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Transfusion Error in the Gynecology Patient: A Case Review with Analysis

Carly Madison Hornis, R.S. Vigh, J.F. Zabo and
E.L. Dierking

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Abstract

Emergency blood transfusion (EBT) is a life-saving intervention which also carries a significant risk of harm in the event of a transfusion reaction. Our chapter starts with a hypothetical case study of a gynecology patient who underwent emergent hysterectomy with severe hemorrhage managed with an emergency blood transfusion. During the aggressive resuscitation, the patient was inadvertently transfused with blood products that had been allocated for another patient. Through this clinical vignette, we review the operational aspects of an EBT and identify sources of transfusion-related errors. We emphasize best practices that can be implemented with the goal of improved patient safety. This chapter offers a concise, practical review of EBT for our readers.

Keywords: transfusion error, massive transfusion protocol, postpartum hemorrhage

1. Introduction

Transfusion medicine is used to manage the bleeding patient. An emergency blood transfusion (EBT) protocol describes how a massive blood transfusion (MBT) can be performed in an effort to compensate for the blood loss of a severe hemorrhage. Not every EBT is an MBT: in a patient with a low cardiopulmonary reserve, moderate blood loss can require an EBT but not the volume of an MBT. Near miss and sentinel events in the hospital setting continue to represent a significant concern for patient safety [1]. In the context of blood transfusions, a "near miss" event includes any error that could cause administration of an incorrect blood product but is recognized prior to the start of transfusion. Failure to recognize the error can result in the sentinel event of acute hemolytic transfusion reaction (AHTR) due to major blood

group incompatibility [2]. AHTR was a leading cause of transfusion-related mortality from 2005 to 2009, second only to transfusion-related acute lung injury (TRALI) [3].

The blood administration process is challenging in a chaotic, often time-sensitive environment that employs high-volume blood transfusions to prevent a hemorrhaging patient from dying. This combination of factors creates a formidable risk to patient safety [1]. Optimal strategies have been developed to standardize the management of blood transfusions in the setting of a severe hemorrhage, irrespective of its etiology.

This chapter describes select best practices and identifies system vulnerabilities that may lead to near misses and sentinel events so as to improve patient outcomes and provide an error-free delivery of blood products. We also review potential solutions that our institution has implemented to decrease the transfusion error risk associated with blood product administration. The case review subsequently underscores how imperative it is to identify the critical steps within the process of blood transfusions so as to prevent error.

2. A case review

A 48-year-old female presented to the emergency room of a busy community hospital with the chief complaint of a syncopal episode. She had a history of heavy menstrual bleeding caused by multiple uterine fibroids. Upon arrival, the patient was actively bleeding per vagina. She was pale, but alert and oriented, was tachycardia at 120 beats per minute, and had orthostatic hypotension.

Her past medical history was significant for a DVT while using combined oral contraceptive pills approximately 20 years before. Her past surgical history included a laparoscopic bilateral tubal ligation. She was scheduled to undergo a hysterectomy later that month secondary to her history of heavy menses and her contraindication to estrogen therapy.

While being evaluated in the emergency room, her initial blood work demonstrated a hemoglobin of 9 g/dL, down from her baseline of 12.5 g/dL. Her gynecologist was consulted who recommended performing the hysterectomy in the acute setting given her ongoing bleeding and contraindication to medical management. The patient agreed and consented for surgery.

On the same day, there was a second patient being admitted for a hysterectomy for endometriosis. The patient was known to have two atypical blood antibodies necessitating cross-matched blood to be prepared. The operating staff and blood bank were in close communication for this patient in an event of a hemorrhage.

The first patient was taken to the operating room where a total laparoscopic hysterectomy was performed. Secondary to the location of her uterine fibroids, the patient sustained a laceration to her right uterine artery upon manipulation of the uterus to better visualize the uterine vessels. During attempts to control this bleeding, a massive blood transfusion (MBT) was initiated using non-cross-matched O negative blood. The gynecologic surgeons were unable to properly visualize and control the source of bleeding and therefore converted to a laparotomy.

