

The Perfusionist's Role in a Collaborative Multidisciplinary Approach to Blood Transfusion Reduction in Cardiac Surgery

Edy S. Zelinka, CCP, LP;*† James Brevig, MD;‡§ Julie McDonald, BSN;† Ruyun Jin, MD§

*Advanced Perfusion Care, Inc., Pinehurst, North Carolina; †Providence Regional Medical Center, Everett, Washington; ‡Everett Cardiovascular and Thoracic Surgical Associates, Everett, Washington; and §Medical Data Research Center, Providence Health and Services, Portland, Oregon

Presented at the 47th International Conference of the American Society of ExtraCorporeal Technology, San Antonio, Texas, March 12th, 2009.

Abstract: Red blood cell transfusion is associated with adverse outcomes. Transfusion practices remain varied in cardiac surgery and are a subject of growing debate. We initiated a data-driven, multidisciplinary effort to decrease allogeneic red blood cell transfusion at our institution. Creative perfusion strategies are an essential component of our program and led to a low transfusion rate. Innovations in treatment protocols were implemented and evaluated to reduce hemodilution associated with the cardiopulmonary bypass machine. Frequent review of outcomes guided our evolving clinical practice. Standardization among the perfusionists was the first step to a successful blood conservation program. Techniques included vacuum assisted venous drainage with dry 3/8" tubing, a short (10 foot) arterial-venous loop, retrograde autologous prime, and saline prime removal from the primary and cardioplegia circuit. We used a polymer-coated perfusion circuit. Hemocon-

trator and cell saver use was determined on a case-by-case basis. Normothermia was maintained except in cases of circulatory arrest or specific surgeon request. Two thousand nine hundred and seventy-nine consecutive cardiac surgical procedures (2.8% off pump coronary artery bypass) were performed from January 1, 2003 to December 31, 2008. Our overall utilization of red blood cell transfusion decreased from 43.2% to 13.6% for all patients and 38.5% to 8.7% for coronary artery bypass graft only patients. Patient outcomes were not significantly changed through 2007. Cardiopulmonary perfusion can be performed safely with low utilization of allogeneic red blood cell transfusions. Standardization and creative perfusion techniques, in the presence of a multi-faceted approach to blood management, play an important role in blood conservation. **Keywords:** blood conservation, cardiac surgery, quality improvement. *JECT. 2010;42:45–51*

Despite the growing evidence of the deleterious effects and increasing costs of blood transfusion, administering blood in patients undergoing open heart surgery is still a frequent practice. In July 2009, Rogers et al. revealed that "Allogeneic, but not autologous, blood transfusion increased the odds of in-hospital infection 2.0-fold (95% CI 1.6 to 2.5), in-hospital mortality 4.7-fold (95% CI 2.4 to 9.2), 30-day readmission 1.4-fold (95% CI 1.2 to 1.6), and 30-day mortality 2.9-fold (95% CI 1.4 to 6.0) in elective surgeries." They also concluded that, "Hospital variation in transfusion practices after coronary artery bypass grafting was considerable, indicating that quality efforts may be able to influence

practice and improve outcomes" (1). Recent comparisons by Snyder-Ramos et al. determined a "considerable and disturbing variability in perioperative transfusion practices for red blood cells, fresh frozen plasma, and platelets in patients undergoing the procedure of cardiac surgery". They also stated "This enormous range may be attributed partially to a subjectively based instead of an evidence-based practice and may indicate unnecessary transfusion" (2).

Scott et al. demonstrated that "transfusion is an independent predictor of increased resource utilization." They showed that even in patients with no preoperative morbidities, blood transfusion was associated with increased duration of intubation and length of stay. Additionally, they found that transfused patients were found to have a significantly higher incidence of postoperative co-morbidities such as renal failure, neurological complications, infection, and mortality (3).

Additionally, Murphy et al. showed the 30-day postoperative risk of death was almost six times higher for transfused patients than for those who were not transfused. They also

Received for publication February 27, 2009; accepted September 27, 2009. Address correspondence to: Edy S. Zelinka, CCP, LP, c/o Providence Regional Medical Center, Everett, 1321 Colby Avenue, Everett, WA 98206, Attention: Perfusion Department. E-mail: edy.zelinka@providence.org

The senior author has stated that authors have reported no material, financial, or other relationship with any healthcare-related business or other entity whose products or services are discussed in this paper.

demonstrated that “no apparent benefit was derived from RBC transfusion at hematocrits as low as 21” (4). This may be because hematocrit levels in isolation, unless very low, are poor indicators of tissue hypoxia (5).

