



REVIEW

Maintaining adequate donations and a sustainable blood supply: Lessons learned

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Abstract

Background: The availability of a safe blood supply is a key component of transfusion medicine. A decade of decreased blood use, decreased payment for products, and a dwindling donor base have placed the sustainability of the US blood supply at risk.

Study Design and Methods: A literature review was performed for blood center (BC) and hospital disaster management, chronically transfusion-dependent diseases, and appropriate use of group O-negative red blood cells (RBCs), and the Choosing Wisely campaign. The aim was to identify current practice and to make recommendations for BC and hospital actions.

Results: While BCs are better prepared to handle disasters than after the 9/11 attacks, messaging to the public remains difficult, as donors often do not realize that blood transfused during a disaster was likely collected before the event. BCs and transfusion services should participate in drafting disaster response plans. Hospitals should maintain inventories adequate for patients in the event supply is disrupted. Providing specialty products for transfusion-dependent patients can strain collections, lead to increased use of group O RBCs, and create logistical inventory challenges for hospitals. The AABB Choosing Wisely initiative addresses overuse of blood components to optimally use this precious resource. Group O-negative RBCs should be transfused only to patients who truly need them.

Conclusions: Collecting and maintaining a blood supply robust enough to handle disasters and transfusion-dependent patients in need of specialty products is challenging. Collaboration of all parties should help to optimize resources, ensure appropriate collections, improve patient care, and ultimately result in a robust, sustainable blood supply.

KEYWORDS

blood center operations, transfusion service operations, transfusion practices (oncology-hematology)

Abbreviations: BC, blood center; MDS, myelodysplastic syndrome; PBM, patient blood management; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; SCD, sickle cell disease.

1 | INTRODUCTION

The availability of safe blood is a key component of current medical practice.¹ Although use is decreasing, blood is transfused during 10% to 15% of all hospitalizations.² More than 16% of Medicare claims include blood.^{2,3,4} In the United States, the blood supply is collected by a network of federally regulated but nongovernmental, independent, nonprofit organizations. This system has proved extraordinarily robust for more than 50 years. A decade of decreased blood use and changes in health care delivery have altered market conditions to place the sustainability of the current system at risk and made patient blood management (PBM) increasingly important and relevant.⁵ It has now been shown that outcomes may be improved with more restrictive thresholds.⁶

Striking a balance between adequate collection and supply is something that blood centers (BCs) and hospitals struggle with daily. Natural disasters such as Hurricane Katrina (2005) and pandemics such as severe acute respiratory syndrome 1 (2009) and severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2; 2019-20) affect donations and hospitals' use. This was not appreciated on September 11, 2001, when the US government issued messages that prompted an immediate response by US blood donors. Even if 50 000 victims had been hospitalized, instead of the 200 who were admitted, more blood than was already available could not have been used immediately. Nevertheless, almost 500 000 units of blood were collected.⁷ The American Red Cross normally discards 3% of its inventory but due to expiration in this case discarded 17% (49 860 units) of the 287 000 extra units collected.⁸

During planned and unplanned disasters, the AABB Interorganizational Task Force on Domestic Disasters and Acts of Terrorism is available to assist the BC community with adequate blood supplies, keeping communication lines open, and updating transfusion services on changes to US Food and Drug Administration policy.⁹

Many events have occurred since September 11, 2001¹⁰⁻¹⁴ (Table 1). Since that time, BCs have become more adept at addressing overcollections by requiring

appointments, collecting only O-negative red blood cells (RBCs) or AB plasma, and using social media to tell the public that the most important donation needs to occur before the event.¹²

Certain patients with medical conditions are transfusion dependent and will be most affected by disruption in the blood supply. Review of the literature is limited by a paucity of high-quality studies. Better-designed studies are warranted.¹⁵ In its latest guidelines, AABB was unable to make a recommendation due to lack of evidence.⁶

Regarding the topic of supply, this may include both predictable shortages during holidays and summer vacation when collections decrease and during unpredictable disasters. While surgery and procedures may not be canceled, delays in receiving blood may mean a patient has to stay in the hospital or clinic longer to await a needed procedure.