Upon arrival of the blood products, the patient was immediately transfused. The surgeons completed the hysterectomy but continued to observe significant and diffuse pelvic bleeding. At this

time, a surgeon noted that the blood being transfused was not O negative blood. The anesthesiologist was alerted and he immediately stopped the transfusion. The circulating nurse called the blood bank to notify them of the error. The blood bank personnel had incorrectly assumed that the MBT was initiated for the patient who had tested positive for the antibodies. The operating room staff removed all blood products from the operating room, and new O negative non-cross-matched blood was sent. By this time, the patient had developed a state of disseminated intravascular coagulation (DIC). With no identifiable active bleeding source, the patient's pelvic cavity and vagina were packed, and she was transferred to the intensive care unit (ICU).

The patient's ICU course included aggressive resuscitative efforts with multiple blood transfusions and ventilator support due to transfusion-related acute lung injury (TRALI). Once stable, the patient was taken back to the operating room for removal of packing and re-exploration where no active bleeding was noted. Fortunately, the patient recovered from her near-fatal injuries, and she was eventually discharged home with a close outpatient follow-up.

3. Discussion

Hysterectomy is one of the most commonly performed surgical procedures in the United States. Symptomatic uterine fibroids are the leading indication for the procedure, accounting for 52% of this procedure. Abnormal uterine bleeding is the indication for another 42% of hysterectomies [4].

Similarly, maternal hemorrhage is a leading cause of maternal morbidity and mortality worldwide. Its incidence varies widely but is thought to occur in 1–5% of all deliveries [5, 6]. This is a concerning fact since obstetric services are provided in 92% of rural hospitals [7]. These smaller hospitals do not have the same resources as their larger urban counterparts to handle severe hemorrhage from a variety of etiologies. For these smaller institutions, developing a standardized plan to manage emergencies such as postpartum hemorrhage is critical [7]. All surgical and emergency services should devise comprehensive approaches that identify, evaluate, treat, and monitor a hemorrhaging patient in order to stop bleeding at earlier stages, reduce the number of blood products transfused, and to reduce adverse outcomes [1]. The case review above demonstrates the need for an institution to establish and practice sound policies for the emergency preparation, transportation, and administration of blood products.

Root cause analysis (RCA) is a process with the primary aim of identifying any factors that may influence the nature, magnitude, timing, and/or occurrence of an error, keeping in mind that more than one root cause can impact an event. Through such a methodical approach, RCA is commonly employed after an occurrence of an error in order to develop and implement preventative strategies to improve future response and outcomes. Through this chapter, we perform a root cause analysis to systematically identify "root causes" of potential errors in the blood transfusion process.

Medical errors fall into one of two broad classes, errors of omission and errors of commission. An error of omission is one that occurs because an action was not taken, whereas an error of commission occurs because an incorrect action was taken [8]. The clinical vignette described

in this chapter is a combination of both types of error. The errors of commission are the blood bank sending the inappropriate blood to the operating room as well as the anesthesiologist administering the wrong blood to the patient. The failure of the blood bank to properly identify which patient was receiving the transfusion as well as the failure of the anesthesiologist to verify that O negative blood was sent to the operating room would be considered acts of omission. These omissions acted in conjunction with the errors of commission to result in a nearly disastrous outcome for the patient involved. Therefore, systems must be in place to combat both of these types of errors in order to keep patients safe in complex medical situations.

Secondary to human error, as many as one in 12,000 blood transfusions are administered to the wrong patient [1, 9, 10]. The serious hazards of transfusion (SHOT) Hemovigilance Program of England reports that mortality risk from transfusion in 2012 was one in 322,580 transfusion blood products while the morbidity rate was one in 21,000 [10, 11]. The transfusion of incorrect blood products, specifically ABO-incompatible blood, with resulting acute hemolytic transfusion reaction is one of the most grave and yet preventable causes of transfusion-associated morbidity and mortality [1, 12].

Transfusion-related acute lung injury (TRALI) is another rare life-threatening adverse event that can present to a recipient of a blood transfusion, as was seen in our patient in the clinical vignette [13]. The incidence is estimated to be approximately one in 5000 transfused units with more recent literature citing one in 12,000 blood products [14]. However, some literature argues that the true incidence is unknown secondary to underdiagnosis and underreporting. Regardless, TRALI rates are affected by patient population with an increased occurrence observed in critically ill patients [13]. As reported by the International Haemovigilance Network, TRALI is one of most common etiologies behind transfusion-related fatalities. Specifically, it remains the leading cause in the United States [13, 14]. The study has cited TRALI-associated mortality ranging from 5 to 8%, but up to 50–60% in critical care patients [13]. Respiratory symptoms typically present within 6 h of a transfusion of any plasma-containing blood products including intravenous immunoglobulin and cryoprecipitate [14]. TRALI is diagnosed based on clinical and radiographic findings indicating new-onset acute lung injury/acute respiratory distress syndrome within these 6 h [13]. Majority of patients require ventilator support with oxygen levels returning to pre-transfusion levels in 48–96 h [14].

Currently, there are two hypothesized theories behind the pathophysiology for TRALI. The "two hit model" is the most widely accepted hypothesis and postulates that TRALI occurs in two steps [14]. The initiating event occurs pre-transfusion and is thought to be related to the clinical condition of the patient such as recent surgery, infection, or burns [14]. This event will result in the activation of the pulmonary endothelium followed by neutrophil sequestration to this endothelium [13–15]. The second step involves the activation of neutrophils adhered to this endothelium. Activation typically occurs by donor-derived antihuman leukocyte antigen (HLA) or antihuman neutrophil antigen antibodies targeting antigens on these surfaces (HNA) [14]. The activated neutrophils then incite endothelial damage which results in capillary leak and pulmonary edema [14, 15]. This second step is postulated to be either immune-mediated or non-immune-mediated. The majority of TRALI is immune-mediated, whereby neutrophil and HLA class I and II antibodies initiate TRALI [15]. However, approximately 15–20% of cases are

non-immune, whereby other biological response modifiers in the transfused blood are believed to be the etiology behind the reaction [14]. These factors include bioactive lipids and sCD40L molecules, both of which are found in stored red cell and platelet components [15]. This may explain why TRALI reactions can also occur in the absence of donor-derived antibodies and why every blood transfusion does not result in TRALI [14]. Another model known as the "threshold model" is believed to support cases, whereby TRALI occurs in otherwise healthy recipients who receive donor blood [13]. This theory postulates that if the second event is significant enough, then a TRALI reaction may occur without the initial clinical event [13, 14].

Given the high morbidity and mortality associated with TRALI, many preventative measures have been instituted in an attempt to limit these adverse transfusion reactions. These aims include decreasing donor-derived antibodies in blood products with elevated levels of plasma. This is done by obtaining blood from male donors as opposed to females with a history of pregnancy [14]. A history of pregnancy places these patients at an increased risk of exposure to anti-HLA antibodies [14]. In addition, blood donor management strategies include the inability of patients who have had TRALI to donate whole blood or apheresis platelets [14].

With strategies in place to reduce these transfusion-related adverse events, there remains an additional complication to the blood transfusion process known as mistransfusion [16]. The SHOT program reported that nearly 30% of mistransfusions were a result of hospital laboratory or blood bank error [11]. These sources of error include the selection of the wrong blood sample for testing, inaccurate blood product labeling, technical errors, or incorrectly selected blood components of the wrong specification [11]. As such, an electronic pre-issuing system within the blood bank should be implemented to further reduce transfusion-associated morbidity and mortality [11]. As a best practice, blood bank staff members should

1. print the blood order request form with patient identifier information, blood product number, blood type, and the name of the ordering physician;

2. prepare the blood products, print a compatibility label with a bar code, and then attach the label to the blood product;

3. using a handheld device, sequentially scan the bar codes and include the staff member identifier, the original blood product label, the newly attached bar code label, and the compatibility report form; and

4. ask an additional blood bank staff member to verify whether the data on the handheld scanner matches the data on the labels and forms. If they do, the blood product is issued (**Figure 1**).

The SHOT hemovigilance scheme noted that up to 70% of transfusion errors are related to ABO-incompatible transfusion at the clinical bedside, with the majority of these errors attributed to a failure to properly identify the intended transfusion recipient [11, 17]. These sentinel events are unlikely to be caused by a single error in the transfusion process. Instead, a series of errors occurring together allow the opportunity for a sentinel event to occur [18]. Over the past decade, research has suggested moving toward an automated and computerized transfusion process, with the goal of decreasing human-related error [1, 9].
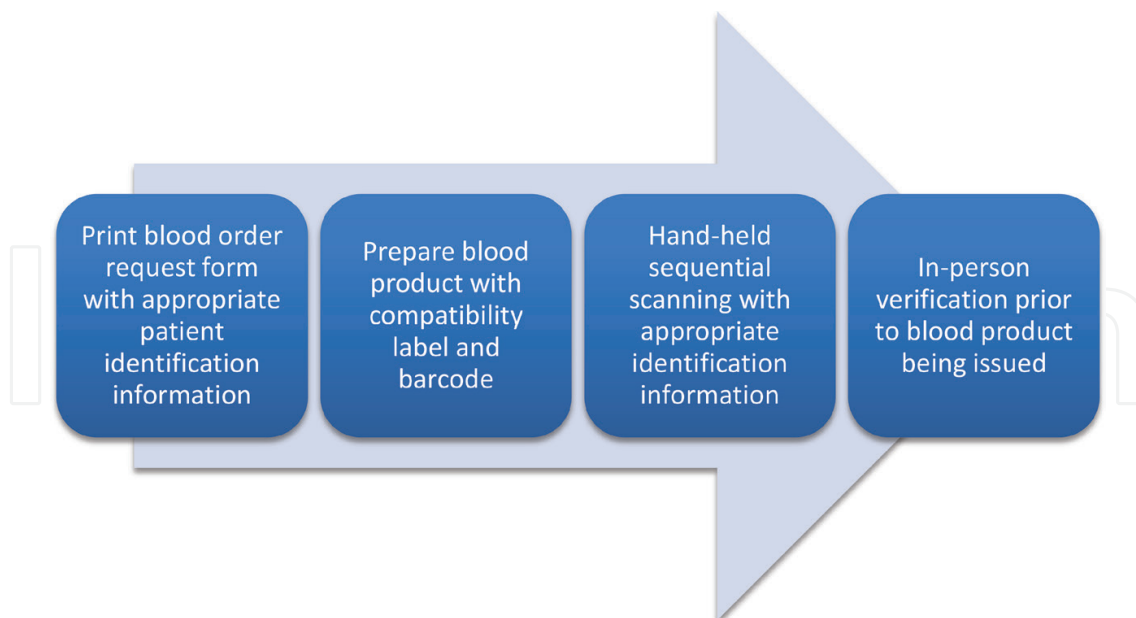
Figure 1. Serious hazards of transfusion (SHOT) best practice flowchart.

Implementation of a software-driven bar code tracking system in place of the conventional "nurse to nurse" double check system for the administration of blood products has been identified as a key strategy for improving transfusion safety [9]. The bar code on blood components identifies blood group, blood type, unit of blood, product number, and the date of collection [9, 10]. Several companies offer a bar code electronic identification system (EIS) which may be portable or built into the electronic medical system [11]. A portable handheld scan and print electronic device can be used to verify and document patient identity. Such a device is utilized at our institution [11]. The common components of the pre-transfusion check list to be scanned include the patient name, medical record number, and blood group [11]. If the bar codes between the patient wristband and blood products match, then the handheld device indicates as such [11]. The bar code EIS is linked to a network host computer that can store, search, and send transfusion data [11]. Multiple studies have indicated that the electronic bar code system is effective in reducing human error related to transfusion procedures as it acts as another barrier for error in the transfusion process [10]. In a time-sensitive event such as a massive transfusion protocol, safety checks including barcoding EIS may be omitted. This may reintroduce transfusion-related human error, such as incorrect blood product administration to the recipient.

