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Bloodless Cardiac Surgery
Not Just Possible, But Preferable

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Blood transfusions after cardiac surgery are very common, and the rates are highly variable among institutions. Transfusion carries the risk of infectious and noninfectious hazards and is often clinically unnecessary. This article discusses the history of bloodless cardiac surgery, the hazards of transfusion, the benefits of reducing or eliminating transfusion, and strategies to conserve blood. It also provides a list of resources for those who are interested in learning more about bloodless care. **Key words:** *blood conservation*, *blood management*, *bloodless surgery*, *cardiac surgery*, *transfusion*

Mr. Adams was scared not just about his upcoming coronary artery bypass graft surgery but also about the possibility of needing a blood transfusion during or after the surgery. He had good reasons to worry. His brother contracted hepatitis after a blood transfusion and might soon need a liver transplant because of the cirrhosis. And then there was his best friend who had a severe hemolytic reaction after being transfused with incompatible blood. Mr. Adams came to his preoperation appointment ready to discuss the possibility of autologous blood transfusion.

After hearing his concerns, Mr. Adams' surgeon offered another option. . . .a technique known as "bloodless surgery." He described a process that screens for and treats preoperative anemia and utilizes a multidisciplinary approach to proactively identify and treat postoperative anemia. Diagnostic tests are minimized and meticulous surgical techniques are used to prevent blood loss. Mr. Adams enthusiastically agreed to this approach. His only question was, "Why doesn't everyone get this treatment?"

Blood transfusions are very common in the United States among patients undergoing cardiac surgery. The frequency of blood transfusions is highly variable among institutions, ranging from less than 5% at centers specializing in bloodless surgery to well more than 90% at some other facilities.[1] The risks and benefits of blood transfusion following cardiac surgery have been studied extensively, but there is little consensus on an optimum transfusion trigger. The traditional rationale for transfusing blood is that an increased number of red blood cells will increase the oxygen-carrying capacity of the blood, but this theory has not been backed up by research. Studies suggest that as many as two thirds of all transfusions might not be necessary.[2]

Healthcare providers have been socialized to accept that blood loss is an unavoidable part of major surgery and that blood can be simply and easily replaced through transfusion. We are correctly told that the blood supply is safer than ever before. While it is true that we have made great strides in reducing the risks of viral transmission, we are only beginning to realize that there are many other risks from blood transfusion. Some of these risks, such as an increased surgical infection rate, are well documented by research.[3] However, many patients and healthcare providers are not familiar with these studies. Other risks, such as the possible transmission of infectious prions, microscopic protein particles that are similar to viruses but lack nucleic acid, we are only beginning to understand.

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One thing is clear: strategies to reduce blood loss benefit patients. Many transfusions can be avoided simply by taking every precaution to minimize blood loss. Most hospitals are not focused on reducing unnecessary blood loss from surgery and diagnostic procedures. This article summarizes the medical and nursing techniques critical to reducing unnecessary blood loss.

HISTORY OF BLOODLESS SURGERY

Much of the earliest data available on bloodless surgery were collected from patients who refused blood transfusions for religious reasons, primarily the Jehovah's Witness community. Dr. Denton Cooley performed the first bloodless open heart surgery on a Jehovah's Witness patient in 1962. Fifteen years later, he and his associate published a report of more than 500 cardiac surgeries in this population, documenting that cardiac surgery could be safely performed without blood transfusion.[4] Leaders from the Jehovah's Witness community have collaborated with some of the leading healthcare institutions in this country to help to establish bloodless medicine and surgery programs and protocols. The early work by these pioneers laid the foundation for the mainstreaming and acceptance of bloodless programs.

More than 100 bloodless medicine and surgery centers currently exist in the United States, and this number will surely increase.[5] They are not just for Jehovah's Witness patients but for all patients who wish to avoid a blood transfusion. These centers have physicians, surgeons, and nurses who are familiar with the various procedures available to minimize blood transfusions and staff who specialize in bloodless care. A coordinator meets with the patient and family preoperatively to document their wishes and helps to coordinate their postoperative care. Most important, these facilities have integrated the principles of bloodless care, for example, minimizing diagnostic blood loss, into their policies and procedures.

As patients hear more about the potential risks of blood transfusion and take an active role in their healthcare decision making, we can anticipate that an increasing number will request that they not be given allogeneic blood, otherwise known as donor blood. A patient's stance on this issue may range from complete refusal of all blood and blood products under any circumstances to simply a preference that other options be considered first. Bloodless medicine and surgery is increasingly cited as the "criterion standard" of care. As evidence mounts and bloodless techniques are being taught in schools of medicine and nursing, it will probably become the rule rather than the exception in the future.