In recent years, implementation of the Choosing Wisely initiative has helped physicians and patients engage in conversations to reduce overuse of tests and procedures and support physician efforts to help patients make smart and effective care choices.¹⁶ This review is intended to provide direction to those programs just beginning the journey of blood product inventory management or to established programs interested in improving their impact and success. Its purpose is to describe what has been published, to identify current practice, and to make recommendations for BC and hospital actions.

2 | DONATION

2.1 | Disaster management - BC perspective

Since the attacks on September 11, 2001, there has been increased awareness of overdonation in response to mass casualty events.

"More than 500 000 units of blood were collected in the two months following than was normal for that time of year. This tremendous response to help others ran headlong into the limits of the blood supply systems to store, maintain, and use the donated blood. Thousands of donors were upset to read news reports that a large portion of the blood collected in this period had to be discarded."¹⁷

As an industry, the blood community was not prepared to handle the large influx of donors and recognized the need to participate in and be better integrated into national disaster planning. Also identified was that emergency agencies and medical professionals outside of the blood community were unaware of the complexities of blood collection, processing, distribution, and storage; many had the misconception that large quantities of blood components were readily available at all times in hospitals.¹⁸

TABLE 1 Recent disasters and number of RBC units used¹⁴

Event	Year	Number of RBCs used
Minneapolis bridge collapse ¹⁰	2007	50
Boston Marathon bombing ¹¹	2013	168
Orlando pulse nightclub shooting ¹²	2016	292
Las Vegas shooting ¹³	2017	500

In 2003, the AABB's Interorganizational Task Force on Domestic Disasters and Acts of Terrorism created the Disaster Operations Handbook, an online tool designed for BCs and hospitals to help prepare and respond to disasters and acts of terrorism that could affect the US blood supply.¹⁹ The handbook highlights the importance of BCs reaching out to their local emergency medical agencies for blood management to be incorporated into the overall disaster plan. There are various ways to categorize a disaster in the blood community: There are disasters "external to the BC," which could be due to natural phenomena such as hurricanes or flooding, or to human causes such as acts of terror or mass casualty events; or disasters "within the BC" that could cause acute loss in mass quantities of product, for example, from fire, flooding, or large-scale manufacturing failures. Depending on the disaster types, specific BC operations would be affected. For example, a major pandemic could greatly affect blood collections. Donors may not be able to donate due to illness, and employees may be too ill to work. A general fear of gathering in public spaces such as BCs may affect collections. Widespread natural disasters may shut down a local BC or disrupt transportation routes between the BC and local hospitals. Mass casualty events could quickly exhaust a hospital's or BC's inventory, and as the need for blood is constant, a coordinated, national media message is required.

Depending on the type of disaster, the donor base may not be able to donate, and the local BC may not be able to adequately collect, process, or distribute the blood. BCs therefore need to be prepared to handle diverse types of disasters and be fully integrated into their local hospital and area-wide emergency medical disaster plans. Equally important, BCs need to be connected at a national level, such as with the AABB Task Force, so that a national strategy can be determined and efforts coordinated. At this level, procurement and transportation of products and dissemination of consistent messages to the blood community, blood donors, and media could be performed.

When a disaster occurs in a community, a BC must first assess the blood need. Local hospitals and emergency medical services can be contacted to understand the nature of the emergency and the number and types of injuries; blood inventory levels should be determined.⁷ The AABB Task Force offers an adverse event calculation form to help BCs calculate the expected RBC unit need; however, this form predates current damage control resuscitation principles and does not incorporate plasma or platelets.¹³ The Prospective, Observational, Multicenter Major Trauma Transfusion (PROMTTT) and Pragmatic, Randomized Optimal Platelet and Plasma Ratios (PROPPR) randomized controlled trials have directed the hospitals and Level I trauma centers to integrate plasma

and platelet ratios.^{20,21} Although many blood providers offer online ordering systems, software specifically designed for disaster inventory management could not be found during the research for this paper. Given the potential acuity of blood needs, the ability to view hospitals' and BCs' inventory levels in "real time" could greatly improve inventory management.

Second, a BC should activate their emergency communication plan as soon as possible after the event. The AABB Task Force stresses the importance of this to quickly contact internal staff, the hospitals, emergency response organizations, and the AABB Task Force to coordinated national efforts. The AABB's Task Force Disaster Operations Handbook addresses different plans of action for sudden disasters such as mass casualty events or tornados as well as slow-moving disasters such as pandemics and can also help ensure media and public receive clear and consistent messaging regarding blood needs.¹⁹ When disasters occur, the public often wants to help by donating blood. BCs in the local area of the disaster tend to get a large influx of donors.⁶ This altruistic response provides little benefit to victims, as the amount of blood collected often greatly exceeds need. In the aftermath of 9/11, of the 500 000 units collected, only 260 units were used to treat victims.⁷ Even when the need is acute, having blood flown to a disaster area can be more efficient than waiting for collected blood to be distributed. In addition, the donor surge can ironically compound the problem.⁸ When the disaster has ended, there tend to be blood shortages, as "everyone" has already donated. Fortunately, the events of September 11, 2001, resulted in an influx of first-time donors without a substantial increase in absolute risk of transfusion-transmissible viral infections. Unfortunately, first-time donor rates were relatively low before and after the attacks, suggesting that those donating in times of crisis have return behaviors similar to those of other first-time donors. This was a good example of the need for education about the importance of donating regularly.²²

2.1.1 | Recommendations

The following are recommended strategies for BCs to strategically maintain a constant blood supply:

1. BCs must publicize the need for a constant supply of blood before a disaster occurs.
2. The ability to maintain a blood supply in an area varies among BCs. Factors such as donor demographics, marketing and incentive budgets, and the ability to correctly ask and make blood donation convenient all play a role.
3. Greater transparency and collaboration among the BC organizations (eg, American Red Cross and America's

Blood Centers) may allow for the sharing of best practices and further help to stabilize supply.

4. Donor messaging must communicate that blood collected today will not be used today, so future donations will be required to replace and maintain the blood supply.

2.2 | Chronically transfusion-dependent medical conditions

Transfusion-dependent patients include those with sickle cell disease (SCD), thalassemia, and myelodysplastic syndrome (MDS). Considering that SCD affects approximately 100 000 in the United States, while MDS prevalence ranges from 60 000 to 170 000, these conditions represent a sizeable population that is expected to grow as more active therapies develop and patients live longer.^{23,24} Transfusion support continues to be a mainstay therapy, and high proportions of these patients receive transfusions of RBCs, presenting a challenge to BCs to meet inventory needs. More than 40% of patients with MDS require regular RBC transfusions for supportive care.²⁵ Meanwhile, the rate of transfusion in patients with SCD is more nebulous, since many patients receive only sporadic RBC transfusions during more severe crises, though the incidence of some high-risk complications, particularly initial and recurrent stroke in children, have been found to be reduced by chronic transfusion therapy.^{26,27} There is evidence that the rate of RBC transfusion in adult patients with SCD has been increasing, as reported in a 10-year (2000-2009) study in a UK center, which noted that transfusion increased from 1.7 to 3.86 RBC units per patient per year and transfused patients increased from 15% to 19%.²⁸ Moreover, the most significant increase occurred in the latter half (2005-2009) of the study, which investigators attributed to increasing use of automated RBC exchange and increased transfusions for control of SCD complications. Since the UK study, guidelines and recommendations have been published aiming to better optimize therapy in SCD, including simple vs automated exchange transfusion and use of hydroxyurea. These guidelines favorably impacted the blood supply, especially antigen-matched RBCs and human leukocyte antigen-matched platelets without negatively impacting patient outcomes.²⁹⁻³¹