Current research is exploring the use of smartphone or tablet devices in transfusion medicine with the aim of achieving enhanced integrity of the transfusion process [10]. In addition, systems utilizing radiofrequency identification (RFID) are being analyzed as a new way of integrating technology into blood transfusion best practice. However, high costs for an institution can be a barrier [10, 11]. RFID is a more user-friendly technology and can be applied to improve visual and bar code electronic identification systems [11, 16]. Radiofrequency transponder microchips have been utilized on patient wristbands, blood sample tube labels, and

blood product containers [1, 16]. The microchips are scanned by a handheld portable device and uploaded to a program with the operator alerted to a misstep and the program pausing until the error is corrected [16]. RFID can be used to further standardize and monitor blood collection, preparation, and transfusion in order to reduce transfusion-related human error and improve patient safety [16].

4. The operational aspects of EBT

The operational aspects of EBT present many challenges that can be overcome by planning and employing best practices. These challenges include describing how to recognize, initiate, and alert others to an EBT. A hospital system must also decide on what kind of blood products to store and how to prioritize select products when they are in high demand. In addition, determining where to store blood products and deciding how to transport them to the bedside require careful planning, especially when faced with multiple concurrent patients requiring EBTs. Personnel should also be trained on how to resuscitate patients while waiting for the arrival of blood products.

The first step in any EBT starts with the attending provider recognizing the need to transfuse. Common indications for EBT include an elevated Assessment of Blood Consumption (ABC) score, the presence of visible rapid blood loss such as that seen in postpartum hemorrhage, or the observation of even moderate blood loss in the setting of comorbidities such as low cardiopulmonary reserve. This list is not exhaustive. The ABC score is calculated by assigning a score of one to each parameter present: penetrating injury, positive focused assessment sonography for trauma (FAST), systolic blood pressure of 90 mm Hg or less, and an elevated heart rate of at least 120 beats per minute (**Table 1**). An ABC score of 2 or higher is 75% sensitive and 86% specific for predicting the need for massive transfusion (MT) [19].

After recognizing the need for transfusion, the second step in an EBT is to alert the blood bank. Our institution offers two levels of response to an EBT: emergency blood release (EBR) and an elevated response level of "code crimson" (CC). Either is initiated by a medical provider dialing a simple hotline—"5555" at our institution—that is answered immediately by the emergency operator. Notification of an EBR arrives in the blood bank via an alphanumeric

Criteria		
Penetrating Mechanism	No 0	Yes + 1
ED Systolic BP ≤ 90 mmHg	No 0	Yes + 1
ED HR ≥ 120	No 0	Yes + 1
Positive Ultrasound FAST Exam	No 0	Yes + 1

ED, emergency department; BP, blood pressure; HR, heart rate; FAST, focused assessment with sonography in trauma.

Table 1. Assessment of blood consumption score.

pager alert. By contrast, a CC is initiated by an overhead announcement broadcast throughout the hospital, alerting support personnel from anesthesia, surgery, trauma, intensive care, and emergency medicine to move toward assisting resuscitation of the patient. Either level of response can be initiated by pre-hospital professionals such as paramedics, transporting a hemorrhaging trauma patient.

Selecting which blood products to offer is an important decision made well before an alert is initiated. While regional blood bank centers can effectively offer continuous availability and supply of blood products to local hospitals—even at times of disaster [20]—there may be occasions when the hospital runs low on specific products, such as platelets or Rhesus negative blood. With only a small minority of the US population exhibiting an O negative blood group, the finite supply of O negative blood may dwindle in the face of ongoing massive transfusion. Switching to O positive blood reserves a minimal supply of emergency O negative blood for obstetric patients or other women of reproductive age who may need blood before depleted stocks can be replenished. This forethought helps prevent alloimmunization-associated problems in future pregnancies [21]. Aside from O negative blood, another scarce blood product is platelets. Though they can be used for up to 5 days after collection, the effective life of a pack of platelets is just 1–2 days by the time the collection is processed, tested, packaged, and transported from the regional blood bank to the hospital. Hospital blood banks can now take advantage of the Platelet PGD test (Verax Biomedical, Marlborough, MA) approved by the FDA in 2015 to extend the life of platelets by an additional 2 days, dramatically reducing the waste and expense of these products.

Once an EBT is initiated, the next consideration at some institutions is to determine which blood bank will respond. Close proximity to blood products is desirable, though not universally feasible. Many hospitals in America feature several hundred beds [22] that are spread across medical, surgical, obstetric, operative, intensive care, emergency, and trauma areas. A large campus with many buildings may have satellite blood stores. Attempts to minimize time and distance to blood products via the setup of decentralized blood refrigeration units add cost, complexity, and forgoes the expertise offered by specialized blood banking personnel during the early stages of an emergency transfusion.

After the appropriate blood bank has been alerted, the transport of emergency blood products to the patient requires a transport protocol. At our institution's centralized blood bank, an EBR utilizes a pneumatic tubing system (PTS) to move a maximum of two units of ice-packed erythrocytes, whereas a CC uses a human transporter—a "runner"—with a cooler. The cooler contains six units of iced erythrocytes, four units of thawed fresh-frozen plasma, and a single unit of platelets. Subsequent coolers are prepared regularly until the CC is terminated. The number of runners and their speed is the limiting factor in bringing blood to the patient, not the rate of cooler preparation. A PTS is faster than a runner [23], moving at up to 25 feet per second, often taking a route that is more direct than what is achievable by hallways and stairwells. PTS performance can be further enhanced with priority signaling or the use of dedicated tubing channels to patient areas that frequently require EBT, such as the emergency department.

Though advantageous in some ways, the PTS also has disadvantages. The dimensions and weight capacity of PTS containers can be limiting, with six containers needed to carry the cargo of a single cooler. Though rare, leaking blood product packaging can seep into the container.

If the seal of a poorly maintained container is compromised, the leak can enter into the system tubing. Cleanup of a contaminated PTS system is a non-trivial task. Another limitation of PTS containers is that they arrive only in the vicinity of the patient and still require a runner for final transport to the bedside. A final concern with a PTS is that once a container enters the tubing system, the acceleration and speed of the system exerts at least some hemolytic effect [23].

In concurrent emergency transport of blood products for two or more patients, separate pneumatic tube containers or separate runners must be used to carry blood products for each patient. Runners should be instructed to avoid exchanges along their route to the patient. The requirement of a unique runner for each patient can be challenging to meet during off-peak times when staffing levels are reduced.

During the interval between recognition for the need of EBT and the arrival of blood products, medical personnel should work to prepare the patient for transfusion. The airway needs to be assessed and protected. Vital signs should be measured. If possible, an attempt should be made to correct the underlying etiology of the hemorrhage. Tourniquets should be applied to the bleeding wounds of trauma patients, packing should be used to tamponade bleeding surgical patients, and uterotonic agents should be administered in cases of postpartum hemorrhage. A blood sample should be collected to facilitate a type and cross-match, though providers should expect at least a 45-min wait time for the screen to be completed. Large bore needles should be inserted to establish intravenous access. A baseline set of hemoglobin, platelets, electrolytes including calcium, a calculated anion gap, creatinine, lactate, prothrombin time, partial thromboplastin time, and fibrinogen level should be drawn [21]. The patient should be warmed to help stop the development of a coagulopathy. Depending on the clinical situation, volume resuscitation using intravenous fluid boluses may be judiciously used. The infusion of a crystalloid may dilute the remaining platelets and coagulation factors as well as cause hypothermia.

