed from outdated red cells and the hemoglobin molecules are cross-linked to prolong shelf-life.²⁹ Many of these products are currently in phase III testing, in large prospective pre-hospital trauma and elective surgery studies. These products have capacity to deliver oxygen to the tissues.

Insta Blood Packs, extensively used by Israel army, are packets of freeze dried blood carried by soldiers as a part of their mandatory personal kit. The idea is to take a soldiers blood, freeze it in lab conditions and remove ice crystals, leaving only the blood component.⁴

The use of *new additive solutions* have increased the shelf-life of RBCs to more than 3 months enabling blood and its derivatives to be transported to the far-flung areas in the most difficult terrains of CI Ops.⁴

The transfusion experiences from Gulf War have shown that installation of *Apheresis technology in peripheral hospitals* has contributed significantly in bringing down the mortality and morbidity in field trauma cases.

The use of *Glycerolized frozen packed RBC's* is a newer modality of long-term blood storage. RBC's processed in this manner and subsequently frozen and stored up to 10 years have shown sufficient post-storage yield and transfusion survival.⁴ Thawing and deglycerolization by reincorporating the red cells into their native plasma as whole blood, or into any media adjusted to fit the exact recipient requirements have revolutionized the handling of red cells stored for years. In Gulf war an attempt was made to use frozen RBCs based on centrifugal RBC washing.

Providing blood at the times of national emergencies and war-like scenarios is not only a challenge to the transfusion service but also a time to showcase the efficiency and commitment of the transfusion services in the service of the nation. The dictum should be adequate bleeding, minimum storage time, quick transportation and maximum utilization of blood as soon as possible. For the successful implementation of its role, forward transfusion services should be fully mobile with integral transportation and communication systems. Mobile augmentation teams must concentrate their medical efforts in areas of greatest need. Supplementation of blood supplies has to be prompt, & for this adequate air transport facilities will have to be established. A rational approach to using blood products in patients with bleeding, requires an understanding of the principles of managing hemorrhagic shock. The main priorities are controlling hemorrhage and restoring adequate oxygen delivery to the tissues. Surgical control and treatment of coagulopathy are required to stop hemorrhage in these patients. Resuscitation with fluids and red cells are necessary to improve perfusion and oxygen delivery to tissues. Once patients are resuscitated and further bleeding is stopped, use of conservative transfusion triggers is recommended to avoid excessive transfusion and adverse

outcomes. The trend toward reducing allogeneic blood exposure will likely continue. A host of new technologies are being developed that have the potential of reducing blood loss. These will help in reducing the transfusion requirements in trauma patients with massive hemorrhage.

Conflicts of Interest

All authors have none to declare.

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