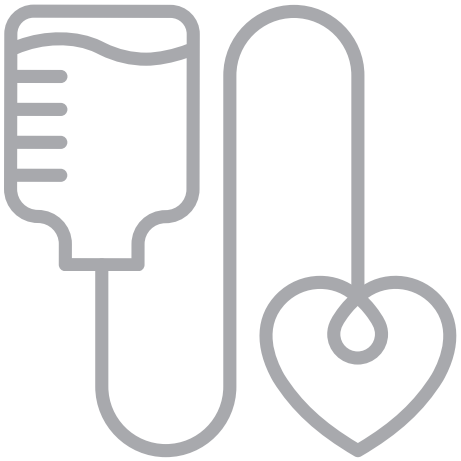

DONATION VS. SUPPLY

WHITEPAPER

AABB TRANSFUSION SAFETY/PATIENT BLOOD MANAGEMENT SUBSECTION

Introduction

BY RICHARD R. GAMMON, MD

The availability of safe blood is a key component of current medical practice.[1] Although utilization is decreasing in many settings, blood is transfused during 10 to 15% of all hospitalizations. More than 16% of Medicare claims include blood use.[2] In the United States (US), the blood supply is collected by a network of federally regulated but non-governmental independent nonprofit organizations. This system has proved robust for more than 50 years. A decade of decreased blood utilization and changes in health care delivery (e.g., new effective treatments for anemia, more endoscopic surgery, etc.) have altered market conditions sufficiently to place the sustainability of the current system at risk and, therefore, have made patient blood management more important and relevant.[3]

Striking a balance between adequate collection and supply is something that blood centers and hospitals struggle with every day. This was a particular challenge in the aftermath of the September 11, 2001 terrorist attacks, when the executive branch of the US government issued messages prompting an increase in blood donations throughout the country. 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 half a million units of blood were collected nationwide in the days following the attacks.[4] Liquid blood has a shelf-life of 42 days, and the American Red Cross, which ordinarily has to discard 3% of its stored blood supplies because of the expiration date, in this case discarded 17%(49,860 units) of the 287,000 extra units collected.[5]

Many other events prompting an increase in blood donations have occurred since September 11, 2001.[6-9]

EVENT	DATE	# RBC USED
Minneapolis Bridge Collapse	2007	50
Boston Marathon Bombing	2013	168
Orlando Pulse Nightclub Shooting	2016	292
Las Vegas Shooting	2017	500

Since 2001, blood centers have become more adept at addressing excessive collections and have implemented various policies such as requiring appointments, collecting only O-negative Red Blood Cells (RBCs) or AB plasma, and using social media to remind the public that the most important donation needs occur before a mass casualty event.[6]

There availability of blood is important to patients with medical conditions such as hemoglobinopathies (e.g., thalassemia and sickle cell anemia) and myelodysplastic syndromes that are transfusion-dependent. Review of the literature is limited by a paucity of high-quality studies on this topic. Better designed studies are warranted.[10] In its latest guidelines, AABB was unable to make a recommendation on this issue due to lack of evidence.[11]

Regarding the topic of supply, this may include both shortages that occur during routine scenarios such as holidays and summer vacation when collections decrease and during disasters as described earlier. While surgery and procedures may not be cancelled, 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 of the American Board of Internal Medicine Foundation 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.[12] This white paper was developed by subject matter experts 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.

Donation

BY RHONDA COOKE, MD, AND LIZABETH ROSENBAUM, MD

Disaster Management – Blood Center Perspective

Since the September 11, 2001 terror attacks on the World Trade Center and Pentagon, there has been increased awareness regarding excessive blood donations in response to mass casualty events. There was a concern that upwards of a half million more units of blood were collected in the two months following the attacks than was normal for that time of year. Sadly, this tremendous response to help others ran headlong into the limits of our 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. [13] 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 often unaware of the complexities of blood collection, processing, distribution and storage; many agencies outside of the blood industry have the misconception that large quantities of blood components are readily available at all times in hospitals.[14]

In 2003, AABB's Interorganizational Task Force on Domestic Disasters and Acts of Terrorism created the Disaster Operations Handbook, an online tool designed for blood centers and hospital blood banks to help prepare and respond to disasters and acts of terrorism that could affect the US blood supply.[15] The handbook highlights the importance of blood centers reaching out to their local emergency medical agencies in order 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 blood center," which could be due to natural phenomena such as hurricanes or flooding, or to human cause such as acts of terror, chemical spills or mass casualty events; or disasters "within the blood center" that could cause acute loss in mass quantities of product, for example from fire, flooding, or large-scale manufacturing failures. Depending on the type of disaster, various parts of the blood center would be affected. For example, major pandemic disasters could greatly affect blood collections. Donors may not be able to donate due to illness and employees may be too ill to work. Widespread natural disasters may shut down a local center or disrupt transportation routes/vehicles between the blood center and local hospitals. Mass casualty events could quickly exhaust a local hospital's or a local center's blood inventory and, since the need for blood is constant, this requires coordinated national media messages.