The next step in an EBT lies in the administration of emergency blood products from the responding blood bank. Two different patient identifiers, such as hospital identification number and patient name, should be used by medical personnel to confirm the patient identiy [24].

While many different transfusion protocols exist, warmed erythrocytes, fresh-frozen plasma, and platelets are commonly transfused at a 1:1:1 ratio. Some centers have added 6–10 units of cryoprecipitate to their MBT practice to aid repletion of low fibrinogen levels [25]. However, there is a lack of high-quality randomized trials to show improved outcomes with the use of cryoprecipitate to raise fibrinogen levels [26]. The FDA's approval of the human fibrinogen concentrate drug RiaSTAP (CSL Behring, King of Prussia, PA) has been investigated in the off-label setting of MTP [27]. A second similar drug—Fibryna (Octapharma, Lachen, Switzerland)—was approved by the FDA in 2017. Further clinical trials are needed to establish whether human fibrinogen concentrates improve outcomes in severe hemorrhage featuring hypofibrinogenemia.

Irrespective of the products transfused, the rate of infusion is a prime concern. Rapid infusers such as the RI-2 (Belmont Instruments, Billerica, MA) inductively warm and infuse blood at selectable rates of up to 1000 mL/min. This speed can surpass the loss in a postpartum hemorrhage patient, in whom at term blood perfuses the placental site at a rate of 500–700 mL per minute [25].

In addition to the use of fibrinogen-rich medications or cryoprecipitate, anti-fibrinolytics also play a role in EBT. Tranexamic acid can safely reduce the risk of death in both trauma and obstetric-related hemorrhage [28, 29]. The drug must be administered within 3 h of bleeding onset. It is associated with a minimal adverse event rate [28].

Different solutions exist for bleeding while anticoagulated on warfarin. The prothrombin complex concentrate drug Kcentra (CSL Behring, King of Prussia, PA) can reverse coagulation factor deficiency induced by a vitamin K antagonist faster than fresh-frozen plasma [30].

Determining when to stop transfusing can also be challenging. An i-Stat device (Abbott Point of Care Inc., Princeton, NJ, USA) should be avoided if possible [31]. Evaluating the response to transfusion can be achieved via a serum hemoglobin value 15 min after transfusion. Other reassuring laboratory values include a platelet count greater than 50,000/μL, an international normalized ratio (INR) of less than 1.5, or a fibrinogen level greater than 100 mg/dL. Ultimately, the normalization of the patient's hemodynamic status in conjunction with visible signs of hemostasis should signal the medical provider to terminate the code crimson. Alternatively, the recognition of the futility of resuscitation should also be viewed as a terminal end point. Upon termination of the blood transfusion, unused blood products should be returned to the blood bank for refrigeration and storage. The blood products transported by runners or the PTS are continuously monitored thermally to ensure the integrity of returned, unused products.

5. Benefits of emergency blood transfusion protocols

EBT protocols facilitate the efficient ordering and transport of blood products for patients with moderate to severe hemorrhage. These protocols also ensure that an ongoing supply of blood products arrives at the patient's bedside until hemostatic control is achieved. Many hospitals have established an MTP. In obstetrics, 95% of hospitals with a postpartum hemorrhage protocol possess an MTP [32]. An MTP is traditionally defined as more than 10 units of pRBCs in 24 h or more than four units of pRBCs in 1 h.

An MTP can be used to manage severe maternal hemorrhage and improve patient safety. In their study, Shields et al. showed a faster resolution of maternal bleeding, the use of fewer blood products, and a 60% decline in the rate of DIC with the use of MTP [33]. In addition, the establishment of an MTP protocol led to both physicians and nursing staff reporting improved clinical knowledge and comfort level with responding to significant bleeding events.

Health-care providers have varying experience levels in dealing with EBT and MBT. The relatively low frequency with which MBT is encountered limits the accumulation of experience with severe hemorrhage. This suggests that standardized interventions are critical in order to achieve an optimal outcome. One way to gain experience and familiarity with standardized EBT protocols is through simulation.

6. Benefits of simulation

Simulation is used to train and familiarize providers with how to respond to emergency situations. By using team approaches to problem solving and utilizing root cause analysis, patient

outcomes can be continuously improved [34]. Such methods are highlighted in the *Joint Commission Sentinel Alert* publication that recommends the adoption of protocols to address, for example, morbidity and mortality associated with maternal hemorrhage [35].

There are many advantages to developing high-fidelity simulations. They include establishing a safe environment for patients and trainees, the opportunity for multidisciplinary team training, and the rehearsal of specific behavioral skills. In addition, simulations allow the difficulty levels of scenarios to escalate, providing multiple exposures to complex clinical scenarios. Simulators also allow the testing and learning of new technologies without exposing the patients to learning-associated risk [36]. High-fidelity simulators also allow individuals to train on demand rather than waiting for an uncommon or very specific situation to occur. Simulations allow for pause, discussion, feedback, and reflection in response to certain circumstances, as well as the opportunity to identify and correct recurrent mistakes in an expedited manner [37].

7. Error tracking systems

Though uncommon, transfusion-associated adverse events can occur in the emergency setting. In response, programs have been established that track these events. The goals of these programs are to ultimately improve patient safety by minimizing the morbidity and mortality of transfusion procedures. The programs also serve to identify emerging complications, including errors and near misses, as well as pathogens associated with blood transfusion. One such surveillance protocol is the National Healthcare Safety Network Biovigilance Component Hemovigilance (NHSN HV) module [38]. This module can be used by any US health-care facility where blood components and products are transfused. Participation requires a comprehensive surveillance of patients and blood components throughout the transfusion process, from product receipt until patient administration. In addition, the reporting of all adverse transfusion reactions and associated incidents that occur for patients transfused at the studied facility is required. By participating in the module, health-care facilities can use data entered into the National Healthcare Safety Network to monitor adverse reactions and events. This allows for better identification of areas requiring intervention and to modify prevention strategies that reflect the specific needs of a particular health-care facility.

8. St. Luke's University Health Network: blood transfusion information

Like other tertiary-care centers, our hospital system has implemented an MTP designated as "code crimson" to facilitate the rapid availability of blood products when persistent hemodynamic instability occurs in a patient, among other indications. In line with our institution's initiative for continuous quality improvement, departmental risk assessments and safety management plans have been enacted. This program requires managers of departments with unique risks to assess their department's risk profile and submit a summary of safety guidelines to the safety and security manager of their campus. This call for ongoing quality improvement allows for brainstorming sessions with physicians and staff to identify risk and to determine the methods, equipment, policies, and training that can be used to manage and mitigate such risks.

9. Conclusion

Emergency blood transfusion remains a clinical challenge, occasionally marked by improper transfusion of incompatible blood that leads to severe patient morbidity and mortality. Through this hypothetical case scenario, we have highlighted the risks of improper transfusion and discussed improvements in patient safety during emergency transfusion, including developing best practice models, integrating new technologies, as well as improvements in operational aspects via simulation and error tracking systems. By further investing in protocols and systems that enhance safeguards in transfusion medicine, we can continue to strive toward the elimination of transfusion errors and their sequelae. Ongoing research, continuous intensive analysis, and quality improvement initiatives are needed for further advancement of transfusion safety.

Conflict of interest

The authors report no conflict of interest.

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Author details

Carly Madison Hornis*, R.S. Vigh, J.F. Zabo and E.L. Dierking

*Address all correspondence to: carly.hornis@sluhn.org

Department of Obstetrics and Gynecology, St. Luke's University Health Network (SLUHN), Bethlehem, Pennsylvania, United States of America

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