HAZARDS OF BLOOD TRANSFUSION

The primary concern about blood transfusion for most patients is transmission of viral infections, such as hepatitis or HIV. While there is still a risk, the healthcare community has been able to greatly minimize the risk of contracting HIV and hepatitis C by implementing nucleic acid testing. The risk of HIV transmission is estimated to be 1:1,215,000 per unit of blood transfused, and the risk of hepatitis C transmission is even lower, at 1:1,935,000. However, the current risk of contracting hepatitis B from a blood transfusion remains relatively high at 1:205,000.[6]

While great strides have been made in reducing the risk of viral transmission through blood transfusion, we are only beginning to recognize that there may be other risks. Infectious prions have the potential to be transmitted through blood transfusion. Prions are thought to be the cause of certain infectious diseases of the central nervous system. One of these diseases is variant Creutzfeldt-Jacob disease. This disease originated from the mutation of the prion that causes bovine spongiform encephalitis , more commonly known as mad cow disease, into a form that can infect humans. The literature reports 2 cases of variant Creutzfeldt-Jacob disease possibly being transmitted through

blood transfusions from asymptomatic donors who went on to develop the disease.[7,8] While it is possible that these recipients acquired this disease through eating infected meat rather than through blood transfusion, the link between blood transfusion and transmission of infectious prions certainly warrants consideration.

The American Association of Blood Banks (AABB) states that although a 10,000-fold reduction in the transmission of infectious diseases through blood transfusion has been achieved, we have made very few strides in reducing the risk from noninfectious hazards.[9] The AABB estimates that the risk of injury from noninfectious hazards is 100 to 1000 times higher than the risk of contracting an infectious disease from a blood transfusion.[9] In July 2000, the AABB Board of Directors ordered the Transfusion Practices Program Committee to study these noninfectious serious hazards of transfusion and identify ways to reduce these risks. Some of the most common noninfectious serious hazards of transfusion are mistransfusion and ABO/Rh-incompatible transfusion, cardiopulmonary toxicity, transfusion-related acute lung injury (TRALI), and transfusion-related immunomodulation.

Mistransfusion, or the transfusion of incompatible blood, is a common problem. Studies show that transfusion to unintended recipients occurs in about 1 of every 10,000 transfused units, and it is widely believed that the actual number is probably much higher because not all cases are reported.[10] There are many points in the system where errors can occur, including at the time of collection of the specimen for type and crossmatch, in the lab, at the point where the blood is labeled, and at the bedside when the blood is administered. Recent reports indicate that errors in the whole blood transfusion chain, "from vein to vein," occur at a rate of approximately 1 out of every 1000 events.[11] The AABB has focused a great deal of effort recently at reducing the rate of transfusion errors, and these numbers can be expected to improve as a result of their efforts.

Circulatory overload is another common complication. A study of patients randomized to either a liberal or a conservative transfusion trigger showed that patients under the conservative protocol had better survival rates.[12] Patients in the liberal transfusion protocol received blood if their hemoglobin level dropped below 10 g/dL, whereas patients in the conservative group received blood only if their hemoglobin level dropped below 7 g/dL. Patients in the more liberal transfusion protocol had significantly higher rates of morbidity from cardiac and pulmonary complications. TRALI, which is one cause of adult respiratory distress syndrome, is one of these complications. In severe cases, TRALI can be fatal, and it is the third most commonly reported cause of transfusion-related deaths.[9] Many times, it is probably not recognized as being associated with the blood transfusion, and thus is underreported. A recent study identified the incidence of suspected TRALI as 1 in every 1271 units transfused, possible TRALI as 1 in every 534 units transfused, and transfusion-associated circulatory overload as 1 in every 356 units transfused.[13]

The immunological consequences of blood transfusion are just beginning to be recognized. Allogeneic blood transfusions have been linked to increases in cancer recurrence rates (80% in colorectal cancers) and postoperative bacterial infections (as much as 200% to 1000% in some studies).[14] This effect is thought to be due to the immunosuppressive effects of blood transfusions. It is generally the sickest patients who receive blood transfusions, and then face the consequences of immune system depression for weeks, months, or years.

These serious complications of blood transfusion, both infectious and noninfectious, certainly warrant a close look at current transfusion practices. There is no clear evidence that using blood transfusions to restore the oxygen-carrying capacity of the blood is effective. Moreover, there is strong evidence that this therapy has the potential to cause serious, and possibly fatal, consequences.

BENEFITS OF REDUCING OR ELIMINATING BLOOD TRANSFUSIONS

Banked blood is a limited resource. The current cost of acquiring and processing a unit of blood is estimated to range from $337 to $658 per unit.[15] Cost will continue to rise as more testing for transfusion-transmitted diseases is implemented and the blood supply decreases even more because of the increased identification of tainted blood. The indirect costs of treating complications related to blood transfusions must also be considered, but these are much more difficult to quantify. One hospital that implemented a bloodless medicine program documented a 16% reduction in surgical costs if blood was not used and a 17% reduction in overall costs due to decreased length of stay.[16]

Reducing or eliminating blood transfusions also results in improved patient outcomes. Many studies document an increase in morbidity and mortality after a blood transfusion. In a study of 1915 patients, those who received a blood transfusion had twice the 5-year mortality rate of those who did not. Even after correcting for comorbidities, age, and other factors, there was still a 70% increase in mortality.[17] A recently published study from the Cleveland Clinic Foundation confirms these results. A study of 10,289 patients undergoing coronary artery bypass graft surgery over a $7\frac{1}{2}$-year period demonstrated a significant reduction in both immediate and long-term survival among transfused patients, even after controlling for the effects of demographics, comorbidities, and other factors.[18]

Blood management programs also have the potential to improve patient and family satisfaction by acknowledging and addressing spiritual and ethical preferences.[19] This specialized service can result in decreased length of stay, improved patient outcomes, and decreased costs and can be used as a powerful hospital marketing tool. All of these factors, in addition to providing patients with the opportunity to have some control over their care by collaborating with healthcare professionals, are key advantages to these programs.

BLOOD CONSERVATION STRATEGIES

Blood conservation strategies fall into several categories. There are preoperative strategies, such as identifying and correcting anemia, and banking one's own blood through autologous donation. There are intraoperative strategies, such as surgical and anesthetic techniques. There are pharmacological agents to treat bleeding. Efforts can be made to reduce the volume of blood lost from diagnostic testing. And lastly, there is the concept of lowering the traditional transfusion trigger, or the point at which a patient receives a blood transfusion.

Preoperative identification and management of anemia is an important strategy in bloodless surgery. When possible, patients who wish to avoid blood transfusion should be evaluated for anemia, and this should be corrected before surgery. By building up their blood supply as much as possible in the time available, patients are less likely to lose enough blood to get to a level where transfusion is critical. Depending on the level and type of anemia and the duration of time before surgery, this can be accomplished through improvements in diet and iron and folic acid supplementation, or through the use of erythropoietin. This drug can be used both preoperatively and postoperatively to help increase the production of red blood cells. It can be administered subcutaneously or intravenously, and it can be given either weekly, starting 3 weeks before surgery and ending on the day of surgery, or daily, beginning 9 days before surgery and continuing for 4 days after surgery.

Autologous blood donation, where patients donate their blood for future use, can also be considered. However, it is not always possible. In general, a hemoglobin level of 11 g/dL is required for blood donation. Cardiac surgery patients are also more likely to have factors that are contraindications to donation. Cardiac conditions that would preclude autologous blood donation are listed in Table 1.[20] While autologous blood removes the possibility of viral transmission or incompatibility

Table 1. Cardiac conditions that preclude autologous blood donation[20]

- Cardiac dysrhythmias
- Congestive heart failure
- Unstable angina
- Myocardial infarction or cerebrovascular accident within 6 mo of donation
- High-grade left main coronary artery disease
- Low hematocrit levels
- Uncontrolled hypertension
- Scheduled surgery to correct aortic stenosis
- Cyanotic heart disease
- Any significant cardiac or pulmonary disease unless cleared for surgery by the physician

issues, it still carries a risk of bacterial infection and mistransfusion similar to that of heterogenous or banked blood transfusion. There are also similar expenses involved in using autologous blood, due to collection, testing, and storage. Many patients are surprised to hear that they are being charged to receive their own blood. Also, autologous blood donation is not considered an acceptable option for Jehovah's Witness patients from a religious standpoint, since the blood has been separated from their body.

There is an extensive arsenal of surgical, anesthetic, and pharmacological techniques that have been developed to minimize blood loss during surgery. One of these techniques is acute normovolemic hemodilution. This involves removing and storing several units of blood in the operating room just before surgery. The patient's remaining blood is then diluted with either crystalloids or colloids to maintain a normal circulating blood volume. Any of this diluted blood that is lost during surgery will have fewer red blood cells and lowered levels of clotting factors. The whole fresh blood that was stored is then readministered after surgery, or, if necessary, during the procedure. This procedure may also be acceptable to some Jehovah's Witness patients by using a modified technique known as closed-circuit acute normovolemic hemodilution, where the blood does not completely leave their system but remains in a continuous circuit with the patient's circulatory system.

Several pharmacologic agents are commonly used to reduce intraoperative blood loss. Aprotinin (Trasylol) is an antifibrinolytic that works to prevent bleeding by inactivating plasmin, an enzyme produced in the blood to break down fibrin, the major constituent of blood clots. By inactivating plasmin, aprotinin prevents it from breaking down blood clots, and thus prevents bleeding. Aprotinin has been commonly used but has recently come under fire for increasing the risk of death, renal damage, congestive heart failure, and stroke. The United States Food and Drug Administration currently recommends that it be used only when the risk of blood loss outweighs the risk of these adverse effects and stresses the importance of monitoring patients who receive this drug for organ toxicity.[21]

Other commonly used pharmacologic agents are antifibrinolytic aminocaproic acid (Amicar) and desmopressin (DDAVP), which is thought to increase the levels of factor VIII in blood and increase von Willebrand's factor expression, helping to promote necessary clotting.

The blood substitute PolyHeme has also generated much interest, although it is just completing clinical trials and not yet available for patient use. PolyHeme is manufactured from human red blood cells using steps to reduce the risk of viral transmission. It has the advantage of being universally compatible and immediately available.[22]

Minimizing blood loss from phlebotomy is another key strategy in blood conservation programs. There are several factors to be considered here. First, it is important to evaluate whether each blood test is absolutely necessary and to attempt to coordinate and consolidate blood tests. One study found that blood drawn from cardiothoracic intensive care patients ranged from 234 to 478 mL in a 24-hour period, which is the equivalent of

1 to 2 units of blood.[23] The smallest possible volume of blood should be used, that is, pediatric-sized laboratory tubes should be used for collecting blood. Point-of-care testing is ideal since it uses smaller volumes for testing and results are immediately available, which enables care providers to correct abnormalities as quickly as possible. There are various techniques and commercially available closed-system devices for arterial and central line phlebotomy that can be used to avoid wasting the blood volume that is usually discarded to clear the line.[24]

Perhaps the most controversial topic in blood management is the reevaluation of traditional transfusion triggers. As recently as 10 years ago, a hemoglobin level of less than 10 g/dL or a hematocrit level of less than 30% was considered the accepted point at which to initiate blood transfusions. There has been a considerable amount of research and discussion but little consensus on the ideal transfusion trigger. If experts agree on anything, it is that multiple factors, such as the patient's age, cormorbidities, and cardiopulmonary status, which may affect a patient's ability to compensate with a demand for increased cardiac output, must all be considered and that the transfusion point must be individualized for each patient. The optimal point for transfusion is now considered the lowest level of hemoglobin necessary to meet that individual patient's tissue oxygen demands, which will ultimately depend on the patient's condition and circumstances. Healthy hearts have been able to withstand hemoglobin levels of 3 to 4 g/dL by compensating with increased blood flow and increased fraction of extracted oxygen, but patients with cardiac or pulmonary disease may require much higher hemoglobin levels.[25]

FINAL THOUGHTS

It is vital that healthcare providers be aware of the potential risks of blood transfusion and recognize that it is not a "magic bullet." Evidence does not support the common wisdom that it helps to significantly increase the oxygen-carrying capacity of blood. Blood transfusion carries significant risks from the transmission of infectious diseases, incompatibility issues, and immunological complications. It is vital to continue to examine

Table 2. Additional resources on bloodless medicine and surgery

Name of the organization	Purpose/Service	URL
No Blood	Blood management and avoidance for healthcare professionals and the public	http://www.noblood.org/
Bloodless Medicine and Surgery Institute	Providing education for healthcare professionals who want to develop an integrated blood conservation program	http://www.bmsi.net/
Society for the Advancement of Blood Management	Improving patient outcomes through optimal blood management	http://www.sabm.org/
Network for Advancement of Transfusion Alternatives	Information about recent advances in blood conservation and transfusion alternatives	http://www.nataonline.com/
Jehovah's Witnesses official Web site	Medical care and blood for Jehovah's Witnesses	http://www.watchtower.org/

the risk-benefit ratio of blood transfusions to make the best possible decisions regarding this therapy, giving weight to the patients' wishes, their unique condition and set of circumstances, and the most current evidence available. Table 2 provides a list of Web resources for those who are interested in learning more about bloodless care.

As for Mr. Adams, his heart surgery went without complication and without the administration of blood. He was back home 4 days after his surgery and does not have to worry about later developing a transfusion-related disease. Like thousands of other patients, Mr. Adams has benefited from the choice of bloodless care.

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