Depending on the type of disaster, the donor base in the local area may not be able to donate, and the local center may not be able to adequately collect, process, or distribute the blood. Blood centers therefore need to be prepared to handle a diverse type of disasters and be fully integrated into their local hospital and area-wide emergency medical disaster plans. Equally important, blood centers need to be connected at a national

level, such as with AABB's Interorganizational Task Force on Domestic Disasters and Acts of Terrorism, so that a national strategy can be determined, and national efforts can be coordinated. At this level, procurement and transportation of products as well as dissemination of consistent messages to the blood community, blood donors and media could be performed.

When a disaster occurs, a blood center must first assess the need for blood. Local hospitals and emergency medical services can be contacted to better understand the nature of the emergency and the number and types of injuries; blood inventory levels at each local facility and center should be determined.[4] The AABB Task Force offers an Adverse Event Calculation Form to help blood centers calculate the expected red blood cell unit need; however, this form predates damage control resuscitation principles and does not incorporate plasma or platelet estimates.[8] Although many blood providers offer online ordering systems, software specifically designed for disaster inventory management could not be found during research for this paper. Given the potential acuity of blood needs during a disaster, the ability to view hospitals' and blood centers' inventory levels by product type and blood group in "real time" could greatly improve inventory management.

Second, a blood center should activate their emergency communication plan as soon as reasonably possible after the event. AABB's Interorganizational Task Force on Domestic Disasters and Acts of Terrorism stresses the importance of a blood center having a communication plan in order to quickly contact internal staff, the hospitals, emergency response organizations, as well as the Task Force so that national efforts can be coordinated. The Task Force can also help ensure the media and public receive a clear and consistent message regarding blood needs. As previously mentioned, when disasters occur, the public often wants to help by donating blood. Blood centers in the area of the disaster, as well as nationally, often experience a large influx of donors.[6] This altruistic response typically provides minimal benefit to victims, since the amount of blood collected often greatly exceeds the need for transfusion. Of the 500,000 units collected in the aftermath of the September 11, 2001 terror attacks, only 260 units were used to treat victims.[7] Even when large quantities of blood are needed, the need is often acute; having blood flown in to a disaster area can be far more efficient than waiting for collected blood to be ready for distribution. In addition, the donor surge during a disaster can ironically compound the problem.[8] When the disaster has ended, there tends to be blood shortages, since "everyone" has already donated.

Blood collection centers must also publicize the need for a constant supply of blood before a disaster occurs. Donor messaging must communicate that blood collected today will not be used today, so future donations will be required to replace and maintain the local and national blood supplies. Most importantly, the blood community must determine how we can best increase security of our blood supply by harnessing the immediate altruistic human response to disaster into patterns of regular future blood and apheresis platelet donations.

Chronically Transfusion-Dependent Medical Conditions

BY MARK FRIEDMAN, DO, AND LINDA LEVINUS, MLS, CQA, RABT

Transfusion-dependent patients include those with sickle cell disease (SCD), thalassemia and myelodysplastic syndrome (MDS). Together, considering that SCD affects an estimated 100,000 people in the United States and MDS affects between 60,000 and 170,000, these conditions represent a sizeable population that is expected to grow as more active therapies are developed and patients are able to live longer.[16,17] Transfusion support remains a mainstay therapy for patients with these conditions; high proportions of these patients receive transfusions of RBCs during their treatment course, presenting a challenge to blood collection centers to meet these needs. In fact, more than 40% of patients with MDS require RBC transfusions for supportive care.[18] Meanwhile, the rate of transfusion in patients with SCD is a bit more nebulous owing to the fact that many such patients only receive sporadic RBC transfusions during more severe crises though the incidence of some high-risk complications, particularly initial strokes and stroke recurrence in children, have been found to be reduced by chronic RBC transfusion therapy.[19,20] Yet, there is some evidence that the rate of RBC transfusion in adult patients with SCD has been on the increase as reported in a 10-year (2000-2009) study in a United Kingdom (UK) center, which noted that the rate of RBC transfusion increased from 1.7 to 3.86 RBC units per patient per year during the study time, while the percentage of transfused patients also increased from 15% to 19%.[21] Moreover, the most significant increase in RBC transfusions occurred in the latter half (2005-2009) of the study, which the investigators attributed to increasing use of automated RBC exchange transfusions and general increased transfusions for control of SCD complications. However, since the time of the UK study, guidelines and recommendations have been published aiming to better optimize therapy in SCD, including simple versus automated exchange RBC transfusion as well as the use of hydroyurea.[22-24]

The logistics of providing not only enough blood products for these transfusion-dependent patients, but blood products that meet special requirements also presents unique challenges. Many institutions, for example, provide RBCs that are treated to prevent transfusion-associated graft-versus-host disease (TA-GVHD), a severe and often fatal complication of blood transfusion in susceptible recipients, to their MDS patients, usually through provision of irradiated RBCs.[25] However, given that most institutions do not have the capacity to irradiate RBCs on site, owing to space and security limitations of maintaining an irradiator within the confines of their blood bank laboratory, irradiated blood must be specifically ordered and maintained in inventory to meet patient needs. Due to higher cost and shortened shelf life associated with irradiated RBCs, many blood banks maintain only a small portion of their RBC inventory as irradiated product which is typically weighted toward group O blood type for compatibility with all blood types. This, in turn, leads to a skewed blood utilization distribution that is challenging for blood collection facilities.

Patients with SCD present challenges beyond ABO compatibility, given that they have a much higher rate of alloimmunization than other transfused patient populations, ranging from 18-37% versus 2-5%, respectively.[26] Many chronically transfused patients with SCD develop multiple alloantibodies, making it especially difficult to find compatible blood. As a result, many hospital transfusion services have implemented policies for

the prophylactic provision of antigen-matched RBCs to their patients with SCD to reduce the incidence of alloimmunization in this population.[26] Yet again, this presents unique challenges to blood collection facilities to provide such RBCs that are phenotypically matched, largely because of genetic differences between the donor population (which is predominantly of European descent) versus patients with SCD (who are predominantly of African or Mediterranean descent).[27] Chronically transfused patients with thalassemia (β-thalassemia), who are predominantly of Mediterranean or Asian descent, also have reportedly high rates of alloimmunization, again, presenting challenges for blood collection centers to provide compatible RBCs.[28] Blood collection centers are challenged by the tendency of hospital transfusion services to overuse group O blood in order to find RBC units that are phenotypically matched for the extended antigen profile of patients with SCD. There is an opportunity for blood suppliers to work with their customer transfusion service and blood banks to partner with them to manage special requirements for patient transfusion needs with the best available product, including using type specific vs. group O blood.[29] Despite current efforts in blood conservation/management, ensuring the blood supply meets demand, particularly special products, remains a challenge. As the world population ages, it is anticipated that blood supply demand will once again increase.[29]

Finally, there are the logistics of managing chronically-transfused patients in the outpatient setting. Patient populations to which this is a challenge include patients with cancer and chronic renal disease and anemia.[30] 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 for these patients are quite common. In particular, warm autoantibodies commonly found in this patient population can be challenging in finding compatible blood because of the specialized immunohematology testing that is required and the potential need for antigen-matched RBCs to avoid hemolytic transfusion reactions. Newly developed cancer immunotherapeutic agents, such as daratumumab (an anti-CD38 monoclonal antibody used for treatment of multiple myeloma), have also been found to interfere with antibody testing, thus, resulting in crossmatch delays.[31] 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 outcomes measures for their patients. Delays in the availability of special blood products may have detrimental effects to a hospital or clinic's ability to provide timely care.[29,30,32] Delays in the scheduling of treatment for outpatients, as well as delays in discharge/prolonging the length of stay, may occur, as some patients may need to be held overnight as an observation status outpatient until transfusion can be given. This may be a dissatisfier to patients and can result in increased costs for the hospital/clinic.[29,30,32]