A previous retrospective study by our institution (6), comparing patients from January 2002 to December 2002 with a similar group from September 1998 to April 1999, demonstrated a significant decrease in blood transfusion as a result of retrograde autologous prime, shortened bypass circuits, and alternate priming methods. To further minimize our patient’s risks associated with blood transfusion, we have continued to refine our perfusion techniques in addition to implementing a multidisciplinary approach to blood transfusion reduction, as described in Brevig et al. (7). Our transfusion rate has continued to decrease and we will demonstrate that innovative perfusion techniques along with a collaborative multidisciplinary approach to transfusion reduction allowed us to achieve low transfusion rates.

MATERIALS AND METHODS

Patient Population and Data Collection

Providence Regional Medical Center Everett (PRMCE) is a community hospital in Everett, WA. Data from all cardiac surgeries were collected. Definitions of variables used for data collection match those in the Society of Thoracic Surgeons (STS) database (8). A data driven effort to decrease allogeneic red blood cell (RBC) transfusion for all cardiac surgical patients was instituted at PRMCE in 1999. Innovations in treatment protocols were implemented and evaluated. Subsequently, clinical data from January 1, 2003 to December 31, 2007 were analyzed, leading to changes and a new standard of care. We implemented small-scale studies at our institution to further examine and modify our practice. Patient characteristics, type of procedure, incidence of blood product transfusion, and morbidity and mortality were reported by operation year as well as perioperative RBC transfusion rates (from arrival in the operative room to discharge).

This retrospective study was part of an ongoing quality improvement initiative. In the absence of a local institutional review board, approval was obtained by our Chief Medical Officer and chairperson of the Quality Council of Providence Regional Medical Center, Everett, WA.

Preoperative Evaluation

PRMCE employs a nurse blood conservation coordinator (BCC). A consultation with the BCC was often performed in patients that were severely anemic, had chronic renal insufficiency, and were of advanced age. The BCC used preoperative fasting ferritin, transferrin, serum iron, and complete blood count studies to evaluate the patient’s red cell mass and iron stores. Preoperative iron was commonly used to optimize the patient’s status and readiness for surgery.

A concerted effort was made to perform surgery on an elective basis. Using the STS definitions of acuity, in 2007 53% of our coronary artery bypass graft (CABG) patients returned electively for surgery once their preoperative condition improved, 43% of our CABG patients had an acute coronary syndrome urgent surgery, and 4% of our patients were classified as emergent or salvage.

Perfusion Technique

Standardized Care: An industry wide standard of care for blood transfusion practices in perfusion does not exist. We began regular review and close examination of data related to perfusion and patient outcomes. Prior experience and training brought techniques to the program that demonstrated improved intraoperative hematocrits, especially in patients with low hematocrits. They reduced a patients’ risk of being transfused. At the beginning of our efforts to reduce transfusions, a decision was made to adopt these practices for all open heart cases. Although we sacrificed a level of autonomy, we found that by standardizing our practice we were able to decrease blood transfusion and maintain good patient outcomes. The perfusionists in our program must follow the techniques described below.

Shortened Bypass Circuit: Tubing lengths and prime volume decreased through optimization of the perfusion circuit and has remained stable since 2003. We used an “x-coated” polymer-coated circuit with an open reservoir, the SX25 oxygenator, and Delphin centrifugal pump (Terumo, Ann Arbor, MI). The location of the pump was across from the surgeon, behind the first assistant, very close to the surgical field. It was placed at an angle approximately 60 degrees from the surgical table and the reservoir located just below the axilla, approximately 12 inches from the sterile field (Figure 1). The Arterial-Venous loop was 10 feet long and located on a barrier over the patient’s head. Vacuum assisted venous drainage was used. The venous line was 3/8” tubing and bypass was initiated without fluid in the line. The cardioplegia circuit was located in the first roller head position.

Alternate Priming Technique: The method by which the prime and medications were added to the circuit was crucial to decreasing hemodilution. Our priming method involved removal of normal saline from the circuit and replacement with Mannitol (American Regent, Inc., Shirley, NY), Sodium Bicarbonate (Hospira, Inc., Deerfield, IL), heparin, Amicar (Hospira, Inc., Deerfield, IL), and Albumin (Grifols Biological, Inc., Los Angeles, CA) (Table 1).