Provision of not only enough blood products for these patients but those that meet special requirements also presents unique challenges. Many institutions provide RBCs that are irradiated to prevent transfusion-associated graft-vs-host disease, a severe and usually fatal complication in susceptible recipients, to their MDS patients (though not all guidelines support this recommendation).³² Given that

most institutions do not have the capacity to irradiate RBCs on site, owing to space and security limitations of maintaining an irradiator, irradiated blood must be specifically ordered and maintained in inventory. Due to higher cost and shortened shelf life associated with irradiated RBCs, many BCs maintain only a small portion of their inventory as irradiated product, which is typically weighted toward group O for compatibility with all blood types. This, in turn, leads to a skewed blood use distribution that is challenging for BCs.

Patients with SCD present other challenges, given that they have a higher rate of alloimmunization than other transfused patient populations, 18% to 37% vs 2% to 5%, respectively.³³ Many chronically transfused patients with SCD develop multiple alloantibodies, making it especially difficult to find compatible blood. Many hospital transfusion services have implemented policies for the prophylactic provision of antigen-matched RBCs to their patients with SCD to reduce alloimmunization.³³ Yet again, this presents unique challenges to BC facilities to provide RBCs that are phenotypically matched, largely because of genetic differences between the donor population (predominantly of European descent) vs patients with SCD (predominantly of African or Mediterranean descent).³⁴ Chronically transfused patients with β -thalassemia (predominantly of Mediterranean or Asian descent) also have high rates of alloimmunization, presenting additional challenges to provide compatible RBCs.³⁵ BCs are faced with the tendency of transfusion services to overuse group O blood to find units that are phenotypically matched for the extended antigen profile of their patients with SCD. There is an opportunity for BCs to work with their transfusion service customers to manage special requirements for patient transfusion needs with the best available product, including using type specific rather than group O.³⁶ Despite current PBM efforts, ensuring that the blood supply meets demand, particularly specialized products, remains a challenge. Furthermore, it is anticipated that blood supply demand will once again increase to meet the needs of the aging world populations that require more complex surgeries and cancer chemotherapy.³⁶

Finally, there are the logistics of managing chronically transfused patients in the outpatient setting. Patient populations include oncology patients and anemic patients with chronic renal disease.³⁷ As a result of the special product needs of these patients and the often-encountered positive antibody screen results due to auto- and/or alloantibodies, delays in crossmatching RBC units are common. Warm autoantibodies commonly found in this patient population can be vexing to finding compatible blood because of the specialized immunohematology testing that is required and the potential need for

antigen-matched RBCs to avoid hemolytic reactions. Newly developed cancer immunotherapeutic agents, such as daratumumab (an anti-CD38 monoclonal antibody used for treatment of multiple myeloma), have been found to interfere with antibody testing, thus resulting in crossmatch delays.³⁸ Inventory supply shortages often also contribute to a delay in transfusing these patients in the outpatient setting.

Patient satisfaction surveys are a common tool used by hospitals to benchmark value and quality outcome measures. Delays in the availability of special blood products may have detrimental effects to a hospital's or clinic's ability to provide timely care.^{36,37,39} Delays in the scheduling of outpatient treatment as well as delays in discharge may occur, as some patients may need to be held overnight until transfusion can be given. Communication, both good and bad, between caregiver and patient can have a definite impact on these surveys. This may be a dissatisfier to patients and can result in increased costs.^{36,37,39}

3 | SUPPLY

3.1 | Disaster management

Although the word *disaster* implies an unexpected event, there are planned and unplanned disasters from an inventory management perspective. A planned disaster is one for which there is time to prepare in advance and make modifications to a contingency plan (ie, hurricanes, the extended phase of a pandemic weeks after the initial event). An unplanned disaster is a sudden unexpected event that impacts the blood supply (ie, terrorist attack, decreased donations during the initial phase of coronavirus disease 2019). The AABB Task Force develops and implements the national response to such events, and the affected BC should contact AABB within 1 hour of the event. Information regarding AABB's Disaster Response is available on its Web site.⁹ Hospital transfusion services should contact their BC to communicate the current situation and needs as soon as possible after a disaster.⁴⁰

The BC should plan for three RBC, one plasma, and one/four platelet doses per admission per hospital BC and increase this to six RBC, four plasma, and one/two platelet doses for trauma centers.¹⁴

3.2 | Planned disasters

Transfusion service leadership should be involved in all aspects of hospital disaster response plans to ensure that the plan includes collaboration and emergency contact

instructions for the BC. Planning should include conservative transfusion guidelines to triage the available supply to the patients with most urgent need. The use of alternative massive transfusion protocols using whole blood, if not standard practice, may be considered when platelets and plasma become unavailable or it is not feasible to resupply/thaw/store.⁴¹ This is particularly helpful for transfusion services that already supply whole blood.⁴² A supply of frozen blood may be helpful at regional hospitals with the capacity for frozen storage and in rural or island communities where isolation from the outside world for significant periods of time is of concern.^{42,43}

3.3 | Unplanned disasters

The greatest risk in an unplanned disaster is not normally blood supply but the ability to get that supply to the hospital or field treatment facilities.⁷ For this reason, it is recommended that hospitals maintain a several-day supply at all times to be prepared for a disruption in supply lines, which can happen with both natural disasters and terrorist attacks.⁴⁰ In addition, training staff with disaster drills during times of relative calm can be an invaluable experience (Figure 1).^{12,44} Disaster readiness includes having robust policies regarding the triage and appropriate use of precious resources such as group O-negative RBCs. Although there can be a plan to deal with the extended phase of a pandemic, the initial phase of a pandemic is an unplanned disaster (eg, SARS-CoV-2). This pandemic heightened sustainability concerns about the blood supply,



FIGURE 1 In a mass casualty drill, mock paper units are placed in pockets taped to the blood refrigerator door over their respective component and type-specific shelves to make the exercise as close to realistic as possible without disturbing the real blood. (used with permission of J. Hess⁴⁴)

especially with platelets being particularly vulnerable to depletion in the early unplanned phase as they require frequent donations and have limited storage time. During the SARS-CoV-2 pandemic, shortages worldwide have been largely mitigated due to the cancellation of elective surgeries. The hospital response should include implementation of PBM disaster plan with a thorough evaluation of the appropriateness of blood component requests. The BC may implement donations by appointment and triaging of donor temperature at reception. This regulates the donor flow, enables physical distancing, and detects symptomatic active infections.⁴⁵

3.4 | The appropriate use of group O-negative RBCs

O negative is the universal blood type and may be used for any patient; however, is is sometimes used inappropriately. The US population consists of 7% to 10% O-negative individuals, but usage is about 5% greater.⁴⁶ There are many resources including AABB's Association Bulletin 19-02 that define criteria on how to dispense O-negative RBCs.⁴⁷ The criteria are divided into three categories: It is mandatory to give O-negative RBCs; it is recommended to give O-negative RBCs; and it is acceptable to give O positive RBCs.^{46,47}

There are three mandatory or highly recommended situations in which O-negative RBCs are administered: when a patient is known to have developed an anti-D; when a patient is of childbearing age, defined by the facility; and when the facility has no blood type on file.^{47,48}

One area where it may be recommended to give O-negative RBCs is to O-negative and transfusion-dependent patients.⁴⁷ This usually involves patients undergoing bone marrow transplant and patients with aplastic anemia or cancer.

In emergent situations, it is acceptable to provide certain patient groups O-negative RBCs. The group is defined by each institution but usually consists of females of childbearing age. The institutions usually place a limit on the number of units to dispense before obtaining a sample to obtain a blood type and switch these patients to type-specific RBCs. If O-negative blood is not available due to a shortage, it is also acceptable to provide Rh-positive RBCs to anyone during initial transfusion in an emergent situation. The relevant risk of a female of childbearing age being sensitized with D antibody is much less than the alternative of bleeding to death because no blood was dispensed.⁴⁹

Wastage must also be monitored to ensure that O negative RBCs are not expiring and that they are not transfused to non-O-negative patients. The transfusion

TABLE 2 The five Don'ts of choosing wisely¹⁶

1. Don't transfuse more units of blood than absolutely necessary.
2. Don't transfuse RBCs for iron deficiency without hemodynamic instability.
3. Don't routinely use blood products to reverse warfarin.
4. Don't perform serial blood counts on clinically stable patients.
5. Don't transfuse O-negative blood except to O-negative patients and in emergencies for women of childbearing potential with unknown blood group.

service and BC should maintain realistic inventory levels of O-negative RBCs based on historical usage patterns and rotate the O-negative stock to ensure appropriate use. The hospitals also need to maintain adequate supply of all other blood groups and ensure that they switch patients to type-specific blood in a timely and efficient manner.

3.5 | Choosing wisely

In 2014, AABB recommended five statements for Choosing Wisely, the American Board of Internal Medicine initiative to address overuse of blood components and provide support to physicians and patients to enable them to make smarter choices with blood components. The statements all start with "don't" (Table 2).¹⁶

These five statements were chosen to make non-transfusion medicine physicians rethink their liberal transfusion practices and to prompt patients to question why they are being prescribed a transfusion. Hospitals using the Choosing Wisely campaign material, such as posters, can place in multiple areas frequented by the physicians, nurses, and patients, to make them aware of these statements and prompt the questions and education that can lead to further reducing unnecessary transfusions that can diminish the supply of product available to transfusion-dependent patients as well as for emergent needs. The campaign's goal is to promote a more sustainable blood supply.¹⁶

4 | CONCLUSIONS

The availability of a safe blood supply is a key component of current medical practice.¹ PBM has become increasingly important and relevant.⁵ Messaging to the public remains difficult, as donors presenting after a disaster often do not realize that blood available to support emergent needs was collected before the event.

Chronically transfusion-dependent patients represent a population expected to grow as more therapies are developed and patients live longer.^{23,24} Delays in availability of specialized blood products may have detrimental effects to provide timely care.^{36,38} This may be a dissatisfier to patients and result in increased costs.^{36,38}

For planned disasters, transfusion service leadership should be involved in hospital-wide disaster response plans. For unplanned disasters, the greatest risk is in the ability to get that supply to the hospital or field treatment facilities.⁷ It is recommended that hospitals maintain an adequate inventory at all times to be prepared for the possibility of a disruption in supply lines.⁴⁹ Hospitals can assist the BCs by holding regularly scheduled blood drives and encouraging personnel to donate. Another action is to practice good stewardship of the blood supply with PBM.

Collecting and maintaining an appropriate blood supply that is robust enough to handle the routine and planned or unplanned disasters can be challenging. Little is known about inventory levels other than the National Blood Collection and Utilization Survey, which is published every 2 years, and the daily RBC inventory, which does not provide detailed numbers. The lack of a comprehensive hemovigilance system and the fragmented nature of the current system makes it difficult to really know if there is an adequate supply for a disaster. Public perceptions of the need for blood donation may not be realistic or what is needed to maintain appropriate inventory levels. Hospitals have an obligation to maintain an adequate blood supply to support patients. This means having enough inventory to not delay care or result in surgery cancellations, which increases patients' dissatisfaction and hospital costs, and not contribute to needless expiration and wastage of product. Collaboration of all parties would allow optimization of resources and improved patient care and ensure a sustained and adequate blood supply.

Facilities should institute appropriate PBM plans and strategies. These would include establishing appropriate and adequate inventory levels to:

1. React and respond to internal and external disasters and disruptors to the blood supply chain.
2. Ensure appropriate use of all products, particularly group O and Rh-negative RBCs.
3. Provide timely availability of products to meet the needs of chronically transfusion-dependent patients.

More importantly, the question arises: How can we increase the security of our blood supply by harnessing the immediate altruistic human response to disaster into patterns of regular future blood and apheresis platelet

donations? Additional studies to obtain the answer may be warranted.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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