Supply

BY TRACY NICHOLS, MT(ASCP)SBB, AND SARAH VOSSOUGHI, MD

Disaster Management

During both planned and unplanned disasters, the AABB Interorganizational Task Force on Domestic Disasters and Acts of Terrorism is available to assist the blood banking community with obtaining and maintaining adequate blood supplies, keeping open communication lines with blood collectors, and updating transfusion services on changes to regular FDA policy.[33] The Task Force develops and implements the national response to such events, and

the affected blood collector (BC), should contact AABB within one hour of the event whenever possible. Hospital transfusion services should contact their BC to communicate the current situation and needs as soon as possible after a disaster, so that information is provided in real time to the Task Force.[34]

Planned Disasters

Transfusion service leadership should be involved in the drafting and implementation of hospital disaster response plans. Furthermore, this plan should include collaboration and emergency contact instructions for the local/regional blood collection center(s). Hospital contingency planning should include conservative transfusion guidelines, so that the available supply can be triaged to the patients with most urgent need. The use of alternative massive transfusion protocols using whole blood, if not standard practice, should be considered in situations when platelets and plasma become unavailable or it is not feasible to resupply/thaw/store. This can be particularly helpful for transfusion services that already supply whole blood with existing policies and infrastructure in place.[35,36] In addition to planning for alternative transfusion strategies and massive transfusion, an oversupply in the form of frozen blood can be considered for larger regional centers 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.[36, 37]

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.[4] Due to this, it is recommended that hospitals maintain a 7-day supply at all times in order to be prepared for the possibility of a disruption in the supply lines, which can happen both with natural disasters and terrorist attacks.[33]It is possible to plan for the unplanned disaster by using the strategic planning strategies mentioned above. In addition, training staff with disaster drills during times of relative calm can be an invaluable experience when the unexpected disaster strikes.[6]

The Appropriate Use of Group O-Negative Red Blood Cells

Since the universal donor is O-negative and may be used for patients of any blood type, they are sometimes used inappropriately. The US population consists of 7-10% O-negative individuals; however, the documented usage is about 5% greater. There are many resources that define criteria on how to dispense O-negative RBCs. The criteria is divided into three categories: patients where it is mandatory to give O-negative RBCs, patients where it is recommended to give O-negative RBCs, and patients where it is acceptable to give O-positive RBCs.[38]

There are three situations in which it is mandatory or highly recommended that O-negative RBCs be administered. This is also true when a patient is known to have developed an anti-D, when a patient is of childbearing age (which is usually defined by the facility), and when the facility has no blood type on file .[7,38]

One area where it may be recommended to give O-negative RBCs to a patient who is known to be O-negative is when a patient is transfusion-dependent.[38] This usually involves patients treated with a bone marrow transplant, patients with aplastic anemia and/or patients with cancer. When the transfusions are non-emergent, these patients should be provided O-negative RBCs.

In emergent situations, it is acceptable to provide O-negative RBCs to certain patient groups. The group is defined by each institution but usually consist of females of childbearing age. The institutions usually place

a limit on the number of units to dispense prior to 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 risk of being sensitized with anti-D is favorable to the alternative risk of exsanguination because no blood was dispensed.[39]

Wastage must also be monitored to ensure that O-negative RBCs are not expiring on the shelf and that they are not transfused to non O-negative patients. The transfusion service and blood bank should maintain realistic inventory levels of O-negative RBCs based on historical usage patterns and rotate the O-negative stock so that these units are being used appropriately. The hospitals also need to ensure that they maintain adequate supply of all other blood groups.

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":

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

These five statements were chosen to make non-transfusion medicine physicians rethink their liberal transfusion practices and to prompt patients to questions why they are being prescribed a transfusion. Hospitals utilizing the Choosing Wisely campaign material, such as posters, can place these in hallways, lunchrooms and other areas frequented by both 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 transfusion. Unnecessary transfusions can diminish the supply of product available to transfusion-dependent patients as well as when needed for emergent needs.[12]

Conclusions

BY RICHARD R. GAMMON, MD

The availability of a safe blood is a key component of current medical practice.[1] Patient blood management has become increasingly more important and relevant.[3]

While blood centers are much better prepared for handling disasters regarding collections and inventory management than they were prior to September 11, 2001, messaging to the public remains challenging. Donors presenting when a disaster occurs often do not realize that the blood available and used to support emergent needs was collected prior to the event.

Chronically transfusion-dependent patients (e.g., patients with SCD, thalassemia or MDS) represent a sizeable population that is expected to grow as more active therapies are developed and patients are able to

live longer.[16,17] Delays in the availability of special requirement blood products may have the detrimental effects to a hospital's or clinic's ability to provide timely care.[29,31] This may be disadvantageous to patients, as well as result in increased costs for the hospital/clinic.[29,31]

For planned disasters (e.g., approaching hurricanes), transfusion service leadership should be involved in the drafting and implementation of a 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.[4] Due to this, it is recommended that hospitals maintain an adequate inventory to serve their patient population at all times in order to be prepared for the possibility of a disruption in the supply lines, which can happen both with natural disasters and also terrorist attacks.[31]

Collecting and maintaining an appropriate blood supply that is robust enough to handle the routine and planned or unplanned disasters can be challenging. 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 enough inventory to not delay care or result in surgery cancellations that increase patients' dissatisfaction and hospital costs and not contribute to the needless expiration and wastage of product. Collaboration of all parties would allow optimization of resources, improved patient care and ensure sustained and adequate blood supply.

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

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

References

1 Klein HG, Hrouda JC, Epstein JS. Crisis in the Sustainability of the U.S. Blood System. *N Engl J Med* 2017; 377:1485-88.

2 Mulcahy AW, Kapinos KA, Briscombe B, et al. Toward a sustainable blood supply in the United States: an analysis of the current system and alternatives for the future. Santa Monica, CA: RAND, 2016.

3 Goel R, Chappidi M. Patel EU. Trends in Red Blood Cell, Plasma, and Platelet Transfusions in the United States, 1993-2014. *JAMA* 2018; 319: 825-827.

4 Schmidt PJ. Blood and Disaster Supply and Demand. *N Engl J Med* 2002; 346: 617-620.

5 Gaul GM, Flaherty MP. Red Cross kept asking for more: 5% of blood given after attacks was discarded: donor backlash feared. *Washington Post*. December 16, 2001:A34.

6 Schweitzer, J. On the front lines after a mass causality event. AABB News 08/18. 14-18.

7 Gorlin J. et al. Bridge Disaster. *Transfusion and Apheresis Science* 2013; 49:403-407.

8 Lozada MJ, Cai S, Li M, et al. The Las Vegas mass shooting: An analysis of blood component administration and blood bank donation. *J Trauma Acute Care Surg* 2019; 86: 128-133.

9 Quillen K, Luckey CJ. Blood and bombs: blood use after the Boston Marathon bombing of April 15, 2013. *Transfusion* 2014; 54: 1202-03.

10 Lauren S. Prescott, Jolyn S. et al. How low should we go: A systematic review and meta-analysis of the impact of restrictive red blood cell transfusion strategies in oncology? *Cancer Treatment Reviews* 2016; 46: 1-8.

11 Carson JL, Guyatt G, Heddle NM, et al. Clinical Practice Guidelines from the AABB Red Blood Cell Transfusion Thresholds and Storage. *JAMA* 2016; 316(19):2025-2035.

12 Callum JL, Waters JH, Shaz BH, et al., The AABB recommendations for the Choosing Wisely campaign of the American Board of Internal Medicine. *Transfusion* 2014; 54:2344-2352.

13 America's Blood Supply in the Aftermath of September 11, 2001. US Congress. House. Committee on Energy and Commerce. Subcommittee on Oversight and Investigations. 107th Congress, 2nd session, 10 September 2002.

14 Doughty, H, et al. Mass casualty events: blood transfusion emergency preparedness across the continuum of care. *Transfusion* 2016; 86(1):S208-S216.

15 AABB Task Force. Disaster Operations Handbook: Coordinating the Nation's Blood Supply During Disasters and Biological Events. 2003. Last updated in 2008.

16 Cogle CR. Incidence and burden of the myelodysplastic syndromes. *Curr Hematol Malig Rep*. 2015; 10(3):272-281. Doi: 10.1007/s11899-015-0269-y

17 State of Sickle Cell Disease: 2016 Report. American Society of Hematology (ASH). Available at: http://www.scdcoalition.org/pdfs/ASH%20State%20of%20Sickle%20Cell%20Disease%202016%20Report.pdf Accessed May 25, 2019.

18 Lucioni C, Finelli C, Mazzi S, Oliva EN. Costs and quality of life in patients with myelodysplastic syndromes. *Am J Blood Res*. 2013; 3(3): 246–259.

19 Lee MT, Piomelli S, Granger S, et al. Stroke Prevention Trial in Sickle Cell Anemia (STOP): extended follow-up and final results. *Blood*. 2006; 108(3): 847–852. Doi: 10.1182/blood-2005-10-009506

20 Adams RJ, Brambilla D, STOP 2 Trial Investigators. Discontinuing prophylactic transfusions to prevent stroke in sickle cell disease. *N Engl J Med*. 2005; 353: 2769-2778.

21 Drasar E, Igbineweka N, Vasavda N, et al. Blood transfusion usage among adults with sickle cell disease – a single institution experience over ten years. *Br J Haematol*. 2011; 152: 766-770. Doi: 10.1111/j.1365-2141.2010.08451

22 Davis BA, Allard S, Qureshi A, et al. Guidelines on red cell transfusion in sickle cell disease. Part I: principles and laboratory aspects. *Br J Haematol*. 2017; 176(2): 179-191. Doi: 10.1111/bjh.14346

23 Davis BA, Allard S, Qureshi A, Porter JB, Pancham S, Win N, Cho G, Ryan K. Guidelines on red cell transfusion in sickle cell disease. Part II: indications for transfusion. *Br J Haematol*. 2017; 176(2): 192-209. Doi: 10.1111/bjh.14383

24 Howard J. Sickle cell disease: when and how to transfuse. ASH Education Book. 2016; 2016(1): 625-631. Doi: 10.1182/asheducation-2016.1.625

25 Bahar B, Tormey CA. Prevention of transfusion-associated graft-versus-host disease with blood product irradiation: the past, present, and future. *Arch Pathol Lab Med.* 2018; 142(5): 662-667.

26 Campbell-Lee SA, Kittles RA. Red blood cell alloimmunization in sickle cell disease: listen to your ancestors. *Transfus Med Hemother.* 2014; 41: 431-435. Doi: 10.1159/000369513

27 Khan J, Delaney M. Transfusion support of minority patients: extended antigen donor typing and recruitment of minority blood donors. *Transfus Med Hemother.* 2018; 45: 271-276. Doi: 10.1159/000491883

28 Dhawan HK, Kumawat V, Marwaha N, et al. Alloimmunization and autoimmunization in transfusion dependent thalassemia major patients: Study on 319 patients. *Asian J Transfus Sci.* 2014; 8(2): 84–88. Doi: 10.4103/0973-6247.137438

29 Williamson LM, Devine DV. Challenges in the management of the blood supply. *The Lancet.* 2013; 381(9880): 1866-1875. Doi: https://doi.org/10.1016/S0140-6736(13)60631-5

30 Schrijvers D. Management of anemia in cancer patients: transfusions. *The Oncologist.* 2011; 16(suppl 3): 12-18. Doi: 10.1634/theoncologist.2011-S3-12

31 Quach H, Benson S, Haysom H. Considerations for pre-transfusion immunohaematology testing in patients receiving the anti-CD38 monoclonal antibody daratumumab for the treatment of multiple myeloma. *Internal Medicine Journal* 2018; 48: 210-20. https://doi.org/10.1111/imj.13707

32 Shander A, Hofmann A, Gombotz H, et al. Estimating the cost of blood: past, present, and future directions. *Best Practice & Research Clinical Anaesthesiology*. 2007; 21(2): 271-289. Doi: https://doi.org/10.1016/j.bpa.2007.01.002.

33 AABB. Disaster Operations Handbook Hospital Supplement. Bethesda, MD: AABB Press; 2008.

34 AABB. Disaster Operations Handbook Response Plan Flow Chart. Bethesda, MD: AABB Press; 2008.

35 Simonetti A, Ezzeldin H, Walderhaug M, et al. An inter-regional US blood supply simulation model to evaluate blood availability to support planning for emergency preparedness and medical countermeasures. *Disaster Med Public Health Prep.* 2018; 12(2):201-210.

36 Doughty H, Glasgow S, Kristoffersen E. Mass casualty events: blood transfusion emergency preparedness across the continuum of care. *Transfusion.* 2016; 56:S208-S216.

37 Erickson ML, Champion MH, Klein R, et al. Management of blood shortages in a tertiary care academic medical center: the Yale-New Haven Hospital frozen blood reserve. *Transfusion.* 2008; 48:2252-2263.

38 NHS, The Chief Medical Officer's National Blood Transfusion Committee, The Appropriate use of group O RhD negative Red Cells.2019. https://www.transfusionguidelines.org/document-library/documents/nbtc-appropriate-use-of-group-o-d-negative-red-cells-final-pdf (Accessed September 16, 2019).

39 Gammon R. Presentation at Florida Society of Clinical Laboratory Scientists 2017 Annual Meeting.