Initially, two liters of normal saline (Hospira, Inc., Lake Forest, IL) and 10 mL (10,000 units) of beef-lung heparin sodium (Baxter, Deerfield, IL) were used to prime and de-air the circuit, including the cardioplegia circuit. After the patient was prepared, the arterial-venous loop was passed to the sterile field where it was clamped and divided. The

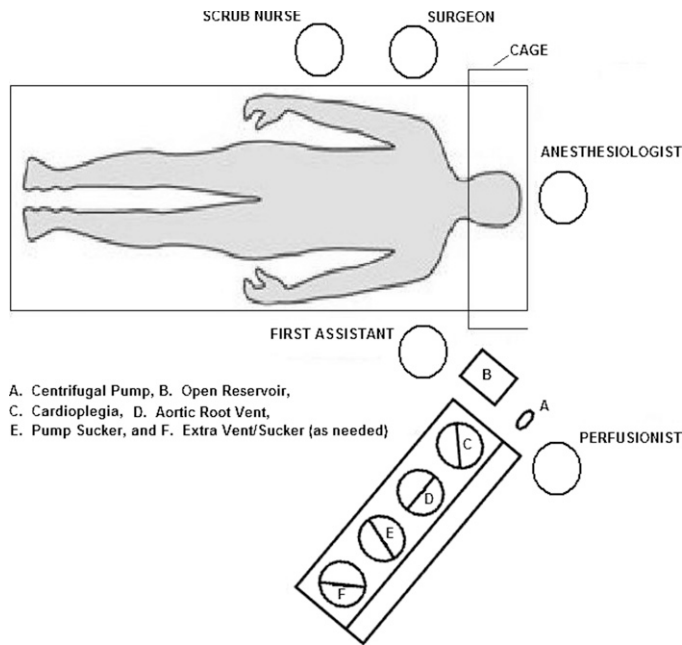


Figure 1. Pump location in relation to sterile field.

Table 1. Perfusion algorithm used to minimize prime volume.

Sequence	Prime Constituent	Volume (mL)
Initial prime of main perfusion and cardioplegia circuits	Normal saline/Heparin	2010
Fluid removed (wasted) during cardioplegia circuit priming	Normal saline/Heparin	-100
Lines cut and prebypass filter removed in sterile field	Normal saline/Heparin	-250
Fluid from venous line placed into reservoir then removed from circuit	Normal saline/Heparin	-130
Fluid removed from circuit to a level of 40 mL	Normal saline/Heparin	-690
Medication added to reservoir	Mannitol, Sodium Bicarbonate, Amicar, Heparin, Albumin	550
Fluid removed from reservoir to a level of 200 mL	Normal saline/Heparin	-200
Retrograde autologous prime	Normal saline/Heparin	-300
Remove saline from cardioplegia lines after bypass initiation	Normal saline/Heparin	-190
Total prime volume		700
Final normal saline volume		150

The final normal saline prime volume will be increased if a lower volume or higher concentration of albumin is used. Without using any albumin, the normal saline prime volume increases to 400 mL.

fluid in the venous line was drained into the reservoir. The pre-bypass filter was removed and the fluid discarded.

The recirculation lines on the top of the arterial filter and blood draw manifold, located distal to the oxygenator, were closed. A blood transfer bag was connected to the stopcock located at the end of the arterial filter recirculation line on top of the reservoir. The stopcock to the blood transfer

bag was opened and fluid pumped from the bypass circuit via the recirculation line until the level in the reservoir reached 40 mL. At this time, 200 mL of 25% Mannitol, 50 milliequivalents (50 mL) Sodium Bicarbonate, 10 g (40 mL) Amicar, 10 mL (10,000 units) heparin, and 12.5 g (250 mL) of Albumin were added. Additional fluid was removed via the blood transfer bag until the reservoir level reached 200 mL. Once completed, the recirculation line from the arterial filter to the reservoir was closed and the fluid circulated via the blood draw manifold. The blood transfer bag was discarded. The volume of normal saline remaining in the circuit at this time was 640 mL.

Retrograde Autologous Prime: Prior to arterial cannulation, 300 units per kilogram of heparin was given to the patient and circulated for a minimum of 2 minutes. After arterial cannulation, retrograde autologous prime was initiated.

A clamp was placed proximal to the arterial filter and a new blood transfer bag placed on the stopcock distal to the arterial filter recirculation line. The clamp that was placed distal to the arterial filter previously was removed and the stopcock opened to the blood transfer bag. This allowed the patient's blood to fill the arterial cannula, tubing, and arterial filter, and displace normal saline into the blood transfer bag (Figure 2).

When the patient's blood reached the top of the arterial filter the clamp distal to the arterial filter was replaced. The stopcock was then closed to the blood transfer bag, the clamp proximal to the arterial filter removed, and the blood transfer bag discarded. Finally, the stopcock was reopened to the reservoir to allow all the fluid to circulate. The final volume of normal saline remaining in the circuit prior to bypass initiation was 340 mL.

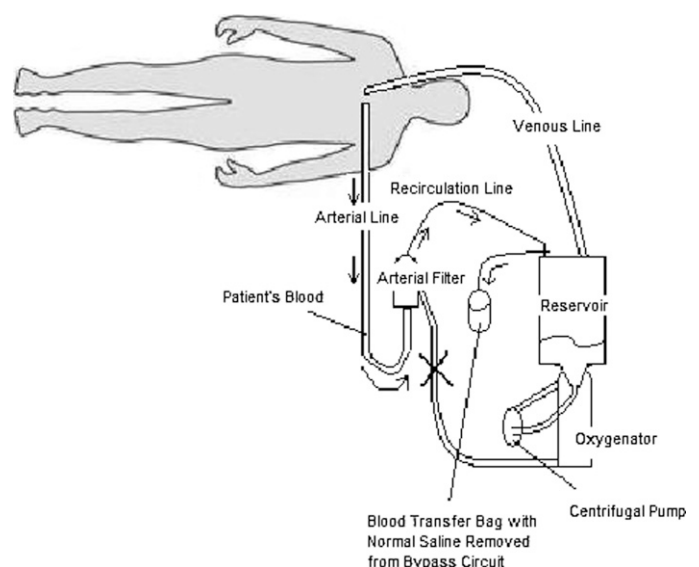


Figure 2. Retrograde autologous prime diagram.

Final Prime Removal: Immediately after the initiation of cardiopulmonary bypass (CPB), prior to placement of the aortic cross clamp, normal saline from the cardioplegia circuit was pumped to the field until blood filled the tubing. This final priming technique allowed us to achieve a final normal saline prime of 150 mL.

Additional Techniques: Cold four to one blood cardioplegia was used with high dose potassium to limit crystalloid administration. Normothermia was maintained except in cases of circulatory arrest or specific surgeon request. Additional normal saline given during bypass was limited. Twenty-two percent of our patients received additional normal saline during CPB, the volume averaged 173 mL.

The volume and concentration of Albumin used was determined by preoperative blood albumin levels, kidney function, hematocrit, and body surface area. Albumin was used to correct low preoperative albumin levels or small body surface area with a low hematocrit. Albumin was not used if a patient's creatinine was high unless they were already on hemodialysis.

The use of cell saver and hemoconcentrator was determined on a case-by-case basis and there was no standardized approach to either technique. A cell saver was commonly used for re-operations, patients that refused blood products, or upon surgeon request. A hemoconcentrator was typically used on patients with a reservoir blood level greater than 1500 mL in the presence of a hematocrit less than 21%.

After separation from bypass, the blood remaining in the circuit was placed into blood transfer bags and reinfused to the patient by the anesthesiologist. If a cell saver was being used, a portion of this volume was washed. Normal saline was added to the circuit as the blood was removed to maintain its integrity.

Surgical Technique

Most (97.2%) of our cases were performed on pump through a median sternotomy. Specific techniques that minimize blood loss included meticulous attention to hemostasis, immediate closure of saphenous vein and radial artery donor sites, and limited irrigation of the surgeons' hands and field to avoid introducing crystalloid into the CPB circuit. Proximal anastomoses in CABG patients were performed using a single cross-clamp technique. Cardiomy suction and vents were temporarily discontinued when irrigation was used in the field for valves. Shed blood was routinely returned to the perfusion circuit; however, one surgeon refused cardiomy suction on CABG patients unless unusual bleeding was noted. If cardiomy suction was not used, wall suction was used and shed blood was rarely greater than 200 mL.

Anesthesia techniques were varied. Intravenous fluid administration was judicious. During the study period Aprotinin (Bayer Healthcare, Wayne, NJ) use was low and those patients who did not receive Aprotinin received

Amicar. Aprotinin use had always been rare, being reserved primarily for patients undergoing re-operation and patients who refused blood products. Those who received Aprotinin were dosed using the full dose method. Prior to CPB, blood pressure was maintained with phenylephrine (Baxter, Irvine, CA) or norepinephrine bitrate (Bedford Labs, Bedford, OH) rather than fluid administration as long as monitoring parameters did not indicate a deleterious fluid deficit.

Postoperative Protocol

The postoperative care was provided by the surgeons and physician's assistants. Although our average discharge hematocrit was 28%, patients may be discharged with hematocrits in the low 20% range and sent home with instructions for anemia treatment. Patients with a hematocrit less than 35% were treated with an anemia protocol designed to replenish iron stores. Erythropoietin stimulating agents were rarely given. Our major strategy for limiting the use of RBCs postoperatively was permissive anemia. There was no transfusion trigger. Persistent hypotension, orthostatic hypotension, tachycardia, and inability to participate in rehabilitation were common indications for transfusion. Crystalloid administration was restricted and judicious use of pressors was encouraged. Albumin was commonly used for additional volume resuscitation. Our extubation protocol minimized the use of arterial blood gases. The operating surgeon was consulted prior to blood administration by other subspecialists.

Statistical Analysis

We compared our actual blood utilization to our predicted risk of giving blood using the "Transfusion Risk Understanding Scoring Tool" (9). The predictors in the tool included age, gender, weight, preoperative hemoglobin and creatinine, reoperation, urgency of operation, and type of operation. Since only the preoperative hematocrit was available in our data, the formula of hematocrit (%) = $2.953 \times \text{hemoglobin (g/dL)}$ (10) was used to calculate hemoglobin values.

RESULTS

Two thousand nine hundred and seventy-nine open-heart surgeries were performed from January 1, 2003 to December 31, 2008. Our mean "Lowest on Bypass" hematocrit in 2008 was 27.3% and our average venous oxygen saturations were greater than 75%. Table 2 shows our CABG patient demographics and comorbidities. With the exception of an increase in renal failure, the patient preoperative characteristics were similar over time. Table 3 is a summary of all cardiac surgery cases by year. The volume and type of procedures were similar over time. The morbidity and mortality either decreased or remained stable while the transfusion rate decreased. It is noteworthy that

Table 2. Patient characteristics in isolated CABG patients by year.

Year of Operation	2003	2004	2005	2006	2007
Number of cases	378	329	329	301	281
Demographic					
Female gender	26.5%	24.6%	23.4%	23.3%	23.8%
Age in years	65.4 + 10.7	65.0 + 11.0	64.3 + 10.5	65.7 + 10.6	65.5 + 10.8
Weight in kg	89.0 + 21.1	88.7 + 20.1	88.7 + 16.9	88.2 + 18.0	89.7 + 19.1
Body surface area in m ²	2.0 ± .2	2.0 ± .3	2.0 ± .2	2.0 ± .2	2.0 ± .2
Comorbidities					
Cerebrovascular disease	17.0%	13.4%	12.8%	12.0%	14.1%
Peripheral vascular disease	11.1%	15.2%	16.7%	10.3%	14.4%
Renal failure	2.1%	4.6%	8.8%	9.6%	10.8%
Non-insulin dependent diabetes	22.5%	33.7%	18.8%	20.6%	22.7%
Insulin dependent diabetes	9.3%	7.3%	7.9%	8.6%	11.6%
Chronic obstructive pulmonary disease	11.7%	12.2%	13.7%	20.9%	19.5%
Hypertension	81.2%	82.4%	76.9%	84.1%	84.8%

Table 3. Summary of all cardiac surgery cases from 2003–2007.

Surgery Year	2003	2004	2005	2006	2007
Number of cases	530	513	538	471	479
Type of Procedure					
CABG only	71%	64%	61%	64%	59%
Valve only	7%	11%	11%	11%	13%
Mixed CABG/valve and non-CABG	22%	25%	28%	25%	29%
Blood Products Transfused					
Mean units of RBCs per recipient	3.3	3.3	2.8	2.4	3.0
Mean units of RBCs per patient (population)	1.4	1.3	.7	.5	.5
Mean units of platelets per patient population	0	.12	.03	0	0
Mean units of fresh frozen plasma per patient population	0	.012	0	.003	.007
Mean units of cryoprecipitate per patient population	0	0	0	0	0
Mean discharge hematocrit	N/A	N/A	30.9 ± 3.8	28.8 ± 3.7	28.8 ± 3.8
Morbidity and Mortality					
Reoperation for bleeding	2.3%	2.0%	1.7%	1.7%	.8%
New hemodialysis	.8%	.6%	.7%	.9%	1.0%
Respiratory complications	4.5%	4.9%	3.3%	3.4%	4.2%
Prolonged ventilation	5.3%	5.8%	3.7%	4.5%	3.7%
Postoperative myocardial infarction	.6%	1.0%	.4%	.2%	.2%
Postoperative cerebral vascular accident	1.1%	.8%	1.5%	.9%	1.3%
In-hospital death	3.0%	2.7%	3.5%	3.2%	3.5%

the mean units of platelet, fresh frozen plasma, and cryoprecipitate transfusions during the study period were less than .12, .012, and .00, respectively.

Figure 3 shows trends in intraoperative strategies used to manage red cell mass. Figure 4 shows an annotated rate trend illustrating the impact of interventions on the transfusion rate over time. Not every intervention had the desired effect and it clearly took a full team buy-in of the program to achieve the most significant results. Figure 5 shows the RBC transfusion rate by location of administration (intra- vs. post-operatively), and compares these results to the STS national benchmarks. A less significant decrease in transfusion was noted in the postoperative setting compared to intraoperative transfusion. PRMCE's transfusion rates are significantly less than the STS benchmarks. Figure 6 illustrates the cumulative number of patients transfused

and the cumulative number of RBC units used over the past 6 years. The divergence of the slope from the trend line shows that blood utilization decreased starting in 2005. Four hundred and eight patients were not transfused and 1575 RBC units were saved as a result of our blood conservation program over the last 4 years. Figure 7 shows the observed versus expected transfusion rate for the study period. The predicted risk of transfusion was similar for each year and less blood was used each year.

DISCUSSION

This retrospective study was part of an ongoing quality improvement initiative that began in 1999. A limitation of this study was the absence of a control group. In addition, the 2008 patient outcomes were not yet analyzed at the

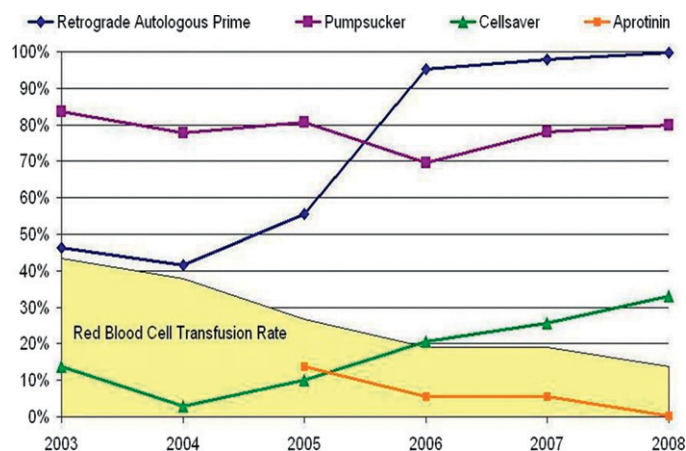


Figure 3. Intraoperative strategies and red blood cell transfusion rate (by year) for all cardiac surgical procedures.

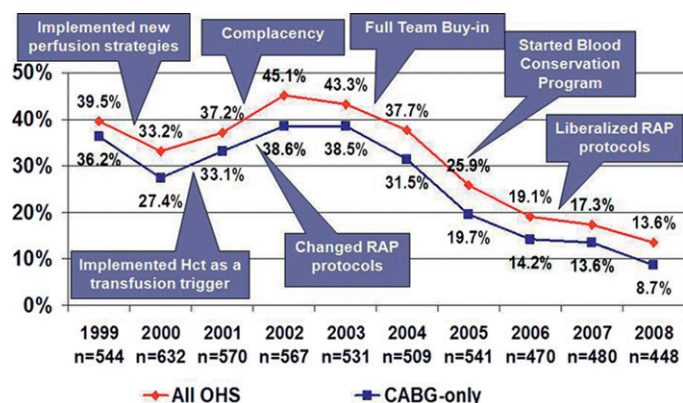


Figure 4. Blood transfusion rate and interventions. HCT, Hematocrit; OHS, Open Heart Surgery; RAP, Retrograde Autologous Prime.

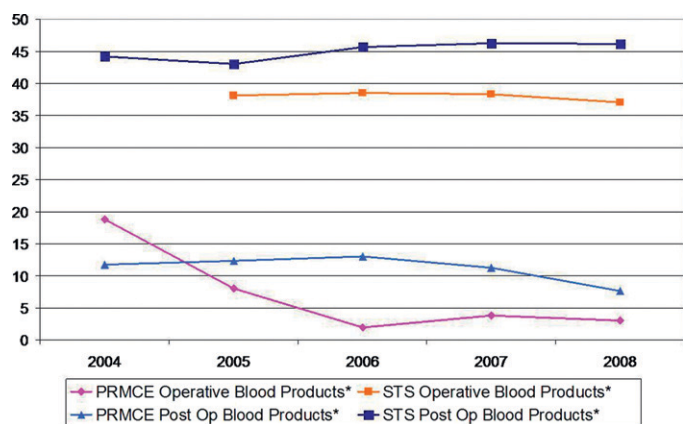


Figure 5. CABG blood utilization with STS national benchmarks. Op, Operative. Data source = Society of Thoracic Surgeons National Adult Cardiac Surgery Database, annual report, q1 2008.

time of submission. Finally, the absence of accurate anesthesia data made it difficult to review whether the anesthesia teams were practicing similarly. Based on the evidence that there was no significant variation in transfusion rates between anesthesia practitioners, we concluded that they

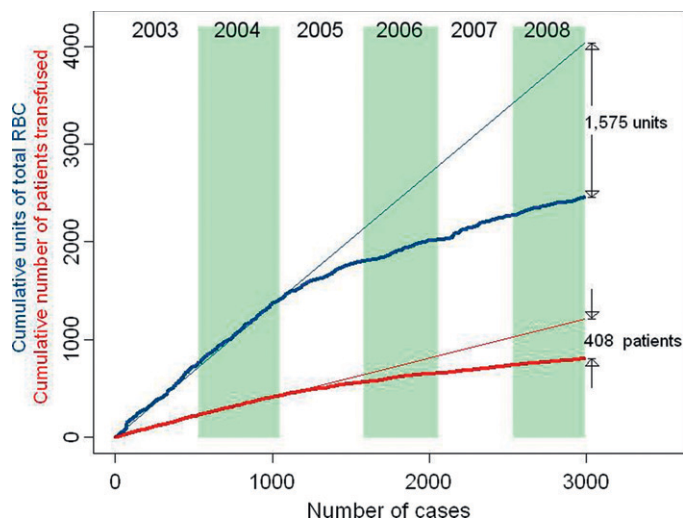


Figure 6. Cumulative number of patients transfused and units of red blood cells given. The straight trend line is extrapolated from the 2003 and 2004 data. Divergence away from the trend line in 2005–2008 represents a decrease in both the number of patients transfused and the number of units of red blood cells given.

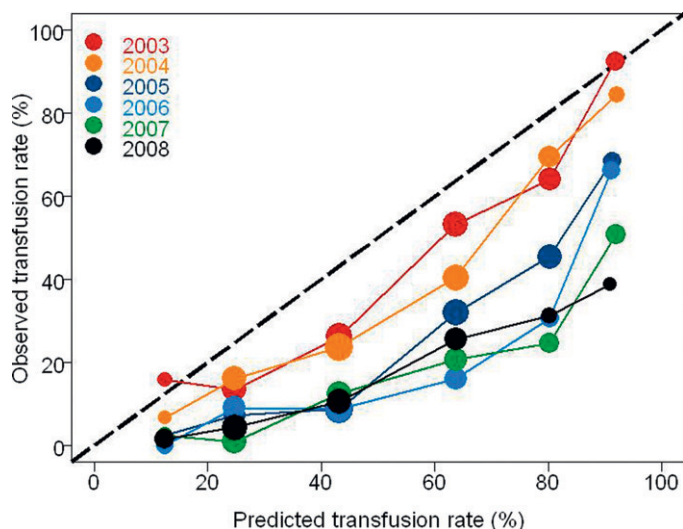


Figure 7. