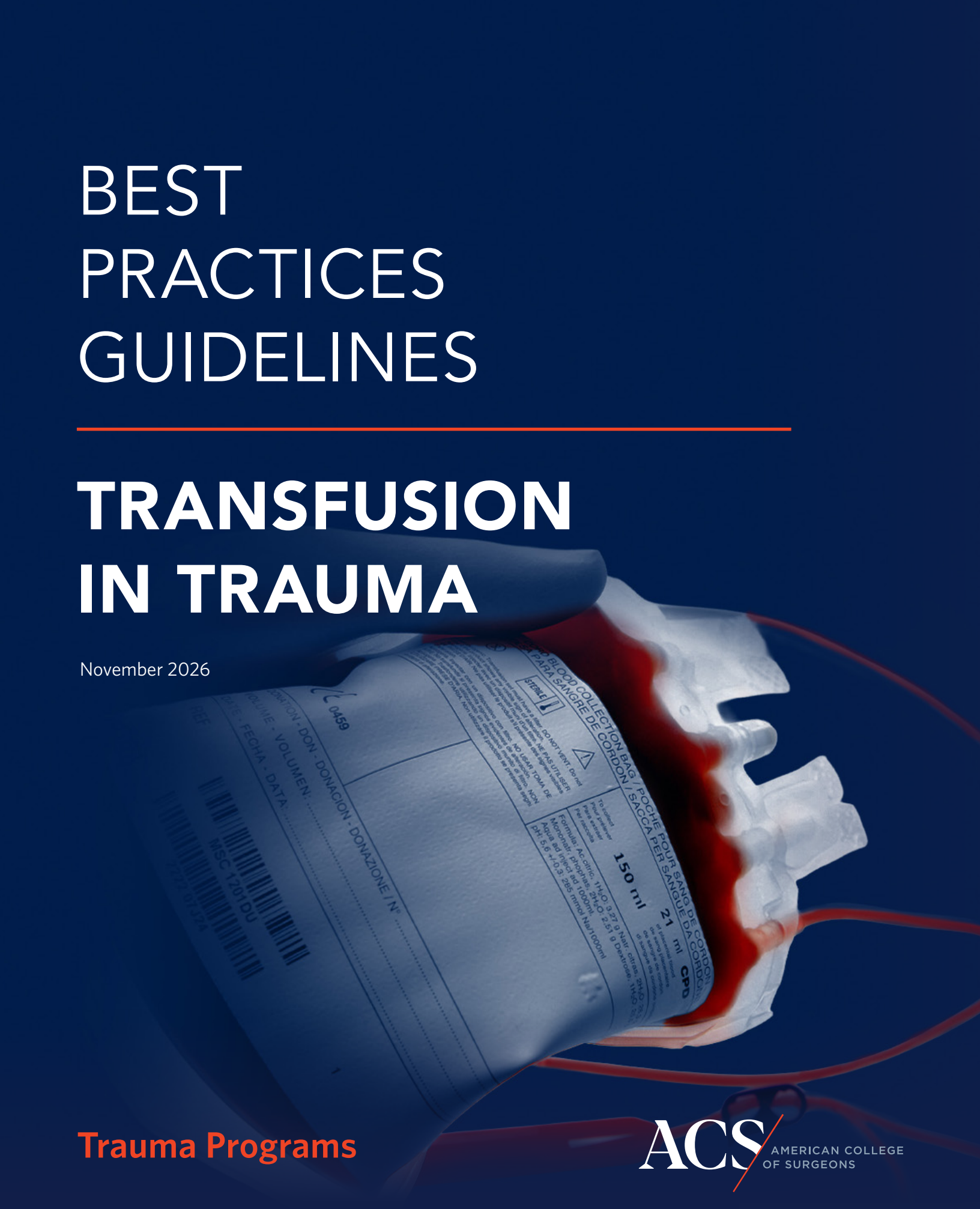
BEST PRACTICES GUIDELINES

TRANSFUSION IN TRAUMA

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Trauma Programs

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OVERVIEW OF TRANSFUSION IN TRAUMA



INTRODUCTION

Injury is a significant cause of death worldwide and the leading cause of death and disability for those 1 to 44 years of age in the US. To prevent injury from progressing to death or disability, the American College of Surgeons (ACS) works with many groups to improve the quality of prehospital, hospital, and rehabilitative injury care through the development of standards and guidelines. Each year, these standards and guidelines shape treatment for an estimated 3.3 million people (approximately 1 in 100 Americans) who seek care or are hospitalized for serious injury. Adherence to evidence-based clinical practice guidelines improves outcomes in bleeding trauma patients.[1,2] Major advances in blood-based resuscitation and blood product development warrant an update to the 2014 *Massive Transfusion in Trauma Best Practices Guidelines*.[3]

Uncontrolled bleeding is the most common cause of preventable death following major injury, but many bleeding individuals die before receiving care.[4] Early recognition and control of external hemorrhage are critical for survival. Global initiatives such as the **ACS Stop the Bleed** program (https://www.stopthebleed.org) emphasize immediate bleeding control as a foundational component of trauma care. Blood transfusion is an adjunct to injury care. It restores and maintains volume, oxygen transport, coagulation capacity, endothelial function, and vascular homeostasis while obtaining hemorrhage control.[5]

The timely availability of blood and blood components for transfusion is a major logistical effort with many complex parts. The relationship between blood supply and demand is well established for large trauma centers, where it is a routine part of daily trauma center operations. However, major gaps remain in our ability to deliver blood-based resuscitation in other scenarios, such as mass casualty incidents, low-resource hospitals, and prehospital response settings.[6,7] Balanced transfusions and blood warmers are particularly important for patients with large-volume blood loss or prolonged time to surgical care. However, in austere and resource-limited environments, efforts to limit the loss of blood and heat can save lives as well. Protocols need to reflect local situations and be agreed upon prior to use.

Interdisciplinary collaboration and practice are critical. Care teams must maximize the resources available to care for injured patients, practice the protocols they plan to implement, and fine-tune those protocols to support practice. Familiarity with blood products and their proper handling will vary widely among care providers, and training to avoid damage to blood products or injury to the patients is necessary. Adequate resources for training in handling blood must be part of the plan.

Finally, more lives can be saved if blood resources can be made available to injured patients earlier, emphasizing the important role of prehospital access to blood products. Some blood products, such as freeze-dried plasma (FDP) and whole blood, are much more "field compatible" with prehospital care, and efforts to make them more readily available are important. This *Best Practices Guidelines for Transfusion in Trauma* focuses on best practices at various patient care phases and locations (e.g., prehospital, trauma resuscitation, operating room, and post–hemorrhage control), unique considerations for special patient populations, and blood product access in low-resource and austere environments.[8,9]

IMPORTANT NOTE

The intent of the ACS Trauma Quality Programs (TQP) Best Practices Guidelines (BPGs) is to provide healthcare professionals with evidence-based information regarding care of the trauma patient. The BPGs do not include all potential options for prevention, diagnosis, and treatment, and they are not intended as a substitute for the provider's clinical judgment and experience. Responsible clinicians must make all treatment decisions based upon their independent judgment and the patient's individual clinical presentation. This *Best Practices Guidelines for Transfusion in Trauma* is not intended to be a comprehensive guide to all services, personnel, and processes needed to conduct quality, complex hemorrhage resuscitation and care. The guidance herein does not constitute a standard of care and is not intended to replace the medical judgment of the physician or healthcare professional in individual circumstances.

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HISTORICAL PERSPECTIVES ON TRANSFUSION IN TRAUMA

KEY POINT

- Whole blood transfusion has proven to be feasible and safe with comparable outcomes to component therapy with plasma, platelets, and red blood cells (RBCs).

The resuscitation of patients with hemorrhagic shock after trauma has changed significantly over several decades, moving from crystalloid-heavy strategies toward hemostatically targeted blood product resuscitation. Early approaches, influenced by civilian and military experience in the mid- to late-20th century, emphasized large-volume crystalloid infusion to restore circulating volume and normalize vital signs. While effective for short-term hemodynamic support, this strategy contributed to dilutional coagulopathy, tissue edema, lung injury, abdominal compartment syndrome, and worse outcomes in severely injured patients.

Recognition of trauma-induced coagulopathy (TIC) as an early and primary driver of mortality led to the adoption of damage-control resuscitation (DCR) centered on balanced transfusion strategies. Seminal studies—particularly from military cohorts and large civilian registries—demonstrated improved survival when injured patients received higher ratios of plasma and platelets relative to RBCs, approximating whole blood composition (i.e., 1:1:1). This approach aimed to mitigate coagulopathy, reduce ongoing bleeding, and limit crystalloid exposure. The concept was further reinforced by randomized trials such as the PROPPR trial, which showed that early, balanced transfusion improved hemostasis and reduced death from exsanguination.[1]

More recently, renewed interest in low-titer group-O whole blood (LTOWB) led to a return to physiologic resuscitation. Whole blood provides red cells, plasma, and platelets in a single product with preserved functional interactions, logistical simplicity, and reduced donor exposure. Both military experience and emerging civilian data suggest that whole blood transfusion is feasible and safe, with comparable outcomes to component therapy. This is an important advance for streamlining massive hemorrhage protocols (MHP), particularly in prehospital and resource-constrained settings.[2–4] Collectively, this evolution reflects an increasing emphasis on early hemorrhage control, minimization of iatrogenic coagulopathy, and restoration of effective hemostasis as central tenets of modern trauma resuscitation.

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BEST PRACTICES GUIDELINES
TRANSFUSION IN TRAUMA

PREHOSPITAL TRANSFUSION



INITIATING PREHOSPITAL TRANSFUSION

KEY POINTS

- Immediate mechanical control of external hemorrhage is essential and precedes blood product administration in the prehospital setting.
- Prehospital transfusion is associated with reduced mortality in injured patients at risk of hemorrhagic shock.
- Pragmatic clinical indicators for initiating prehospital transfusion include hypotension, tachycardia, and shock indices. No standardized scoring criteria are currently recommended for initiating prehospital transfusion.

Victims of trauma with significant hemorrhage are at high risk of hypovolemic shock and death. Early intervention is critical, beginning at the point of injury and continuing during transport and into the trauma center. DCR, implemented in conjunction with damage-control surgery, focuses on restoring homeostasis and mitigating coagulopathy, hypoxia, and tissue hypoperfusion.[1] While this section emphasizes blood product–based resuscitation to restore tissue oxygen delivery and hemostatic potential, it must be accompanied by other DCR measures, beginning with rapid hemorrhage control along with limited crystalloid use and prevention of hypothermia.

Early Hemorrhage Control at the Point of Injury

Immediately initiate external hemorrhage control at the point of injury and continue hemorrhage control during transport. Consistent with principles emphasized in the **ACS Stop the Bleed** initiatives, rapid identification and immediate control of life-threatening bleeding is essential, using direct pressure, wound packing, or tourniquet application when indicated. These actions precede blood product administration. Early bleeding control by trained civilians and trauma system first responders is a critical component of patient survival from hemorrhage. Blood product administration does not replace the need for prompt mechanical bleeding control.

Even with optimal mechanical hemorrhage control, some patients develop or remain at risk for hemorrhagic shock and require blood-based resuscitation. This is especially common when mechanical control of hemorrhage is not feasible or effective in the prehospital setting, such as torso or junctional hemorrhage.

Triggers for Initiating Prehospital Transfusion

Prehospital transfusion of blood products, with a goal of reducing mortality in injured patients with or at risk of hemorrhagic shock, is feasible and safe.[2,3] Two randomized trials reported that prehospital administration of whole blood to injured patients with hemorrhage did not reduce mortality when compared with component therapy, suggesting that emergency medical services (EMS) agencies may choose the product that is operationally expedient.[4,5] No evidence-based triggers currently exist to determine which prehospital patients are at risk of hemorrhagic shock and need prehospital transfusion, or for determining when prehospital transfusion is futile. In selected studies, suggested triggers for prehospital transfusion in adults include a systolic blood pressure (SBP) <90 mm Hg **and** a heart rate (HR) >108/min, **or** SBP <70 mm Hg.[2,6] Some prehospital guidelines have attempted to adapt in-hospital scores used to identify the prehospital patient's need for massive transfusion—for example, HR >120/min, mean arterial pressure <60 mm Hg, a positive focused assessment with sonography for trauma (FAST) exam, lactate >4 mmol/L, end-tidal carbon dioxide ($EtCO_2$) <25 mm Hg, and a shock index (SI) >1.0.[7,8] However, this strategy is complicated by the need for prehospital ultrasound, and it assumes that a trigger for in-hospital massive transfusion is generalizable to the prehospital setting.[6]

A recently developed prehospital clinical practice guideline recommended transfusion with **any** of the following patient indicators in the prehospital setting, in addition to a clinical sign of hypoperfusion (altered mental status, pallor, delayed capillary refill, tachypnea, or $EtCO_2$ <25 mm Hg):[9]

- SBP <90 mm Hg (SBP <100 mm Hg in patients >65 years)
- HR >100/min
- SI >1.0

However, these recommendations have **not** been validated. AI tools for prehospital transfusion clinical decision support are undergoing testing and may be available soon.[10,11] See Box 1 for transfusion guidance when prehospital triggers are met.

Box 1. Guidance for Prehospital Transfusion in Patients With Signs of Hypoperfusion

- Check blood products for type, expiration, temperature sensor, and visible defects.
- Begin blood product transfusion and stop crystalloid infusions.
- Transfuse either LTOWB or balanced component therapy beginning with plasma.
- Transfuse until the physiologic triggers that prompted transfusion are reversed.
- Avoid delays to definitive care, especially if additional blood products are not available.
- Perform frequent assessments for subsequent hypoperfusion, response to transfusion, or adverse transfusion reactions.
- Transfer blood product bags and documentation to the hospital-based trauma team accepting the patient transfer.

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BLOOD PRODUCTS AND HEMOSTATIC ADJUNCTS

KEY POINTS

- LTOWB provides RBCs, plasma, and platelets in a physiologic ratio.
- Blood products most likely to be transfused in the prehospital setting include LTOWB, RBCs, and plasma.
- Maintain proper blood storage conditions while blood products are stored outside the blood bank, whether in a remote EMS agency refrigerator or during transport to the patient.
- Consider tranexamic acid (TXA) administration in prehospital patients being transfused within 3 hours of the bleeding onset.

Patients meeting criteria for prehospital transfusion need to be resuscitated with blood products as soon as practicable.[1] The blood products transfused may vary based on availability. The products stocked in prehospital settings are universal-type compatible products, and they are typically either LTOWB or balanced component therapy beginning with type-AB or type-A plasma and group O RBCs/LTOWB.[2,3] Current national prehospital transfusion guidelines strongly encourage the use of a warming device and/or rapid infusion when available, with clinically indicated infusion duration commonly targeted at approximately 3–5 minutes.[4]

To safely manage blood products in the prehospital setting, it is recommended that the EMS agency partner with a blood bank that can support blood typing, temperature monitoring, and chain of custody in the cold chain (the unbroken sequential documentation that tracks the movement, control, and temperature of the blood products). See Table 1 for blood product storage characteristics that are feasible to use in the prehospital resuscitation phase.[5–7] The temperatures recommended might vary by jurisdiction, particularly outside of the US.

ABO Blood Group Type Selection

The ABO blood group system is the most important blood type in transfusion medicine, as all individuals possess naturally occurring antibodies against whichever ABO antigens they lack. Adherence to ABO compatibility is essential to prevent acute hemolytic transfusion reactions, which can lead to severe organ injury or death.

Table 1. Guidelines for Management of Blood Products in the Prehospital and Hospital Settings

Blood Product	Mechanism of Action	Storage Conditions	Transport Conditions	Expiration
LTOWB	Increases oxygen carrying capacity Restores coagulation factors and platelets to support hemostasis	1–6 °C	1–10 °C	CPD: 21 days CPDA-1: 35 days
RBCs	Increases oxygen carrying capacity	1–6 °C	1–10 °C	ACD/CPD/CP2D: 21 days CPDA-1: 35 days With an additive solution: 42 days
Thawed plasma	Restores coagulation factors to support hemostasis	1–6 °C	1–10 °C	5 days from the date product was thawed or original expiration
Liquid plasma	Restores coagulation factors to support hemostasis	1–6 °C	1–10 °C	CPD or CP2D: 26 days CPDA-1: 40 days
Freeze- or spray-dried plasma	Restores coagulation factors to support hemostasis	2–25 °C	2–25 °C	Lyophilized: 24 months Once reconstituted: 8 hours at 25 °C
Cold-stored apheresis platelets	Restores platelets to support hemostasis	1–6 °C	1–10 °C	14 days

Key: CPD = citrate-phosphate-dextrose; CPDA-1 = citrate-phosphate-dextrose-adenine; ACD = acid-citrate-dextrose; CP2D = citrate-phosphate-double dextrose

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- For RBC-containing products (RBC and LTOWB units), group O is considered the universal donor, representing approximately 44% of the donor population.
- For plasma-containing products (thawed, liquid, or freeze-dried plasma), group AB serves as the universal donor type, though it comprises only 4% of donors.
- Studies demonstrate that group-A plasma, which generally contains low anti-B antibody titers, can be safely used for immediate transfusion during early resuscitation in both adults and children without an increased risk of hemolysis.[2,8]
- For group-O whole blood units, which contain both red cells and plasma, testing for low-titer anti-A and anti-B antibodies is required to minimize the risk of hemolytic transfusion reactions. *Low-titer* is generally defined as anti-A and anti-B titer levels of <1:256 or <1:200.[5]

RhD Type Selection

The RhD-positive blood type is present in 85–99+% of people. Having an ample supply of RhD-negative blood is challenging due to the relative rarity of this blood type. The historical practice of emergency transfusion for trauma patients has developed around this practical limitation: **RhD-negative blood is reserved for females with childbearing potential (FCP) and RhD-positive blood is given to males.** When an RhD-negative patient is exposed to RhD-positive blood, anti-D antibodies may be formed. For males, the future ramifications of this antibody development are minimal.

Antibody development is of particular concern to FCP. Future pregnancies for affected females are at risk for hemolytic disease of the fetus and newborn (HDFN). While HDFN is a rare and potentially life-threatening fetal condition, this condition is temporary and treatable when access to expert perinatal care exists. The risk of severe HDFN in a future pregnancy in females with life-threatening hemorrhage from trauma is estimated to be <1%.[9,10] As such, in situations of life-threatening hemorrhage, survival is the immediate priority. Do **not** delay transfusion of available blood products to FCP (see Box 2).

See Box 3 on pg. 12 for guidance on documentation and follow-up with an RhD-negative FCP who receives RhD-positive blood.

Box 2. Guidance for Blood Product Administration for FCP

If RhD-negative blood is unavailable and the FCP has a life-threatening bleed:

- Transfuse RhD-positive LTOWB/RBCs without delay. The risk of preventable death outweighs the potential future risk of HDFN.
- Document RhD status and product type administered.

Prehospital Hemostatic Adjuncts

TXA

TXA is a lysine analog known to stabilize clots and reduce fibrinolysis. When used within 3 hours of injury, TXA reduces mortality in trauma patients at risk of hemorrhage.[1] There are two common administration methods for TXA: a single 2 g bolus, or a 1 g bolus followed by a second 1 g infused over 8 hours or slow bolus (10 minutes).[12] The optimal administration method for TXA is controversial, though recent evidence has demonstrated improved outcomes in those with moderate/severe traumatic brain injury (TBI) and intracranial hemorrhage (ICH) with the single 2 g bolus. Regardless of method, providers should not exceed 2 g in total.

Calcium

Consider giving calcium following blood administration in the prehospital setting. Hypocalcemia is common after severe injury and is compounded by the citrate added to blood products for prevention of clotting during collection, storage, and transfusion. Citrate binds with calcium ions, making them unavailable for clotting. Roughly half of trauma patients are noted to be hypocalcemic, putting them at risk for coagulopathy, as well as decreased smooth muscle contractility in the heart and peripheral blood vessels.[13] After each 2 or more units of LTOWB, plasma, or RBCs, dosage for calcium administration is as follows:[14,15]

- Calcium chloride (10%) 20 mg/kg IV/IO (max 1 g)

or

- Calcium gluconate (10%) 40 mg/kg IV/IO (max 2 g)

If laboratory monitoring is available, providers should maintain ionized calcium >1.0–1.3 mmol/L and monitor frequently in patients receiving ongoing transfusions.[16]

Box 3. Patient Follow-Up for an RhD-Negative FCP Who Received RhD-Positive Blood

- Notify the receiving hospital blood bank and transfusion medicine service immediately if an RhD-negative FCP receives RhD-positive blood.[9,11]
- Posttransfusion Management:
  - Document RhD exposure in the patient's medical record, including the donor unit ABORh type, patient ABORh type, and antibody screen results.
  - Have a knowledgeable team member counsel the patient regarding alloimmunization risk and potential future pregnancy implications. Information and counseling guidance are available from the **Allo Hope Foundation** at allohopefoundation.org.
  - Because of the risk of a patient's failure to follow up, perform antibody screening after exposure to RhD-positive blood products for any FCP during the hospital admission.
  - At discharge, the trauma or designated clinical team must arrange follow-up to ensure postexposure management, including antibody screening at a minimum of 14 weeks after exposure to RhD-positive blood products for any FCP. If antibody screening is performed earlier than 14 weeks from exposure for any reason, repeat the antibody screening between 14 weeks and 6 months from exposure, since the initial antibody testing could be falsely negative.
  - Due to the risk of hemolysis, RhD-immune globulin (RhIg) is **not** indicated for RhD-negative FCPs with life-threatening hemorrhage who have received more than a small quantity of RhD-positive RBC/LTOWB during their resuscitation.
- Registry/Tracking: Ensure that an electronic health record (EHR) tracking system is in place to provide follow-up and continuity of care after discharge.

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SPECIAL CONSIDERATIONS

KEY POINTS

- Prehospital transfusion is recommended for pediatric patients, because mortality from life-threatening bleeding in these patients is higher relative to adults.
- Transfusion is recommended for older adults with a lower SI threshold of 0.9 to mitigate the risk of undertriage.

Pediatric Patients

Trauma is the leading cause of death in pediatric patients (age <15 years), and hemorrhage is the most common cause of preventable mortality in pediatric trauma patients.[1-3] Pediatric patients respond to hemorrhage differently than adults, with greater compensatory reserve relative to the volume of blood loss.[2] Triggers for pediatric transfusion must be based on age-appropriate vital signs. Similar to adults, no evidence-based prehospital transfusion triggers exist, but some pragmatic clinical consensus exists using SBP ≤70 + (2 × age in years) mm Hg **plus** signs of hypoperfusion as a trigger.[4]

In pediatric patients not requiring a massive transfusion, the dose for prehospital transfusion typically starts at 10–15 mL/kg, with doses repeated until resolution of hypoperfusion. For pediatric patients with hemorrhagic shock, perform massive transfusion in 15–20 mL/kg aliquots when using whole blood, RBCs, plasma, or platelets. Weight-based blood product dosing (10–20 mL/kg aliquots) is recommended for pediatric patients, particularly those weighing less than 20 kg. As pediatric patients approach 20–30 kg, standard blood bank units may be used. See Box 4 for pediatric blood product transfusion guidance.

Observational studies demonstrate associations between use of whole blood and improved pediatric patient outcomes.[1] Patients must have continuous monitoring following transfusion management for signs of hypoperfusion or transfusion reaction.

Box 4. Guidance for Pediatric Blood Product Transfusion

Consider the following age-adjusted criteria to trigger prehospital transfusion:

- SBP ≤70 + (2 × age in years) mm Hg
- Signs of hypoperfusion (altered mental status, pallor, delayed capillary refill, tachypnea)
- Active uncontrolled bleeding

If pediatric prehospital transfusion triggers are met:

- Begin universal blood product transfusion, and stop crystalloid infusions.
- Transfuse doses of 10–20 mL/kg of blood products. Transition from weight-based to whole-unit transfusion can be considered as pediatric patients approach 20–30 kg.
- Use the largest available IV or IO access.
- Use a metered pressure infusion device or the push-pull method with a stopcock and syringe.
- Aim for balanced resuscitation (either LTOWB or balanced 1:1 RBCs and plasma component therapy).
- Repeat transfusion until signs of hypoperfusion are resolved.

Older Adult Patients

The population of older adults (age >65 years) presenting with traumatic injuries is increasing, as are related fatalities. Moreover, comorbidities and prescribed drug therapies (e.g., anticoagulant and antiplatelet medications) put these patients at risk and complicate their subsequent management.

A major clinical challenge is the risk of undertriage, because older adult patients may present with vital signs that appear to be within the normal range, despite being in hemorrhagic shock.[4-5] Consequently, traditional scoring systems designed to predict the need for massive transfusion in adults have been shown to perform poorly in this patient group.[6]

Currently, no standardized blood product resuscitation guidelines exist for older adult patients. Consider transfusion with the following signs of hypoperfusion:

- Altered mental status
- Pallor
- Delayed capillary refill
- Tachypnea
- Hypocapnia with SBP <100[7]

Similarly, SI was demonstrated to be more accurate than HR or SBP alone; therefore, using a lower SI threshold of 0.9 to mitigate the risk of undertriage rates is recommended.[8]

Following the primary survey and initial hemorrhage control, obtain details of the patient's previous medical history, particularly regarding cardiovascular morbidity and the use of anticoagulants or antiplatelet agents. This information can further assist in guiding transfusion decisions.

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MEDICAL OVERSIGHT

KEY POINTS

- The EMS Medical Director, the Transfusion Service Medical Director, and the admitting facility each have responsibility for coordination and oversight of prehospital transfusion care.
- Shared oversight includes establishing transfusion criteria, confirming product blood type (ABO/Rh), maintaining cold chain custody, documenting transfusion events, and ensuring mechanisms are in place for adverse event recognition and management.
- Continuity of care, including communication and follow-up across all stakeholders (EMS, the transfusion service, and the admitting hospital), is essential for patient outcome review, management of Rh incompatibility, and continuous program improvement.

Blood Product Management and Collaboration

Prehospital transfusion requires coordinated oversight between the EMS Medical Director, the Transfusion Service Medical Director, and the admitting facility to ensure safe, evidence-based patient care.

Blood products used for prehospital transfusion may be obtained from hospital transfusion services or from a licensed blood supplier in accordance with regulatory and facility-specific requirements. EMS agencies and hospital transfusion services are encouraged to jointly establish protocols that maintain cold chain custody, optimize blood component use, and minimize wastage by considering shelf life and projected utilization.

Communication and collaboration among blood suppliers, regional hospital transfusion services, the EMS agency, and the admitting hospital are encouraged to promote patient safety, continuity of care, and high-quality transfusion practices.

EMS Medical Director responsibilities include:

- Establish transfusion criteria for field use
- Provide authorization (order) to transfuse
- Review documentation to ensure transfusion criteria were met
- Establish guidelines for recognition and management of adverse events
- Establish handover documentation process and, in the event of a transfusion reaction, provide a segment from the transfused RBC/LTOWB unit to the admitting hospital blood bank[1,2]
- Oversee EMS training programs related to transfusion
- Evaluate patterns of anticipated demand to correlate blood component selection and allocation to optimize inventory and minimize wastage

Transfusion Service Medical Director (providing product to EMS providers) responsibilities include:

- Serve as a foundational collaborating partner with EMS for program design and implementation
- The Transfusion Service Medical Director contracted by the EMS agency provides medical supervision of all blood bank and transfusion laboratory procedures
- Confirm ABO/Rh type for LTOWB or RBC products[1,2]
- Guide EMS to maintain cold chain custody during storage and transport
- Provide guidance to support the continual advancement of pretransfusion practices, including blood product selection, ABO/Rh compatibility assessment, and interpretation of antibody screen results
- Collaborate in the oversight of ABO/Rh management and support institutional efforts for the prevention and investigation of transfusion-related adverse events
- Ensure full blood product traceability

Admitting hospital responsibilities include:

- Function as the recipient hospital of the transfused patient
- Provide notification of any suspected adverse reactions to EMS and/or the transfusion service
- Establish and follow policies for RhD-positive transfusion into RhD-negative patients, including follow-up testing

Documentation requirements include:[3]

- Transfusion administration records
- Complete blood product traceability from blood supplier to final disposition
- Continuous temperature monitoring logs
- Validation and maintenance records for all equipment used is the responsibility of the medical director contracted by the EMS agency

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BEST PRACTICES GUIDELINES
TRANSFUSION IN TRAUMA

EMERGENCY DEPARTMENT AND TRAUMA CENTER RESUSCITATION



CONSTRUCTING A MASSIVE HEMORRHAGE PROTOCOL

KEY POINTS

- MHP development requires an interdisciplinary team.
- The policies and procedures for an MHP must be tailored to the facility, acknowledging local resources and limitations.
- Implementation of an MHP requires education, training, and practice to ensure provider competency.

The MHP is a controlled document approved by facility leadership, readily available to all relevant providers, and regularly updated. Involve the trauma center's interdisciplinary team in developing an MHP for children, adolescents, and adults of all ages. This team includes pediatric and adult professionals from trauma/acute care surgery, emergency medicine, critical care, anesthesiology, hematology, obstetrics, nursing, blood bank/laboratory medicine, and quality/safety personnel.

The policies and procedures for an MHP must be tailored to the facility, acknowledging local resources and limitations. The MHP must specifically address the following:[1,2]

- Activation criteria
- Team members and a predefined lead
- Processes for expedient issuance and delivery of blood products to patients
- Approved blood products
- Transfusion targets (goal or reason to stop)
- Use of hemostatic adjuncts
- Laboratory monitoring (specifically clotting studies)
- Cessation criteria
- Strategies for the preservation of unused products
- A plan for MHP performance improvement (PI) reviews

Some aspects of a modern MHP provide opportunities for clinical research, such as MHP activation criteria, blood pressure range parameters, and blood product selection. Thus, health professionals design and implement an MHP using their best judgment in an interdisciplinary approach, taking into account the patient population served, appraisal of the available published evidence for all treatment options, and local resource availability. As definitive clinical trials identify optimal approaches to outstanding clinical questions, practice is expected to coalesce around the most efficacious, safe, and practical transfusion approaches for the relevant patient populations.

Education, training (including drills and simulations), and competency assessment are necessary for all individuals who may participate in an MHP activation. At facilities where MHP activation is infrequent, simulation-based training (when available) needs to be repeated frequently.

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MASSIVE HEMORRHAGE PROTOCOL ACTIVATION CRITERIA

KEY POINTS

- MHP activation criteria for injured patients are locally established.
- Select appropriate activation criteria for the populations served.

The triggers for MHP activation may vary for different patient populations. The MHP is activated by the trauma team leader or their delegate. Determining who has life-threatening bleeding can be challenging in certain circumstances, such as internal bleeding. Therefore, predicting which patient needs an MHP activation to treat life-threatening bleeding can also be challenging. An MHP is an efficient mechanism to provide transfusion and hemostatic adjuncts; however, activation decisions have risks.

- Overactivation can result in unnecessary use of resources and therapies that have respective attendant risks and finite availability.
- Underactivation can result in treatment delays and increased mortality.

Clinical Tools

Multiple clinical tools can predict life-threatening bleeding and an associated need to activate an MHP. The SI is a validated and feasible scoring system, calculated by dividing HR by SBP. An SI >1.0 with a SBP <110 mm Hg is one trigger that can be used to activate an MHP.[1]

Other MHP activation criteria may include the following:[2,3]

- Mechanism of injury consistent with life-threatening bleeding and hemodynamic instability
- Use of multiple blood products in 1 hour for bleeding (e.g., more than 3 units of blood products or more than 20 mL/kg total for pediatric patients)
- $EtCO_2$ of <25 mm Hg (under conditions of controlled ventilation)
- An assessment of blood consumption (ABC) score ≥2
- Elevated lactate, significant base deficit, or fluid in the abdomen identified on the FAST exam

Available data do not clearly support one MHP activation criterion over the others, so the choice must reflect local practice, consensus, resources, and systems-related considerations.

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BASIC RESUSCITATION PRINCIPLES FOR MASSIVE HEMORRHAGE PROTOCOL ACTIVATIONS

KEY POINTS

- Rapid tourniquet and surgical or interventional radiology (IR) control of bleeding are recommended.
- Rapid and reliable vascular access is essential; large-bore peripheral IVs are preferred, but central venous or IO access may be necessary.
- Rapid infusers are used when clinically appropriate.
- Limit crystalloids, and use a balanced blood-based approach for resuscitation.
- Maintaining normothermia is recommended to prevent iatrogenic hypothermia and its associated coagulopathy.
- Permissive hypotension, targeting an SBP of 90 mm Hg, is used until definitive hemostasis is achieved. For patients with TBI, an SBP of 110 mm Hg is recommended as a permissive hypotension goal.

An MHP is a critical component of the larger hemostatic resuscitation strategy in DCR, an orchestrated effort to reduce death from hemorrhage with the following strategies:

- Limit ongoing hemorrhage. Facilities must develop and implement processes to apply tourniquets as needed during the early stages of care for patients with hemorrhage, as well as to recognize and manage tourniquets placed prior to arrival.
- Prevent or mitigate the effects of TIC.
- Preserve enough of a patient's physiological reserve until definitive hemostasis is achieved.

For patients with life-threatening bleeding who require MHP activation, rapid surgical control is prioritized. During resuscitation, maintain normothermia and minimize or avoid crystalloid use. Make an effort to balance adequate perfusion to treat and prevent ongoing tissue hypoxia associated with TIC. Avoid clot disruption, even though doing so is challenging.

With the shift from crystalloid-based to blood-based resuscitation in trauma care, the concept of permissive hypotension has evolved. Prior to surgical control of bleeding, experts now recommend a slightly higher target SBP of 110 mm Hg for polytrauma patients who also have severe TBI, compared to 90 mm Hg for adult patients without severe TBI.[1-3] Permissive hypotension is **not** a recommended strategy for pediatric patients.[2,3]

Vascular Access and Flow Considerations

Rapid establishment of vascular access that can accommodate high-volume transfusion is the foundation of trauma resuscitation. Obtain two large-bore (16 gauge or larger) peripheral IV lines in the upper extremities when possible. Suspected pelvic or intrathoracic hemorrhage prompts the use of vascular access above the diaphragm. When peripheral access is delayed or not achievable, IO access can serve as an initial bridge for transfusion; however, IO flow capacity is not equivalent to large-bore IV sites.[4,5] Sternal IO access provides the highest achievable flow rates, followed by humeral and tibial sites.

IO flow rates are significantly lower than IV or central access flow rates. IO access has estimated flow rates of 50–100 mL/min (or greater when using an inflated pressure bag), compared with more than 1,000 mL/min through a large-bore IV or central sheath access when using rapid transfusers.[6-9] The recommended practice is to convert from IO access to IV or central access as soon as feasible. Temporary use of pressure bags may augment the flow rate, but this is not equivalent to the flow rate with a rapid infuser. When central access is required, placement via a large-bore introducer sheath allows for rapid administration of warmed products.

Pediatric Considerations

Pediatric patients present unique challenges, including smaller veins and delayed signs of hypotension. Peripheral IV access is preferred when it can be obtained quickly. However, IO access (18 gauge in infants; 15 gauge in young children) or femoral venous access (with appropriately sized catheters) are effective alternatives for resuscitation in pediatric patients.

Rapid Infusion and Warming

Maintaining normothermia with the use of patient-warming devices is recommended. Increase the temperature in the resuscitation room when possible. Warmed transfusion helps prevent iatrogenic hypothermia and its associated coagulopathy. The use of commercial rapid infusers capable of delivering up to 1,000 mL/min while also warming blood products is recommended for major hemorrhage.

Platelets stored at room temperature have demonstrated maintenance of functional integrity when passed through warming or rapid infusion devices.[10,11] Although these devices remain off-label relative to US Food and Drug Administration (FDA) approval for their use with platelets, published data support their safety and efficacy in trauma care. The data on the use of warming or rapid infusers on cold-stored platelets and cold-stored whole blood vary with regard to the effects on platelet function. Some in vitro studies show no decrement in platelet function, while others show reduced platelet function.[12–14] The clinical consequences of these results are unknown. The tradeoff between more rapid infusion compared to in vitro function reduction is difficult to determine.

During resuscitation, remove needle-free connectors such as microclaves, because they restrict flow rates and may interfere with the operation of the rapid infuser. Co-administer all blood products only with normal saline or Plasma-Lyte to prevent hemolysis or clotting.[15]

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BLOOD PRODUCTS INCLUDED IN EACH MASSIVE HEMORRHAGE PROTOCOL ROUND

KEY POINTS

- If available, LTOWB or component therapy is recommended for patients with life-threatening hemorrhage, regardless of patient age or sex.
- When component therapy (RBCs, plasma, and platelets) is used, a balanced ratio is recommended for patients with life-threatening hemorrhage. Include platelets and plasma in the first MHP round.
- When ABO blood group testing is completed, switch to ABO-specific products as soon as possible.
- The blood bank needs to have thawed or liquid plasma readily available so that the first round of the MHP can be released without delay, followed by immediate preparation of the second round.
- It is recommended that all blood products, including platelets, be transfused through a rapid infusion system.
- For pediatric patients in hemorrhagic shock, perform massive transfusion using 15–20 mL/kg aliquots of whole blood or balanced ratios of RBCs/plasma/platelet products per round.

Blood products must be available in an expedient and safe manner. This requires preplanned use of uncrossmatched emergency-release blood products. Local storage of blood products near the emergency trauma unit is preferred if the blood bank laboratory is not close; however, this requires significant support from the blood bank laboratory. The blood bank team's close alignment with the clinical emergency trauma teams is essential to ensure safe practice compliant with applicable regulatory and accrediting agencies.

The blood products used in an MHP are intended to improve tissue oxygen delivery, provide hemostasis, reduce organ complications, and maintain endothelial integrity. The current standard of practice is to provide resuscitation using either LTOWB or blood components in a balanced ratio (ideally 1:1:1 of RBCs, plasma, and platelets). Over 250 US trauma centers prioritize the use of LTOWB when available.[1]

Current data do not suggest an upper limit on the amount of LTOWB that can be transfused, and many trauma centers do not set such a limit. The use of LTOWB has several advantages, including the following:

- It efficiently delivers balanced therapy with a lower crystalloid preservative volume.
- The blood bank processes are simplified, allowing for faster allocation of products (e.g., allocating one product instead of three or four; not needing time to thaw plasma).
- Providers do not need to track the order and timing of each component to achieve certain ratios during a high-stress clinical situation.

Blood services in countries outside the US may provide a combined RBC and plasma product (e.g., the NHSBT in England).

Regardless of whether LTOWB or blood components are used for the MHP, once the first MHP round has been assembled and delivered, the second round is assembled to allow for immediate release once the blood products of the first round are transfused. Protocols for preparation, request, and release of subsequent rounds are based on local capabilities and needs. Warming and timely transfusion of these blood products is warranted to stabilize and reverse the patient's clinical indications that initially prompted activation of the MHP. MHPs remain active until they are deactivated. Communication between providers and the transfusion service is critical but will vary by site and is part of the protocol.

Component Therapy

When component therapy is used during an MHP, transfuse RBCs, plasma, and platelets, aiming for a balanced strategy, ideally in a 1:1:1 unit ratio. If the patient's ABO type is not confirmed, these components will generally be the following:

- Group-O RBCs
- Plasma from type-AB donors or type-A donors
- Platelets of any available blood group

Apheresis platelets have the same platelet content as 5–6 units of whole blood–derived platelets, so one unit is transfused for every 5–6 units of RBCs and 5–6 units of plasma.

It is recommended that all blood products—except cryoprecipitate—be transfused through a rapid infusion system. Carefully monitor fluid balances, coagulation studies, ionized calcium, and potassium levels, particularly in pediatric patients.

Switch to ABO-specific products as soon as possible when ABO blood group testing is completed. For patients receiving component therapy, include plasma and platelets in the initial MHP round and transfuse them as early as possible, because this has been shown to improve hemostasis and patient outcomes.[2]

Fibrinogen supplementation with either cryoprecipitate or fibrinogen concentrate (FC) is recommended if laboratory values indicate hypofibrinogenemia or reduced fibrinogen function. Resuscitation for these patients is laboratory-guided and goal-directed. Empiric use of fibrinogen has not been shown to improve outcomes.[3]

Pediatric Considerations

For pediatric patients in hemorrhagic shock receiving massive transfusion, use weight-based dosing (mL/kg) for patients weighing 20 kg or less. Use 15–20 mL/kg aliquots of whole blood, or RBCs, plasma, and platelets in 1:1:1 ratio, per round. As pediatric patient weight approaches 20–30 kg, standard 1:1:1 (RBCs:plasma:platelets) unit-based transfusions can be implemented.

Alloimmunization

Due to the shortage of group-O RhD-negative donors, RhD-positive LTOWB and RBCs are commonly used for patients with life-threatening bleeding requiring MHP activation. Refer to the Blood Products and Hemostatic Adjuncts section and Box 3 on page 12 for guidance when RhD-positive LTOWB is transfused to an RhD-negative FCP, including appropriate counseling and follow-up.

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HEMOSTATIC ADJUNCTS

KEY POINTS

- TXA, in a 2 g IV bolus dose, is recommended for adults as soon as possible after MHP activation, if not already given prior to MHP activation.
- The pediatric dose of TXA is 25 mg/kg IV bolus (maximum 2 g IV), and administration is suggested as soon as possible after MHP activation if not given prior to MHP activation.
- Fibrinogen replacement is recommended for patients with bleeding in conjunction with acquired hypofibrinogenemia or rapidly decreasing fibrinogen levels.
- Consider calcium replacement after 2 or more units of blood products to prevent hypocalcemia.
- Prothrombin complex concentrates (PCCs) and recombinant factor VIIa are not recommended for empiric use in the MHP.

Several hemostatic adjuncts are available for bleeding patients receiving MHP.

Tranexamic Acid

The antifibrinolytic TXA inhibits plasminogen activation and plasmin activity and thus contributes to clot stabilization. TXA may also promote endothelial stabilization. TXA has been shown to improve survival for patients at risk of severe bleeding in multiple trauma research trials in adults.[1] TXA, given as a single 2 g IV bolus or as a 1 g bolus with a second 1 g dose given over 8 hours or slow (10 minute) bolus, is recommended for adults as soon as possible after MHP activation, if it was not already given by prehospital providers or before MHP activation.

> **Caution:** Administering TXA when 3 hours have elapsed since the time of injury is associated with increased mortality. Do not empirically administer more than 2 g total.

Pediatric Considerations

TXA use is not as well studied in pediatric patients, although a dose of 25 mg/kg IV push (maximum 2 g IV) is supported by pharmacokinetic data. This dose is currently used in the Massive Transfusion in Children-2 (MATIC-2, NCT06070350) trial examining its efficacy and safety in pediatric patients with life-threatening bleeding from trauma.[2]

Calcium

Calcium levels decrease following trauma and can decrease further following blood administration. Myocardial dysfunction and QT prolongation occur at ionized calcium concentrations of about 0.5 mEq/L, and the patient needs treatment before interference with coagulation occurs.

Calcium supplementation may improve cardiac function for patients with low ionized calcium. Consider administration of calcium after each 2 or more units of LTOWB, plasma, or RBCs to counteract the depleted calcium chelated by citrate with the following dosages:[3,4]

- Calcium chloride (10%) 20 mg/kg IV/IO (maximum 1 g

or

- Calcium gluconate (10%) 40 mg/kg IV/IO (maximum 2 g)

Point-of-care blood gas measurement devices allow for the timely measurement of calcium, specifically ionized calcium, while also providing additional valuable perfusion information (e.g., pH, lactate, and base excess). When the patient's ionized calcium levels are below the physiologic range (1.0–1.3 mmol/L), calcium chloride or calcium gluconate may be administered. Frequent monitoring of the patient's calcium level is recommended for those receiving ongoing transfusions.

> **Caution:** Do **not** administer calcium in the same IV or IO line as whole blood, RBCs, plasma, or platelets. This can cause clotting.

Pediatric Considerations

Adjust calcium doses for pediatric patients as follows:

- Calcium chloride: 5 mg/kg by slow IV injection; maximum rate: 100 mg/min
- Calcium gluconate: 50 mg/kg IV; maximum rate: 100 mg/min

Potassium

Patients with severe hemorrhage treated with blood products are at risk of developing hyperkalemia. Stored LTOWB or RBC units can have high potassium levels, potentially placing patients at risk for cardiac dysfunction and arrhythmias.[5-7] Neonates, infants and small children are at particular risk when high volumes of RBCs or LTOWB are administered rapidly.[8]

Fibrinogen

Fibrinogen is essential for clot formation and stabilization. Fibrinogen replacement (using transfusion of cryoprecipitate, INTERCEPT® Fibrinogen Complex, or FC) is recommended for patients with hypofibrinogenemia. Hypofibrinogenemia can be diagnosed by either viscoelastic assays or fibrinogen concentration via traditional laboratory testing. High-quality data do not exist to inform which source of fibrinogen is optimal for patients who have life-threatening hemorrhage from traumatic injury. The type of fibrinogen replacement used will depend on local availability, and it may include cryoprecipitate, INTERCEPT® Fibrinogen Complex, or FC.

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LABORATORY EVALUATION

KEY POINTS

- Collect two specimens for blood type at different times according to blood bank policy to determine the patient's ABO blood group and to prevent potentially life-threatening hemolytic reactions from the use of incompatible blood products.
- Complete blood count, blood gases, electrolytes, and coagulation assays are recommended at the initiation of the MHP and at regular intervals for the duration of the MHP.
- Rapid, iterative laboratory monitoring during the MHP, integrated with clinical judgment, facilitates transitioning from a LTOWB or ratio-based transfusion strategy to a laboratory-guided one.

Send two specimens for blood type to the blood bank, according to blood bank policy, for patients to receive ABO group-specific blood products as soon as possible. This testing is essential to reduce utilization of universal donor blood group-O RBCs and group-AB plasma that will be needed for other bleeding patients. Laboratory testing of hemostatic, hematologic, and electrolyte parameters during the MHP is important. Iterative testing, as the clinical situation dictates, allows for assessing efficacy of the resuscitation approach regarding the acid–base status, oxygen delivery, and hemostatic capacity. When developing the facility's MHP policy, stipulate the laboratory test result thresholds that necessitate predetermined medical intervention.

Conventional and Point-of-Care (POC) Testing

Baseline laboratory evaluation includes the following testing:

- Complete blood count
- Coagulation profiles (e.g., prothrombin time [PT]/international normalized ratio [INR], partial thromboplastin time [aPTT], platelet count, and fibrinogen)
- Serum lactate
- Blood gas measures (arterial or venous; can include ionized calcium, potassium, pH, and base deficit)

These tests provide insight into the patient's coagulation status and the adequacy of their end-organ perfusion and tissue oxygenation. This is important, since tissue hypoxia and TIC are strongly linked.

Repeated laboratory testing during active hemorrhage or after major transfusion cycles is a best practice for maintaining situational awareness and avoiding over- or undertransfusion.[1] Maintain ionized calcium levels within the physiologic range (1.0–1.3 mmol/L).

Diagnosis and Recognition of Trauma-Induced Coagulopathy

TIC represents a complex interplay of tissue injury, hypoperfusion, acidosis, and iatrogenic factors, including hypothermia and hemodilution. Recognition requires both clinical suspicion and laboratory confirmation. Conventional testing remains a common diagnostic approach. Typical values suggesting TIC include:

- INR ≥1.4
- aPTT ≥1.5 × the upper limit of normal
- Fibrinogen <1.5 g/L

Viscoelastic Testing

Viscoelastic testing provides a functional assessment of coagulation by measuring aspects of clot initiation, formation, strength, and breakdown (fibrinolysis). When available, viscoelastic testing can be used to guide transfusion decisions, particularly when rapid turnaround and iterative measures are feasible.[2,3] Practitioners need education to interpret the results, and it is recommended that the locally determined associated transfusion guidance (i.e., what specific blood product to give based on results) be incorporated into MHP algorithms.

Evidence suggests that viscoelastic-guided MHP algorithms can reduce plasma and platelet usage and may decrease surgical reintervention rates; however, consistent mortality benefit has not been demonstrated.[4,5]

A best practice is to employ the fastest available hemostatic testing modality (viscoelastic or conventional) within a structured algorithm emphasizing turnaround time and reproducibility. Agreement between team members (surgeons, anesthesiologists, intensivists, and laboratory/hematology coagulation experts) is essential regarding the algorithm and which viscoelastic or conventional values indicate continued coagulopathy to ensure strategic choice and use of component therapy for correction.

Viscoelastic assays can also detect the presence of factor deficiency, fibrinolysis, and platelet dysfunction, allowing targeted replacement therapy. However, thresholds are assay-dependent, and each trauma center must use parameters validated for its platform. A best practice is to use clinical context in combination with conventional laboratory testing and/or viscoelastic testing. This practice can confirm TIC and guide individualized resuscitation including fibrinogen for acquired hypofibrinogenemia, as well as TXA for evidence of fibrinolysis, even if it is indicated beyond the 3-hour window from the time of bleeding.[6]

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MASSIVE HEMORRHAGE PROTOCOL CESSATION CRITERIA

KEY POINTS

- Plan a resuscitation timeout/huddle after transfusion of approximately 20–40 units of product to reassess progress, determine the likelihood of achieving hemostasis, and evaluate patient prognosis.
- Cessation of the MHP is recommended once life-threatening bleeding is controlled, the patient is deceased, or the goals of care change. This is important to reduce blood product wastage and allow the team to return to other essential duties.

Termination of life-threatening bleeding can be identified by surgical or IR bleeding control, achievement of hemodynamic stability, and resolution of shock and coagulopathy. Laboratory parameters can supplement the clinical assessment, but they do not dictate cessation. A best practice is to incorporate a resuscitation timeout/huddle after transfusion of approximately 20–40 units of product to reassess progress, determine the likelihood of achieving hemostasis, and evaluate patient prognosis. This structured pause supports communication, prevents nonbeneficial transfusion, and promotes team situational awareness.[1]

Once life-threatening hemorrhage has ended, the clinical team needs to deactivate the MHP. Prompt and clear communication to the blood bank to deactivate the MHP will help relieve personnel who were recruited to prioritize care for the bleeding patient.[2] It is important to notify the blood bank so that subsequent MHP rounds of blood products will not be prepared. Return any unused products to the blood bank in a method defined by institutional MHP policy to optimize preservation. Complete appropriate documentation and transfer of care as appropriate.

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BEST PRACTICES GUIDELINES
TRANSFUSION IN TRAUMA

POSTRESUSCITATION PHASES OF CARE



TRANSFUSION TRIGGERS AFTER HEMOSTASIS

KEY POINTS

- Perform an overall assessment of the patient's clinical status and laboratory values when considering a blood transfusion after hemostasis.
- Base your assessment of the patient's clinical response and need for transfusion after hemostasis on overall laboratory value trends rather than a single laboratory value.

Blood Transfusion After Hemostasis

For hemodynamically stable patients requiring postanesthesia care, critical care, or general medical floor–level care, perform an overall assessment of the patient's clinical status and laboratory values when considering a blood transfusion after hemostasis.

RBC Transfusion

High-certainty evidence demonstrates that it is appropriate and safe to transfuse RBCs using a hemoglobin (Hgb) value of 7–8 g/dL as a transfusion trigger in most hemodynamically stable patients.[1,2] However, if the patient is anemic with symptoms (e.g., tachycardia, shortness of breath, chest pain, oliguria, or newly altered mental status), RBC transfusion may be indicated at a higher Hgb value. Conversely, an asymptomatic patient with chronic anemia and Hgb value <7 g/dL may not need an RBC transfusion.[3]

Platelets

Several randomized controlled trials (RCTs) support the safety of platelet transfusions for the following patient populations:[4]

- High-certainty evidence shows that it is appropriate and safe to prophylactically transfuse platelets to nonbleeding patients with no other risk factors when their platelet count is $<10 \times 10^9$/L.
- Lower-certainty evidence supports the safety of platelet transfusion for patients needing central line placement.
  - At compressible sites (e.g., internal jugular, femoral), transfuse platelets when the patient's platelet count is $<10 \times 10^9$/L.
  - For noncompressible sites (e.g., subclavian), transfuse platelets when the patient's platelet count is $<20 \times 10^9$/L.
- Very low-certainty evidence shows that it is safe and appropriate to transfuse platelets in the immediate postoperative period when the patient's platelet count is $<50 \times 10^9$/L for major nonneuraxial surgeries and $<100 \times 10^9$/L for major neuraxial procedures.
- When available, viscoelastic hemostatic assays can be used to indicate need for platelet transfusion based on functional data. Data are limited related to an appropriate platelet administration threshold for bleeding patients taking antiplatelet medications.
  - While the common convention is to target a platelet count of $\geq 100 \times 10^9$/L, this is not based on high-quality evidence. A lower threshold may be appropriate to preserve the facility's platelet supply and to reduce risks associated with platelet transfusion without increasing the patient's risk for expanding hemorrhage.
  - Platelet transfusion is not recommended for adult patients with nonoperative ICH and a platelet count $>100 \times 10^9$/L, including patients receiving antiplatelet agents.

Plasma

Transfuse 10–20 mL/kg of plasma to correct coagulopathy (INR >2) or with ongoing non–life-threatening bleeding, such as oozing at open sites. A stable, nonbleeding patient is unlikely to benefit from plasma if their INR is ≤1.8.

Cryoprecipitate or Fibrinogen Concentrate

The patient fibrinogen level goal is >100–150 mg/dL, depending on concern for bleeding. Administering 10 units of cryoprecipitate or 4 g of FC will raise the fibrinogen level by 80–100 mg/dL in a stable adult. For similar increments of 80–100 mg/dL in stable pediatric patients, administer 5 mL/kg of cryoprecipitate or 50 mg/kg (maximum 4 g) of FC. Viscoelastography can also be used to determine fibrinogen activity and need for fibrinogen repletion.

Whole Blood

Whole blood transfusion is generally reserved for resuscitation of trauma patients with hemorrhage. Whole blood is **not** recommended for hemodynamically stable patients.

Laboratory Monitoring

Monitor the patient's laboratory values as needed to assess response to therapeutic measures, including the following:

- Hemoglobin and hematocrit
- INR
- aPTT
- Platelet count
- Fibrinogen level
- Viscoelastography (when available)
- Ionized calcium
- Blood gas analysis, including base deficit

The patient's clinical status determines the ordering frequency of laboratory tests. Base your evaluation of the patient's clinical response on overall laboratory value trends rather than a single laboratory value.

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SPECIAL PATIENT CONSIDERATIONS

KEY POINT

- A hemoglobin value of 8 g/dL or less may be an indication for RBC transfusion in patients with certain heart diseases, sickle cell anemia, and TBI, as well as older adults.

Patients With Low Hemoglobin Values

Patients With Heart Disease

Trauma patients with certain coexisting conditions, such as ischemic heart disease or cyanotic heart disease, may benefit from an Hgb >8 g/dL. Transfuse RBCs when patients present with acute myocardial infarction and anemia (Hgb <9–10 g/dL).[1,2]

Sickle Cell Anemia

Patients with sickle cell anemia often maintain an Hgb <8 g/dL. Transfuse these patients with RBCs only when symptomatically anemic to avoid increased risk of alloimmunization.[3] Transfuse patients with sickle cell disease awaiting a surgical procedure to maintain an Hgb value between 9–11 g/dL.

Older Adults

Patients older than 65 years of age with an Hgb <8 g/dL may benefit from an RBC transfusion.[4]

Pediatric Patients

Transfuse pediatric patients with congenital heart disease with an Hgb <7–9 g/dL.[2,5] The RBC transfusion dose is 10–20 mL/kg.

Patients With TBI

Consider transfusion in all critical care patients with TBI, subarachnoid hemorrhage, or ICH (either primary ICH or anticoagulant-associated) presenting with Hgb values ≤9 g/dL. Recent clinical trial data report mixed results regarding these patients. However, a benefit was found for patients with TBI when a liberal transfusion strategy is used, specifically transfusing for Hgb values ≤9 g/dL.[6] It is not yet known whether mild, moderate, and severe TBI should be treated differently.

TXA Administration

If only the first 1 g of TXA was given (either in the prehospital or hospital setting) and the patient is still in the 3-hour window from the time of bleeding onset, consider giving an additional 1 g TXA upon arrival in the postanesthesia care unit, ICU, or general inpatient unit to complete the recommended dose of 2 g.[7,8]

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BEST PRACTICES GUIDELINES
TRANSFUSION IN TRAUMA

TRANSFUSION MEDICINE AND TRAUMA SUPPORT SERVICES



MASSIVE HEMORRHAGE PROTOCOL MANAGEMENT

KEY POINTS

- In Level I and Level II adult and pediatric trauma centers, each laboratory work shift must have the staffing to ensure the availability of an adequate supply of blood products.
- Transfusion medicine specialists must be available to consult with the trauma team during an MHP activation.
- Transfusion medicine specialists must be involved in the development of MHP protocols.

The safe and expeditious delivery of blood for transfusion is a defining feature of an effective trauma system. Transfusion saves lives, but blood products are highly regulated biological substances with inherent risks. Transfusion practices may vary between jurisdictions, based on local standards and regulations, and with availability of products. This section addresses best practices for establishing trauma transfusion programs that can be applied flexibly across trauma centers of various levels.

Massive Hemorrhage Protocols

Transfusion services in trauma centers need approved protocols for managing massive hemorrhage. An up-to-date MHP must adhere to current best practices in transfusion and incorporate any relevant national guidance.[1]

The MHP must be developed collaboratively between the trauma and transfusion medicine services, with recommended review and update at least every 3 years based on evolving literature. The protocol needs to reflect local limitations and strive to adhere to best practices and universal principles of safety and efficiency. The protocols must include the following elements:

- Details on the activation and cessation criteria and process
- Roles and responsibilities of staff involved in managing patients with massive bleeding
- Transfusion guidance
- Laboratory testing
- Adjuncts such as TXA
- Strategies for the preservation of unused blood
- How and when communication between different parties needs to occur

Although this document refers to an MHP for trauma, a blood bank also needs MHPs for other services, such as obstetrics. While an MHP for trauma is often developed with a focus on adults, it is recommended that all sites consider the need for and development of a pediatric MHP, with appropriate modifications to blood component volumes.

Expectations and goals for blood delivery must be agreed upon between the trauma and transfusion services, documented in standard operating procedures (SOPs), and tracked as quality indicators. For most patients, expect it to be achievable to provide group-specific and/or crossmatched RBCs within 1 hour.

Transfusion Service Support

In Level I and Level II adult and pediatric trauma centers, each laboratory work shift must have the staffing available to ensure that an adequate supply of blood products is always available. High-volume Level I and Level II trauma centers will likely have transfusion service staffing 24 hours a day, validated remote storage, transport systems, and ready access to all blood products. Trauma centers with fewer resources, such as Level III and Level IV trauma centers and critical access hospitals, may have limited access to these services. When a trauma center does not have transfusion medicine staffing 24 hours a day, access to emergency-release blood through the core laboratory or a remotely monitored blood refrigerator is required. If a hospital transfusion service is located far from a trauma bay or lacks continuous staffing, consider installing a validated, remote-monitored blood refrigerator in the hospital emergency department (ED).

A designated trauma center must have SOPs and training for the rapid, early, and continued delivery of blood components as dictated by its MHP.[2] Surge capacity policies are recommended (which may be part of a multicasualty protocol or business continuity plan), enabling the laboratory or transfusion service to bring in additional employees within 30–60 minutes.

Communication

The trauma team needs a simple and reliable means to request blood in an emergency. The ideal model is a direct, person-to-person verbal link between the requesting clinician and the blood bank—via phone, radio, or secure voice-over-internet system. It is recommended that MHP activations use standardized language to eliminate ambiguity. A suggested format includes the caller's identity, patient details, location, and the nature of the request. Responses from the blood service need to be equally structured (see Box 5). Electronic or paper documentation needs to follow verbal orders promptly but not delay patient care.

Box 5. Sample Communication

Activating the MHP

"This is Dr. Smith activating the MHP for patient Jane Doe, approximately 40-year-old female, record #1234567, currently in ED Bay 1."

Blood Service Response

"That's Jane Doe, 40-year-old female #1234567 in ED Bay 1. We will send Cooler #1 as soon as possible, and Cooler #2 is in preparation. Please send a group and screen sample immediately."

Designate one person from the clinical team to communicate with the blood bank to avoid redundant calls for blood. Bidirectional communication is critical. The blood bank must have a reliable means to contact the bedside team for clarification, updates, or urgent queries. This link must remain available throughout the activation.

During massive transfusion, timely and precise communication between the trauma team, the ED, the operating room (OR), IR suites, anesthesiology, ICU, and the transfusion service regarding availability and need for transfusion products is imperative. At a minimum, clear discussion must occur at key points such as the following:

- Patient transfer to another location (for example, ED to OR or ICU)
- Termination of the MHP
- Death or change in goals of care
- Inventory constraints

Patient Movement

MHP activations must allow for patient movement. Trauma MHPs may be activated in the ED, OR, IR suite, or ICU. An MHP may be continued while the patient moves between these locations. It is recommended that clear procedures exist to notify the blood bank about patient movement so MHP coolers are promptly redirected to the patient's new location. Carefully track blood components when they and the patient are moved to a new location. The EHR may provide a seamless means of tracking blood component movement if it is set up to accurately follow the patient's location.

MHP Cessation

The MHP must also include a clear process and criteria for cessation that is developed by the trauma and transfusion services (see Massive Hemorrhage Protocol Cessation Criteria on page 28). Cessation does not mean that all transfusions stop; rather, a transition is made to a slower, goal-directed transfusion strategy that is guided by algorithms and supported with rapid laboratory testing. Indefinite continuation or open-ended "pausing" of an MHP increases the risk of wasting finite resources and critical labor. Communication for stopping the MHP must be as well-structured as for an MHP activation. As part of the cessation process, trauma care providers, with the oversight of blood services, need validated workflows for the safe return of unused products to prevent waste.

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BLOOD PRODUCT STORAGE AND RELEASE

KEY POINTS

- A blood refrigerator in the trauma bay is the most efficient way to initiate an MHP, because initial products are immediately available.
- All verified Level I and II trauma centers are expected to have an adequate supply of the following blood products on hand and available for immediate release:
  - Universal donor whole blood, or
  - A combination of group-O RBCs, group-AB or group-A plasma, and platelets
- High-functioning centers will also have PCCs and either FC or cryoprecipitate available.
- Universal plasma must be immediately available for an MHP to be effective.

Blood Storage and Handling

Remote blood refrigerators containing universal products (e.g., group-O RBCs and/or LTOWB) are recommended at the POC if the blood bank is not located near the trauma bay. The number and setup of such refrigerators are dependent upon local factors such as location of the blood bank relative to the trauma bay.

Clear and strict rules for blood refrigerator access must be agreed upon by the trauma and transfusion teams to balance easy access with avoiding wastage and misuse. All applicable regulations for blood storage must be adhered to (see Table 1 on page 10). RBCs can be safely stored for up to 6 weeks, and they are released using a first-in, first-out system to minimize wastage. Based on RCT results, no justification exists to prioritize the use of RBCs with short storage times to a trauma patient at the expense of other patients.[1,2]

The contents and stocking levels of remote refrigerators are agreed upon by the trauma and transfusion teams based on need and usage data. Continuous monitoring is mandatory, and data are reviewed regularly by an interdisciplinary committee. Education for access to emergency refrigerators must include all clinical teams, including those who need access less frequently.

Blood Product Release

When a blood refrigerator is not used, an alternate option is to dispatch blood automatically to the trauma bay for top-tier activations. However, the trauma team must return the blood as soon as possible when it is not needed, according to their institutional guidelines.

In-hospital blood product transport poses its own risks. Coolers must be designed to maintain blood product temperature even when opened briefly. All clinicians must understand that improper handling—such as leaving lids ajar or placing room-temperature platelets in cold environments—can render blood products unusable. Coolers must be validated for temperature stability under real-world conditions.

Inventory

A verified Level I or II trauma center or its supporting transfusion service is expected to have an adequate supply of blood products available for immediate release, including the following:

- Universal donor whole blood or a combination of group-O RBCs and group-AB or group-A plasma
- At least one dose of platelets (Level I and II trauma centers); a protocol to expedite rapid platelet release or patient transfer if platelet need is anticipated but not available (e.g., Level III or IV trauma centers and nontrauma centers)
- High-functioning trauma centers often will have at least one adult dose of fibrinogen (i.e., 5–10 units of cryoprecipitate or 4 g of FC) and at least one dose of PCCs to be used for urgent reversal of anticoagulants such as warfarin or direct oral anticoagulants (DOACs).
- Level III trauma centers are expected to have an adequate supply only of RBCs and plasma available for immediate release.[3]

Issuing Blood Products

For an MHP to be effective, universal plasma must be immediately available. This can be accomplished by storing thawed or never-frozen liquid plasma. Clinical teams and the transfusion service are encouraged to agree on the number of available prethawed or liquid plasma units to provide for rapid transfusions while minimizing wastage. Expect the transfusion service to be able to provide additional plasma within 20–30 minutes of MHP activation.

The ideal universal plasma is AB plasma, but it is in short supply because only 4% of donors have this blood group. With the increased use of AB plasma in resuscitation, shortages of AB plasma may occur for patients with the AB blood group. However, 40% of donors are type A, and group-A plasma with low anti-B titers can be safely used upon initiation of emergency transfusion until a blood group can be established.[4,5]

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DONOR-DERIVED BLOOD PRODUCTS

KEY POINTS

- Standard banked blood products include whole blood, RBCs, plasma, platelets, and cryoprecipitate.
- Each blood component has its own storage requirements and shelf life that must be considered when designing a trauma transfusion system.

Low-Titer Group-O Whole Blood

Depending on how LTOWB is manufactured, it may or may not be leuko-reduced (removal of >99% of the white blood cells), and it may or may not have a clinically significant platelet content. Because this blood product is often used in prehospital patients who do not have pretransfusion testing, most whole blood comes from group-O donors. To avoid incompatibility between donor plasma and patient red cells ("minor" ABO incompatibility), blood services select donors with naturally low titers of anti-A and anti-B antibodies hence the designation "low-titer." Whole blood is stored at 1–6 °C and has a shelf life of 21–35 days, depending on the preservative used. See Table 1 on page 10 for blood product storage and shelf life information.

Stored Red Blood Cells

Stored RBCs contain red cells (erythrocytes), citrate anticoagulant, additive solution, and trace plasma. Most RBCs are also leuko-reduced. A unit of RBCs in additive solution has a hematocrit of around 60% (range between 50% and 70%). One unit in additive solution will raise the Hgb value of a 70 kg adult by approximately 1 g/dL, although substantial variation exists between units.[1] In a small neonate, these variations are exaggerated, and the absolute Hgb rise may be as little as 1.0 g/dL or as much as 3.0 g/dL after a 10–15 mL/kg dose.[2] RBCs are stored at 1–6 °C and have a shelf life of 21–42 days, depending on the preservatives used.

Plasma

Stored plasma contains all the acellular chemical and protein ingredients of blood, including albumin, coagulation factors, and immunoglobulins. Dilution with anticoagulant lowers the coagulation factor activity in stored plasma to about 80%, or a PT/INR of about 1.1.[3] Most plasma is stored frozen for up to 1 year and must be thawed prior to use. However, some units may be kept at 1–6 °C after donation ("liquid" plasma) so they can be used immediately during an MHP. Once thawed, plasma is stored at 1–6 °C and has a shelf life of up to 5 days.

Platelets

Units of platelets contain platelets (thrombocytes), plasma, storage solution, and trace amounts of red and white blood cells. They may or may not be leuko-reduced or pathogen-reduced. Most platelets in the US are suspended in a 35%/65% mix of plasma and additive solution. Platelets are stored at 20–24 °C under agitation, and they have a shelf life of 5–7 days.

Platelets stored "cold" and unagitated at 1–6 °C are receiving renewed interest.[4] Cold-stored platelets (CSPs) appear to have a longer shelf life (14 days) than platelets stored at 20–24 °C, without any significant change in hemostatic activity. Recent RCTs demonstrate safety and feasibility for use in trauma, and trials for FDA licensure of CSPs are underway.[5,6] Several studies have assessed freeze-dried or frozen platelet preparations, as well as novel biotherapies using platelet-like synthetic particles.[7]

Cryoprecipitate

Cryoprecipitated antihemophilic factor, commonly known as "cryo," is a plasma-derived source of concentrated fibrinogen with variable levels of other hemostatic proteins such as factor VIII, factor XIII, von Willebrand factor, and fibronectin.[8] Cryoprecipitate in the US is typically produced in pools of 5 units, and transfusing two 5-unit pools will increase the fibrinogen level by 80–100 mg/dL in a stable adult patient. Although cryoprecipitate is an important tool in laboratory-guided, goal-directed transfusion, RCTs have not found any benefit in early, empiric fibrinogen supplementation after traumatic injury to unselected patients.[9,10] Cryoprecipitate is stored frozen for up to 1 year and has a shelf life of 4–6 hours after thawing. Commercially manufactured, pathogen-reduced cryoprecipitate with a 5-day liquid shelf life recently became available, although its efficacy and cost-effectiveness in trauma have not been established.

Other Blood Products and Factors

Fibrinogen Concentrates

Human-derived lyophilized (freeze-dried) FCs are commercially available. RCTs involving cardiac surgery and other patient populations suggest that it can be used interchangeably with cryoprecipitate.[11,12] Because FCs can be stored dry and reconstituted at the bedside, they may be a useful alternative to cryoprecipitate when frozen storage with rapid thawing is not possible. FCs have been studied in RCTs, both as an empiric treatment in trauma care and as a substitute for plasma in MHP coolers (in combination with PCCs), without demonstrable superiority.[13,14]

Prothrombin Complex Concentrates

PCCs are human-derived lyophilized factor concentrates. The most common PCCs are "four-factor" (4F-PCCs), which contain factors II, VII, IX, and X, as well as protein C and protein S. PCCs were studied in RCTs, both as an empiric treatment in prehospital trauma care and as a substitute for plasma in MHP coolers (in combination with FCs), without demonstrable superiority and with some concerns about increased thromboembolic events.[15] Beyond its use for reversal of warfarin and DOACs, use of PCCs in trauma is **not** currently a best practice.

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BLOOD ADMINISTRATION

KEY POINTS

- When feasible, administer all blood components using a blood warmer.
- When IV access is limited, all blood products—including platelets but excluding cryoprecipitate—can be transfused through a rapid infusion system. Do not transfuse cryoprecipitate through rapid infusion devices.
- It is recommended that the trauma and transfusion teams develop clear guidelines for reporting transfusion reactions during resuscitation to meet regulatory requirements but that do not interrupt lifesaving transfusions.

Attach an identification armband to a rapidly bleeding patient as soon as practicable, either with the true patient identity (name, date of birth, and medical record number) or a unique, temporary identifier assigned by the EHR. Do **not** update patient identifiers during the MHP, as this may lead to a delay in transfusions and hamper linkage to laboratory and imaging results.

Standard Operating Procedures

Hospitals need preexisting blood administration policies, and SOPs for trauma transfusion must conform to these policies and all other relevant regulatory requirements, including national guidance.[1] It is recommended that SOPs be translated into a bedside guide for easy clinical reference during an emergency. Adaptation may be needed for specific contexts (e.g., pediatric trauma). This bedside guide includes the following information: a summary of available MHPs, contents of coolers, important contact numbers, and critical clinical reminders (e.g., maintaining normothermia, correcting acidosis, and monitoring electrolytes).

The SOPs may also provide reasonable advice for off-label treatments in life-threatening emergencies. For example, although rapid infusion devices are not licensed for platelet administration, good experimental data support the safety and efficacy of administering platelets through them.[2,3] Therefore, it is recommended that platelet concentrates be administered through a rapid infuser during life-threatening bleeding when IV access is limited. Similarly, all blood products (not just RBCs and plasma) except for cryoprecipitate can be safely administered through a validated blood warmer.[2,4]

Complications of Transfusion

Many medical complications of transfusion may occur. Some are clinically obvious, such as hemolytic or allergic transfusion reactions. Others are severe (e.g., acidosis, hyperkalemia, hypotension, volume overload, and acute lung injury) but may be difficult to distinguish from the physiological derangements of traumatic injury. A third set of complications may not become clinically apparent for days to months after transfusion (e.g., alloimmunization, delayed hemolytic transfusion reactions, and infections).

Blood bank regulations require clinician oversight in the case of a transfusion reaction. During the acute management of a transfusion reaction, it is common for blood banks to suspend all transfusions until certain acute diagnoses, such as anaphylaxis or a hemolytic transfusion reaction, are ruled out. While sound reasons exist for this practice in nonacute settings, interruption of blood administration may inadvertently cause patient harm during a resuscitation. It is recommended that the trauma and transfusion team develop clear guidelines for reporting transfusion reactions during resuscitation that meet regulatory requirements without interrupting lifesaving transfusions. Direct communication between the bedside clinician and the blood bank physician is critical to ensure patient safety without compromising ongoing resuscitation in such instances.

Transfusion services are required to monitor for transfusion reactions and regularly review reports—a process called *hemovigilance*. It is recommended that all transfusion reactions in trauma patients be regularly reported to the trauma oversight and/or PI committee.

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BEST PRACTICES GUIDELINES
TRANSFUSION IN TRAUMA

ANTICOAGULATION REVERSAL



ANTICOAGULATION OVERVIEW

KEY POINTS

- Decision-making regarding the need for and selection of antiplatelet and anticoagulation reversal agents is complex, and it is dependent upon multiple patient and healthcare system factors.
- A best practice is for all designated trauma centers to develop a protocol for rapid reversal of antiplatelet and anticoagulant agents in collaboration with pharmacy, hematology, and other key stakeholders.

Anticoagulant and antiplatelet medications are prescribed for many adults in the US. Given the frequency of this practice, and in combination with the increasing age of trauma patients, guidance is warranted regarding the indications and options to reverse these medications in patients with traumatic bleeding.

Decisions regarding the need for and selection of reversal agents for anticoagulants and antiplatelet agents rely on multiple factors, including the following:

- Indication for the anticoagulation/antiplatelet agent
- Time since the last dose
- Injury type and location
- Injury and bleeding severity
- Anticipated bleeding risk (e.g., risk of expansion, need for surgical decompression)
- Clinical course (e.g., decompensation, rate of deterioration)
- Creatinine clearance
- Availability and cost-to-benefit ratio of specific reversal agents in the treating facility

All designated trauma centers (adult Level I–III, pediatric Level I and II) must have a protocol for rapid reversal of antiplatelet and anticoagulant agents in collaboration with pharmacy, hematology, and other key stakeholders. A best practice would be for lower level and nontrauma centers to have a similar practice.

Laboratory Assays

Many clinically available coagulation and hemostasis assays—including INR/PT, viscoelastic testing, and platelet function assays—have limited sensitivity and specificity for assessing or guiding reversal of DOACs and antiplatelet therapies. Therefore, do not use these assays in isolation to guide reversal strategies.[1,2]

Most laboratory tests that could confirm the presence and extent of anticoagulation (e.g., anti–factor Xa activity level, thrombin time, diluted thrombin time, and Ecarin thrombin time) require specialized laboratories. Additionally, they are not performed in a time frame that would impact bedside decision-making, precluding their utility in life-threatening emergencies.

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REVERSAL OF VITAMIN K ANTAGONISTS

KEY POINTS

- The first-line agent recommended for rapid reversal of vitamin K antagonists is 4F-PCC.
- Plasma is a second-line therapy for rapid reversal of vitamin K antagonists.

Vitamin K antagonists are prescribed for multiple indications, including the following:

- Prophylaxis and treatment of venous thromboembolism
- Thromboembolic complications of atrial fibrillation (e.g., stroke)
- Cardiac valve replacement
- Reducing the risk of mortality and morbidity after myocardial infarction

Nonurgent Reversal

For nonurgent reversal, oral or IV vitamin K is often sufficient, recognizing the time to reversal effect is approximately 8–12 hours. Administer vitamin K therapy by slow IV infusion over 30 minutes; a repeat dose at 12 hours may be indicated. When vitamin K is administered, it is not possible to achieve therapeutic warfarin levels again until some days or weeks afterward.

Rapid Reversal

4F-PCC is recommended as the first-line therapy for rapid reversal of vitamin K antagonists. 4F-PCC is licensed by the FDA for this indication. It replaces the clotting factors (II, VII, IX, and X) that are inhibited by warfarin. Dosing can be either weight-based or fixed-dose.

- A weight-based sample regimen: 25–50 international units (IU)/kg depending on admission INR
- A fixed-dose sample regimen:
  - 1500 IU 4F-PCC
  - 2000 IU 4F-PCC if INR is >10 or patient is >100 kg

Benefits of a fixed-dose regimen include noninferiority, simpler logistics, more rapid preparation and administration, and lower cost due to less medication used.[1,2]

Plasma is the second-line therapy for rapid reversal of vitamin K antagonists. A plasma dose of 10–15 mL/kg is typically required for effective reversal, often resulting in a large-volume transfusion. Compared with plasma, 4F-PCCs contain approximately 25 times more vitamin K–dependent clotting factors (including factors II, VII, IX, and Xa).

4F-PCCs are favored over plasma for rapid reversal because of the following:[3,4]

- Rapid administration time
- Low-volume infusion
- Leukocyte-free product
- Minimal risk for transfusion-related lung injury
- Safety in patients with low tolerance of large-volume plasma transfusion (e.g., those with heart failure)

Vitamin K may also be administered in conjunction with 4F-PCCs or plasma to avoid rebound coagulopathy due to the relatively short half-lives of these rapid reversal agents.

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REVERSAL OF DIRECT ORAL ANTICOAGULANTS

KEY POINTS

- 4F-PCCs are recommended as the first-line agent for rapid reversal of factor Xa inhibitors and other DOACs.
- Plasma is not recommended for reversal of DOACs.

4F-PCCs are often used off-label for management of hemorrhage associated with factor Xa inhibitors and other DOACs.[1-6] 4F-PCCs have a nonspecific mechanism of action and produce modest increases in Xa levels and restoration of thrombin generation.[7-9] Dosing can be either weight-based or fixed-dose.

- Weight-based sample regimen: 25 IU/kg for minor bleeding; 50 IU/kg for major bleeding[10,11]
- Fixed-dose sample regimen: 3000 IU

Benefits of a fixed-dose regimen include noninferiority, simpler logistics, more rapid preparation and administration, and lower cost due to less medication used.[12]

Use of 4F-PCCs is recommended for rapid reversal of factor Xa inhibitor–associated hemorrhage, depending on medication availability, individual patient characteristics, risks, and benefits. Plasma is not recommended in this setting.

Andexanet alfa (Andexxa) was a recombinant engineered version of human factor Xa originally licensed in 2018 for rapid anti–Xa agent reversal.[13] Andexxa was withdrawn from the US market in December 2025 due to a high risk of thromboembolic events.

Plasma is **not** recommended for reversal of DOACs.

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REVERSAL OF DIRECT THROMBIN INHIBITORS

KEY POINTS

- Idarucizumab is recommended as the first-line agent for rapid reversal of direct thrombin inhibitors (DTIs).
- Plasma is not recommended for DTI reversal.

DTIs are used for stroke and systemic embolism prophylaxis in patients with nonvalvular atrial fibrillation, as well as for prevention of recurrent deep vein thrombosis. The overall use of DTIs is decreasing because DOACs have a favorable safety profile.

Idarucizumab was approved in 2015 for reversal of dabigatran-induced coagulopathy in patients with life-threatening or uncontrolled bleeding and in patients requiring emergent/urgent procedures.[1–3] This medication is a specific, neutralizing, monoclonal antibody fragment that adheres to the thrombin binding site of dabigatran. Idarucizumab is recommended as the first-line agent for reversal of DTI-associated hemorrhage.

4F-PCCs may be used as a second-line agent when idarucizumab is not available. Data suggest that 4F-PCCs can improve hemostasis and correct dabigatran-induced laboratory abnormalities in animal models and healthy volunteers.[4]

Hemodialysis may also be considered for reversal of dabigatran-induced coagulopathy. Dialysis removes 60% of the medication over 2–3 hours, but it requires high blood flow rates of 200–400 mL/min, and dialysate flow rates of 700 mL/min for at least 4 hours, followed by continuous renal replacement therapy.[5] Considerations for use of hemodialysis in patients with ICH include avoidance of blood pressure or electrolyte shifts, which may not be tolerated by patients with TBI.

Plasma is **not** recommended for reversal of DTIs.

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BLEEDING MANAGEMENT IN THE PATIENT TREATED WITH ANTIPLATELET AGENTS

KEY POINTS

- For patients with antiplatelet-associated ICH who require operative intervention, platelet transfusion is recommended.[1]
- For patients with antiplatelet-associated ICH who do not require operative intervention, observation without platelet transfusion may be considered.[1]

For injured patients taking antiplatelet agents who present with a low quantitative platelet count, data to support platelet transfusion at any threshold are very limited. While common convention is to target a platelet count of ≥100 × 10^9/L, this is not based on high-quality evidence. A lower threshold (e.g., ≥50 × 10^9/L) may be appropriate for some patients. This enables platelet supply preservation and reduction of patient risks associated with platelet transfusion without increasing the risks of expanding hemorrhage.

For patients with antiplatelet-associated massive hemorrhage, transfuse platelets following the standard MHP guidelines targeting balanced resuscitation.

- For patients with antiplatelet-associated ICH who do not require operative intervention, observation without platelet transfusion may be considered.[1] RCTs comparing platelet transfusion to no platelet transfusion are lacking and needed.
- Platelet transfusion is recommended for patients with antiplatelet-associated ICH who require operative intervention.[1]

If the clinical team indicates that platelets are needed, dosing is based on the antiplatelet agent used.

- For aspirin, a single dose of platelets is typically sufficient to achieve effective hemostasis.
- For clopidogrel, reversal is dose-dependent. Multiple doses of platelets may be required to achieve hemostasis.[2]
- Reversal of ticagrelor is particularly challenging. Platelet transfusion within 24 hours of medication dosing is not likely to be effective.

Data are conflicting regarding the use of arginine desmopressin (DDAVP) in the setting of ICH.[3,4] A single dose of DDAVP may be considered for ICH associated with aspirin/COX-1 inhibitors or adenosine diphosphate receptor inhibitors.

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BEST PRACTICES GUIDELINES
TRANSFUSION IN TRAUMA

TRANSFUSION SUPPORT FOR SURGE CAPACITY



DISASTER PREPAREDNESS PLANNING

KEY POINTS

- Trauma systems must be prepared for massive surges in blood product demand following a mass casualty incident (MCI), especially during the first few hours.
- It is recommended that 6–8 units of whole blood (or equivalent) per severe casualty (injury severity score [ISS] >15) be the aim for preparedness.
- It is a best practice for hospitals to conduct disaster drills that include communication and integration with blood suppliers at least twice a year.
- Successful management of extreme blood demand requires preestablished coordination between hospitals, blood collection organizations (BCOs), and the Association for the Advancement of Blood and Biotherapies Interorganizational Disaster Task Force (AABB IDTF).

Trauma system preparedness to manage an MCI is crucial. These events may be caused by natural disasters (e.g., earthquake, hurricane, flood, tornado), industrial incidents, terror attacks, and more. Because these events are often unexpected, planning is required to manage both an abrupt surge in the number of casualties and their ongoing treatment needs. This includes blood product requirements.

Initial Blood Product Demand During an MCI

During an MCI, up to 74% of blood product requirements are needed during the first 4 hours.[1] The blood products used during this initial period will be those that are readily available and stored in an appropriate form (see Donor-Derived Blood Products on page 38). These products are used until they are exhausted.

Dealing with blood product shortages is the cornerstone of transfusion preparedness for MCIs. It is recommended that trauma systems be prepared to access at least 6 (and ideally 8) units of whole blood or whole blood equivalent (e.g., RBCs, plasma, and platelets at a 1:1:1 ratio) per casualty with severe injuries (ISS >15).[1,2]

BCOs able to collect fresh whole blood (FWB) in accordance with applicable regulatory requirements need an emergency plan to rapidly collect and provide FWB (both noncrossmatched type-O and type-specific). It is recommended that this plan include details about mobilizing additional staff, if required, as well as contacting and attracting donors. BCOs are strongly encouraged to develop the ability to collect FWB for these instances.

Systems Coordination

Rapidly and dynamically moving blood where needed during an MCI is challenging, especially in a highly fragmented emergency response system such as found in the US. This challenge is compounded if a single large MCI (or multiple, simultaneous MCIs) are spread across a large geographic area. Trauma system preparedness for these events must include appropriate planning, coordination, training (including drilling), activation, and awareness about how to receive blood product assistance in coordination with the AABB IDTF.[3]

One means of meeting blood product requirements is through assistance from adjacent trauma systems and community hospitals. A regional trauma system can coordinate trauma center preparedness, including blood product allocation. The AABB IDTF handbook recommends that affected BCOs need to assess the potential impact of an MCI on blood collections and inventories. If blood supply assistance is needed, the BCO needs to contact the AABB IDTF office for assistance in blood product allocation.[1] Nonetheless, it must be acknowledged that many causes of MCIs also affect the logistical ability to supply blood products to the affected area (e.g., harsh weather conditions).

Ongoing Transfusion Needs

Following the initial surge in blood product requirements, anticipate the continued need for blood products, both for injured patients and for patients hospitalized for other reasons. Typically, following a disaster, enough volunteers present for blood donation. For proper disaster preparedness planning, have guidelines for how to contact donors and an estimated number of units to collect. Ensure that sufficient blood supplies are collected to meet transfusion requirements and achieve adequate renewal of storage levels while avoiding blood product wastage.

Disaster Preparedness Training

Training for disasters is complex. Disaster preparedness training at timed intervals is recommended because MCIs are infrequent, and staffing changes are common. Disaster drills are effective to familiarize hospital employees with disaster procedures, identify problems in different components of response (e.g., incident command, communications, triage, patient flow, materials and resources, and security), and provide the opportunity to apply lessons learned to disaster response.[4] It is a best practice for hospitals to practice disaster drills, including communication and integrated training with blood suppliers, at least twice a year.

Understanding the maximum capacity of BCOs to meet surge demands is of utmost importance. BCOs are strongly encouraged to adopt the ability to collect FWB for MCIs in accordance with applicable regulatory requirements. Interagency coordination and participation in drills, involving local, regional, and state EMS systems, as well as other community healthcare facilities, such as non–trauma-verified hospitals, must also be considered. Importantly, in a disaster situation, the BCO may be compromised. Plan for and simulate this scenario.

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RURAL AND REMOTE SETTINGS

KEY POINTS

- Limited access to BCOs in a rural or remote setting requires individualized facility planning.
- LTOWB or emergency RBCs and plasma are the preferred options for blood storage in rural or remote settings.
- New products such as FDP may be used when refrigerated plasma products are unavailable. Spray-dried plasma may be a future alternative.

In rural or remote settings, it may be challenging to supply and store blood products, and access to a BCO may be limited. Even a modest increase in the need for blood products may exhaust readily available supplies.

Treating patients who are hemorrhaging in rural or remote settings is even more complicated for several reasons:

- Time required to deliver blood products to the patient
- Distant or limited BCOs
- Logistics and patient evacuation routes are frequently long
- Extended time to transport a patient to a trauma center, even when air transport is available

These issues warrant special consideration and planning for treating trauma patients in rural and remote settings. Preferably, facilities in such settings store RBCs and/or LTOWB in dedicated refrigerators. The RBCs and/or LTOWB are preferably coupled with plasma and, if logistically feasible, with CSPs.

Maintaining an inventory of blood products in these settings presents some additional challenges that include adequate monitoring, managing the replacement of expired products, and blood product wastage. These challenges limit the amount of blood that can and should be stored. In settings where plasma cannot be stored, PCCs and FCs can be stored at room temperature and have a longer shelf life. These products can be used until the patient is evacuated or plasma becomes available.[1]

Lyophilized FDP may be a future option in rural and remote settings. Its major advantages include a long shelf life, low-maintenance storage, ease of administration, and a good safety profile. However, the efficacy of FDP as the main resuscitative agent for trauma DCR requires further high-quality investigation.[2] FDP is recommended for use in remote conditions when other blood products cannot be provided.

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WALKING BLOOD BANK

KEY POINT

- A walking blood bank (WBB) involves emergent blood collection from donors prescreened for ABO type and infectious diseases.

The challenges that may limit the ability to provide blood products to trauma patients who require them (e.g., inventory limits and supply chain disruption) are acknowledged. A WBB involves emergent blood collection from donors prescreened for ABO type and infectious diseases.[1,2] The WBB is a strategy used most commonly in military settings. It is also used in some specific civilian settings, such as Norway, which has an active civilian WBB for rural hospitals.[3]

Planning for and activating a WBB has many regulatory and practice limitations. Due to its novel and less well-defined nature, it is **not** within the scope of these guidelines.

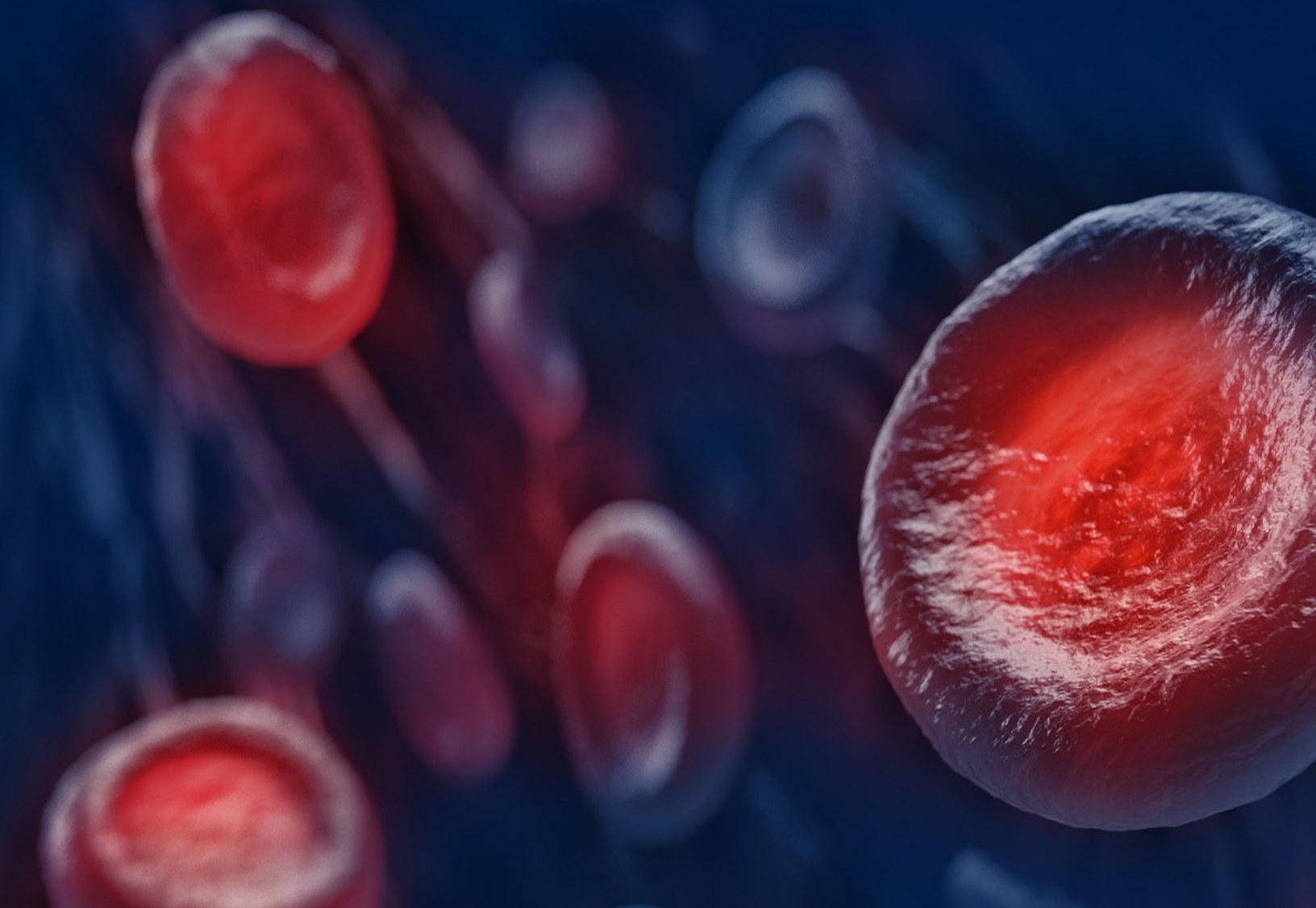
Consider the following issues for the purpose of exploring a WBB program:

- Emergency donor pool selection and the prescreening process for blood type and infectious disease carriage. This also involves questioning about infectious disease at the time of an emergent donation. Decisions regarding screening interval need to be considered, as does rapid diagnostic testing, if available.
- Blood bank position, including sustainability and continuity of function during natural disasters, wars, terror attacks, etc.
- Availability of supplies, including phlebotomy kits, collection bags, blood sample test tubes, documentation/labeling materials, and a means for storage
- Guidelines for administration and patient monitoring during transfusion, as well as posttransfusion monitoring for infectious disease transmission
- Training the providers to perform the blood collection
- Adequate system planning and preparation for the WBB program
- Regulatory approval (e.g., FDA)

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FUTURE DIRECTIONS FOR TRANSFUSION CARE



FUTURE DIRECTIONS FOR TRANSFUSION CARE

KEY POINTS

- Research studies are focused on dried plasma products for use in trauma patients and in conjunction with RBCs, in both the prehospital and hospital setting when whole blood is not available.
- Consider the inclusion of CSPs in the trauma center MHP when room-temperature platelets are either not available or their use is not feasible.

Despite significant advances in resuscitation and transfusion medicine, the frontier of translational science remains dynamic. Rapid development of novel resuscitation agents is ongoing. New products may address many issues related to current blood product access and storage, as well as the feasibility of transfusion in austere settings. However, these new innovations require time for full safety profiling and, ultimately, widespread adoption.

Plasma

Rapid development is focused on the reintroduction of dried plasma.[1,2] New dry plasma products include:

- OctaplasLG® Powder (Octapharma AG—Lachen, Switzerland; Conformité Européenne approval in European Union, Emergency Use Authorization in US, Special Access Program in Canada)[3]
- RePlas™ (Teleflex—Wayne, PA, USA; phase I trial completed)[4]
- EZPLAZ™ (Teleflex—Wayne, PA, USA; FDA approved July 2026)
- Spray-dried plasma from Velico (Beverly, MA, USA; phase I trial completed)[5]

These dried plasma products may become interchangeable with frozen or liquid plasma as they become more available. For example, when whole blood is not available, dried plasma can potentially be used in conjunction with RBCs, in either the prehospital or hospital setting. Even when RBCs are not available or whole blood supplies are exhausted, the use of dried plasma products may offer hemostatic and perfusion benefits over the use of crystalloid. The storage requirements for dried plasma make it attractive to stock and use in the prehospital setting.

Platelets

Platelets are conventionally stored at room temperature with agitation and have a shelf life of 5–7 days.[6] CSPs are stored at low temperatures (1–6 °C), which results in a shelf life of up to 14 days. The FDA has approved the use of CSPs for trauma and MHPs when room-temperature platelets are not available or their use is not practical.[7] The rapid delivery (<15 minutes) of blood products, including platelets, after MHP activation reduces mortality in severely injured patients.[8,9] Consider the inclusion of CSPs in an MHP activation when room-temperature platelets are not available or their use is not feasible. Trials for licensure of CSPs are ongoing at the time of this writing.

Multiple platelet-derived and platelet-like therapies are being tested. The goal is to have a shelf-stable product that can move platelets farther forward in resuscitation and to address platelet deserts (regions in the world that cannot stock platelets due to storage and resource limitations).

Extended Whole Blood Storage

Using methods similar to the already licensed AS-7 RBC additive solution, an 8-week whole blood additive solution was developed and demonstrated. The ability to store blood longer can result in a greater availability of blood with lower wastage.[10]

Blood Substitutes

A shelf-stable, universal whole blood substitute for emergency use is in development by the Defense Advanced Research Projects Agency (DARPA) program FSHARP (Fieldable Solutions for Hemorrhage with bio-Artificial Resuscitation Products). This product is intended for combat and in-field resuscitation. Bio-artificial components mimicking the function of real blood are being created, including an RBC mimetic for oxygen delivery and a platelet mimetic to combine with dried plasma. This would provide the function of whole blood without requiring cold storage and could address the limitations of donated blood.[11]

New Pathogen Reduction Systems

New pathogen reduction systems focus on proactively inactivating microbes in blood products (e.g., platelets and plasma) to improve patient safety. Using technologies like ultraviolet-C light (Theraflex UV—Macopharma, Tourcoing, France) or photochemicals (INTERCEPT®—Cerus Corp., Concord, CA, USA; and Mirasol—Terumo BCT, Lakewood, CA, USA) with psoralen/riboflavin, it may be possible to prevent transfusion-transmitted infections while extending the shelf life of blood products.[12,13] Research continues to evaluate the impact of these systems on the hemostatic function of blood products.

Universal Donor Pool Expansion

Avivo Biomedical Inc. (Vancouver, BC, Canada) is exploring the concept of universal donor pool expansion via use of a proprietary enzyme platform to convert donor RBCs into universally compatible group O. The potential outcome is the elimination of ABO blood-type matching as a barrier to lifesaving transfusions.[14]

Creative Transport Methods

Outside of the hospital setting, far-forward resuscitation capabilities are being investigated, including creative transport methods to maximize access to blood products. Unmanned aerial vehicles, or drones, enable timely delivery of medical supplies to areas where geographic challenges limit access. This has been explored in combat and civilian trauma. It is feasible if appropriate thermoregulation is maintained and personnel are present to receive and transfuse the products.[15]

Interim Guidance

These new innovations require time for full safety profiling and, ultimately, widespread adoption. In the meantime, all hospitals need to have the capability for massive transfusion with whole blood (when possible) and/or components (including plasma, either frozen or freeze-dried), PCCs for anticoagulant reversal, and FCs for pathologies like postpartum hemorrhage.

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IMPLEMENTATION AND INTEGRATION OF THE BEST PRACTICES GUIDELINES



GAP ANALYSIS AND EDUCATION PLAN

KEY POINTS

- These best practices recommendations, based upon evidence and expert opinion, are intended as guidance for trauma centers treating patients who require emergent transfusion in the setting of life-threatening hemorrhage.
- The trauma medical director (TMD), trauma program manager (TPM), transfusion medicine/blood bank medical director (TM/BB MD), emergency medicine liaison, and prehospital liaisons have leadership roles in implementing the ACS TQP *Best Practices Guidelines for Transfusion in Trauma*.
- An interdisciplinary stakeholder workgroup, operating under the direction of the TMD and the trauma operations committee, reviews best practices recommendations, conducts a gap analysis of the trauma center's current care for patients with life-threatening hemorrhage, and implements identified improvements.
- The transfusion service needs to be involved in all aspects of MHP education.
- Developing a targeted education plan to address provider competency needs, equipment requirements, and knowledge gaps related to massive hemorrhage management that are identified through the gap analysis.
- Integrating documentation standards into the EHR to support consistent reporting, facilitate data abstraction, and enable reliable outcome monitoring.

Effective implementation of the ACS TQP *Best Practices Guidelines for Transfusion in Trauma* relies on strong, coordinated leadership within the trauma center. The TMD, TPM, TM/BB MD, trauma liaisons, and registrars serve as the primary drivers of this work, establishing the structure, culture, and processes that support consistent adoption of evidence-based practices across the trauma system. Their leadership ensures alignment across clinical, operational, and administrative domains while fostering meaningful engagement from all stakeholders.

Within this framework, the interdisciplinary massive hemorrhage control guidelines workgroup, supported by a defined lead and reporting structure, reviews current recommendations, determines when a formal gap analysis is needed, and guides the trauma center to identify and prioritize improvement opportunities. This structured process leads directly into the following activities:

Performing a Gap Analysis

The TPM, in conjunction with an interdisciplinary team, reviews the current trauma center practices, compares them to the recommended guidelines, and identifies gaps between the two. This gap analysis identifies opportunities to align the trauma center's massive hemorrhage management practices with the ACS TQP *Best Practices Guidelines for Transfusion in Trauma*.

For recommendations not met or partially met, an action plan is developed and shared with the trauma operations committee for review and assignment of associated tasks. Progress is monitored and reported to the trauma operations committee. See Table 2 for gap analysis recommendations to consider.

Table 2. Gap Analysis Recommendations

Recommendations	Met	Partially Met	Not Met	Priority	Comments
Prehospital					
Protocols exist for prehospital blood product administration. A mechanism for EMS monitoring and reporting includes: - Prehospital transfusion documentation - Defined prehospital transfusion triggers - Blood product temperature monitoring - Transfusion-related events, reporting, and care - Adjunct therapies administered (e.g., TXA, calcium) - Follow-up and feedback for patient outcomes					
Guidelines for population-specific considerations: - FCP RhD-incompatible transfusions (see Box 2) - Weight-based pediatric MHP (see Box 4)					
EMS agency has a quality review process to evaluate and monitor prehospital blood administration that addresses: - Patient selection - Administration - Handoff - Documentation - Minimizing blood product waste					
Data use agreement allowing for reciprocal data sharing between the trauma center and EMS agencies					
Trauma Center					
Triggers for initiation of blood product administration/MHP					
Protocol for notifying blood bank of MHP activation and cessation					
Blood product warming methods present and available in ED, OR, and IR					
Protocols in place to reduce blood product waste, recycling, or downcycling prior to expiration					
Thawed, frozen, liquid, or freeze-dried plasma availability for MHP					
Coagulation testing integrated into MHP (e.g., thromboelastography, POC PT/INR)					
Calcium repletion is included in MHP					
TXA administration is addressed in adult MHP					
MHP accounts for prehospital blood product administration where applicable					
Guidelines for population-specific administration considerations: - FCP RhD-incompatible transfusions (see Box 2) - Weight-based pediatric MHP (see Box 4)					
Anticoagulation reversal protocol includes considerations for ICH with or without operative intervention to include: - Vitamin K antagonist - DOACs - Antiplatelet agents - DTIs					
Contingency plan for inability to deliver MHP (e.g., equipment malfunction, MCI, product shortages)					
Transfusion service is included in PI, case reviews, education, and protocol development and review					
Disaster drills and education with blood supply services integrated					

Posttransfusion					
Follow-up process for FCP RhD-incompatible transfusions (see Box 3): - Identification/notification - Counseling education - Repeat antibody testing - Outpatient clinic follow-up					
End points for MHP are addressed in MHP					

Once the gap analysis is completed, the next step is to revise or develop the trauma center's massive hemorrhage guidelines and protocols for the phases of care provided by the trauma center. These guidelines are reviewed and approved by the trauma operations committee and the TMD. The trauma operations committee is responsible for communicating about and disseminating the revised massive hemorrhage guidelines to all clinicians and departments that participate in trauma care.

Interdisciplinary Education Plan Development

The next priority is development of an interdisciplinary education plan for the revised MHP and guidelines for each trauma center unit and phase of care. This education plan outlines the expectations for the various clinician roles involved in massive hemorrhage control and management, as well as the specific tasks associated with assessment, documentation, interventions, and reassessment.

Trauma center and hospital clinicians must be educated about the MHP. Regular drills and simulations are needed to expose latent weaknesses in the protocols or systems supporting transfusion services and to build familiarity and competence among staff members.

The trauma team needs to involve the transfusion service in all aspects of MHP education. Annual training for bedside providers includes discussion of the following:

- Structure and purpose of the MHP
- Criteria for MHP activation
- MHP activation and cessation procedures
- Type of blood products available on an emergency basis

Simulations and drills are encouraged to build familiarity with the MHP among teams, since activation typically occurs in high-stress, high-acuity situations. Contingency planning is essential for shortages, lack of equipment familiarity, equipment failures, and MCIs. Education needs to emphasize the importance of preserving universal donor blood (e.g., group-O RBCs). Refer to Table 3 for education plan elements to consider for integration of massive hemorrhage control best practices.

Table 3. Education Plan

Education Elements	Priority	Targeted Staff
IV/IO access competency		
Central venous access competency of providers		
Rapid infuser setup, use, and troubleshooting		
Balanced resuscitation with prehospital blood administration consideration		
Primary hemorrhage control focus		
MHP activation and cessation triggers include communication protocols with the blood bank		
Strategies for prevention of hypothermia/coagulopathy during resuscitation		
MHP debriefing process		
Coagulopathy and resuscitation with POC and viscoelastic testing		
MHP is included in mock trauma education and MCI drills at least biannually, or more frequently for low-volume trauma centers, to ensure familiarity with institutional protocols		
Signs of transfusion complications: • Transfusion-associated circulatory overload (TACO) • Transfusion-related acute lung injury (TRALI) • Hemolysis and fluid overload • Transfusion and allergic reactions		
Administration and follow-up process for FCP with RhD-incompatible transfusions		
Disaster education and drills integrating blood supply services		

INTEGRATION INTO TRAUMA CENTER PERFORMANCE IMPROVEMENT

KEY POINTS

- The interdisciplinary workgroup defines elements of the ACS TQP *Best Practices Guidelines for Transfusion in Trauma* to monitor through the trauma performance improvement and patient safety (PIPS) processes.
- After approval by the trauma PIPS committee, the approved MHP elements are integrated into the existing PIPS plan for compliance monitoring.
- Debriefing with the professionals who participated in the MHP clinical team is recommended as soon as possible after an MHP cessation.
- Structured, regular, interdisciplinary MHP case reviews are recommended.

The interdisciplinary workgroup defines and recommends key elements of the ACS TQP *Best Practices Guidelines for Transfusion in Trauma* to integrate into the trauma PIPS processes. These trauma PI recommendations are applicable to the trauma center patient who receives blood products for emergent resuscitation. The interdisciplinary team will integrate blood administration documentation standards into the EHR. See Table 4 for PI recommendations to consider.

MHP Debriefing and Case Review

It is a best practice for a transfusion service representative to participate in debriefing sessions and committees where MHP events are reviewed by the interdisciplinary team. Structured committee meetings, as well as ad hoc huddles for MHP cases, lead to improved understanding by the professionals involved in the MHP while identifying strengths and concerns related to the process and communications.

MHP Debriefing

After the MHP is concluded, conduct a focused debrief and review by the involved interdisciplinary team, and ideally include the prehospital team. Postevent review huddles are beneficial to the professional team present in the moment to reflect on the processes, outcomes, and communications during the MHP event.[2,3] Goals of the review include discussing what did and did not go well during the resuscitation, without judgment and in the spirit of PI. Focusing on systems issues that will improve future performance is important.

Massive resuscitations may also cause distress and harm to providers. A structured debrief is an early opportunity for members of the resuscitation team to express concerns, receive reassurance, and be offered appropriate counseling.

Interdisciplinary Case Review

Interdisciplinary review of each MHP case is a best practice to identify areas for improvement and to document concerns. Reviews need to occur on a regular basis with input from all service lines that participate in the MHP and provide patient care during the MHP timeframe. In some facilities, these reviews can be structured as a subcommittee under the hospital's interdisciplinary transfusion committee.

Review of MHP data at PI conferences for trauma, transfusion, and other stakeholder groups is essential for reinforcing and refining successful practices and for identifying practice improvement opportunities.[4,5] Recommended metrics for review and discussion include:

- Appropriateness of MHP activation
- Time to first issue of the MHP transfusion round
- Process errors (e.g., delay in delivery of blood products, delay in collecting compatibility testing samples, registration error, product waste)
- Overtransfusion of RBCs or significant deviations from expected product ratios
- Compliance with transfusion guidance, hemostatic adjunct use (including administration of TXA), and laboratory testing protocols
- Appropriateness of MHP cessation
- Blood product return and wastage
- Notification of RhD-positive exposure to RhD-negative FCP (with consideration for ordering an antibody screen after 14 weeks to 6 months from exposure to assess for alloimmunization)
- Adverse events

Table 4. Performance Improvement Recommendations

PI Recommendations	Outcome Measure and Thresholds
Prehospital	
Blood product waste monitoring in collaboration with hospitals that serve as transfusion centers or rotation centers	<10% of short date blood product waste
Prehospital IV/IO access	IV/IO access is attempted and achieved in 100% of patients meeting prehospital transfusion protocol guidance
Administration of prehospital blood product when clinical triggers are met by agency protocol	80% of patients who meet hypoperfusion triggers due to hemorrhage receive blood products, if available, per agency protocol
EMS scene time	EMS scene time is not delayed due to blood product need or administration
Documentation of blood product administration: - Indications for administration - Start and stop time of administration - Volume transfused - Method of delivery - Product type - RhD-incompatible transfusions in FCP	No missing documentation components
Administration of TXA, if available, per agency protocol	• 80% of patients who received prehospital blood receive TXA per protocol • TXA is only administered within 3 hours of bleeding onset
Hospital	**Outcome Measure**
Activation of the MHP is based on clinical triggers	100% of patients who receive MHP met clinical triggers for initiation
Transfusion begins within a predetermined, trauma- center-specific timeframe after activation (activation to initiation)	Initiation of blood products begins within institution-specific timeframe 80% of the time
Blood products are given as LTOWB or as components (ideally as a 1:1:1 unit ratio) based on results from conventional coagulation or viscoelastic testing	100% compliance with facility-based MHP protocol
RhD follow-up (documentation of counseling and follow-up for RhD-negative FCP)	100% of RhD-negative FCP who receive RhD-positive blood products receive discharge education with a plan for follow-up antibody testing ≥14 weeks from exposure
Accurate and timely documentation of blood product administration	100% of blood products administered are documented in the EHR, including the timing of initiation and completion of MHP
Patient vital signs include routine temperature monitoring for prevention of hypothermia-induced coagulopathy	100% of patients who receive massive transfusion have vital signs with temperatures documented according to facility policy or protocol during resuscitation and upon transfusion completion
Crystalloid infusion is limited once blood product initiation has begun	Crystalloid infusion is limited once blood products are initiated in 90% of MHP resuscitations
Patient's blood is collected for type and screen upon arrival and sent to the blood bank	80% of patients who receive massive transfusion have type and screen sent to the blood bank (Exception: when a specimen cannot be obtained due to absent pulse)
TXA is dosed and timed appropriately per protocol	80% of patients eligible for TXA per facility protocol receive correct dosage within 3 hours of injury
Calcium is dosed and timed appropriately per facility protocol	100% of patients receive calcium repletion per protocol, and ionized calcium is maintained at 1.0–1.3 mmol/L
Initial laboratory testing and repeat labs performed per facility protocol for those at risk for massive hemorrhage	100% of patients at risk for massive hemorrhage have initial comprehensive or POC testing performed (possible facility exception may include inability to obtain a specimen due to an absent pulse)

Pediatric MHP is used for patients <15 years of age	- IV/IO access is obtained within 5 minutes 80% of the time - Weight-based volume administration is used for all pediatric patients weighing ≤20 kg and may be applied to all patients (adult and pediatric) <50 kg - Weight-based medication dosing is used for all pediatric patients
Anticoagulant reversal protocol is followed by administering the correct drug and dosage within correct time to administration	80% compliance with anticoagulant reversal protocol
Blood products returned to the blood bank follow institutional best practices	<10% of blood products returned did not follow facility protocol for storage (wastage rate)[1]
Transfusion-related complications are reviewed	All transfusion-related complications are reviewed and monitored by the PI process

Other complications of MHP activation may not need special review, since they will be addressed in trauma center PI processes (e.g., death) or transfusion quality process (e.g., transfusion reactions).

Conduct periodic staff training and simulations to maintain competency of all team members and to maintain familiarity with MHP policies and procedures.[6] Expect issues to arise, and view these as opportunities for improvement.

Regional System Integration

Regional integration is essential to ensure timely, coordinated, and equitable access to emergent transfusion resources for patients with life-threatening hemorrhage. A regional system may choose to establish an interdisciplinary collaborative to align protocols, optimize resource stewardship, improve access, and enhance communication across the continuum of care. It is important for this collaborative to include representation from prehospital agencies, trauma centers, blood banks, transfusion services, emergency preparedness partners, and the regional trauma advisory council.

The collaborative defines shared priorities, establishes common processes, and identifies opportunities for regional data collection (e.g., product availability, waste metrics, rotation schedules, utilization patterns, and patient outcomes). This approach strengthens standardization, reduces variability, and supports continuous quality improvement across the system.

Potential priorities for development of a regional collaborative include:

- Prehospital blood transfusion implementation
  - Assessing EMS agency readiness, capability, blood storage, equity of access, and transport standards
  - Aligning triage criteria and early activation/destination protocols
  - Standardizing training requirements and competency expectations
- Blood product stewardship and resource optimization
  - Developing rotation agreements between agencies and transfusion services that also address equity of access
  - Monitoring waste, utilization efficiency, and adherence to triggers for MHP activation
  - Creating shared dashboards or data-sharing agreements to support transparency
- Regional emergency preparedness and surge planning
  - MCI planning for events that exceed local inventory
  - Shared strategies for cross-coverage and mutual aid
- Coordination with blood suppliers and vendors
  - Establishing regional forecasting, ordering, and delivery patterns
  - Assessing whole blood versus component therapy availability
  - Developing contingency plans for shortages
- Standardized clinical and operational protocols
  - Unified prehospital and hospital MHP initiation criteria
  - Consistent documentation and workflows
  - Shared quality metrics

- Regional data, quality improvement, and reporting
  - Defining core data elements
  - Evaluating outcomes
  - Conducting case reviews
- Education, outreach, and continuous readiness
  - Joint training, simulation
  - Regional drills involving blood product mobilization
  - Shared learning through regional conferences, meetings, or after-action reports

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ABBREVIATIONS

4F-PCC—4-factor prothrombin complex concentrate

A

AABB—Association for the Advancement of Blood and Biotherapies
ABC—assessment of blood consumption
ACS—American College of Surgeons
AI—artificial intelligence
aPTT—partial thromboplastin time

B

BCO—blood collection organization
BPGs—best practices guidelines

C

CPD—citrate-phosphate-dextrose
CPDA-1—citrate-phosphate-dextrose-adenine
CSPs—cold-stored plateletsy

D

DCR—damage-control resuscitation
DDAVP—arginine desmopressin
DOAC—direct oral anticoagulant
DTI—direct thrombin inhibitor

E

ED—emergency department
EHR—electronic health record
EMS—emergency medical services
EtCO2—end-tidal carbon dioxide

F

FAST—focused assessment with sonography for trauma
FC—fibrinogen concentrate
FCP—females with childbearing potential
FDA—Food and Drug Administration
FDP—freeze-dried plasma
FWB—fresh whole blood

H

HDFN—hemolytic disease of the fetus and newborn
Hgb—hemoglobin
HR—heart rate

I

ICH—intracranial hemorrhage
ICU—intensive care unit
IDTF—Interorganizational Disaster Task Force
INR—international normalized ratio
IO—intraosseous
IR—interventional radiology
ISS—injury severity score
IU—international units
IV—intravenous

L

LTOWB—low-titer group-O whole blood

M

MCI—mass casualty incident
MHP—massive hemorrhage protocol

O

OR—operating room

P

PCC—prothrombin complex concentrate
PI—performance improvement
PIPS—performance improvement and patient safety
POC—point-of-care
PT—prothrombin time

R

RBCs—red blood cells
RCT—randomized controlled trial
RhIg—Rh immune globulin

S

SBP—systolic blood pressure
SI—shock index
SOP—standard operating procedure

T

TACO—transfusion-associated circulatory overload
TBI—traumatic brain injury
TIC—trauma-induced coagulopathy
TM/BB MD—transfusion medicine/blood bank medical director
TMD—trauma medical director
TPM—trauma program manager
TQP—Trauma Quality Programs
TQIP—Trauma Quality Improvement Program
TRALI—transfusion-related acute lung injury
TXA—tranexamic acid

W

WBB—walking blood bank

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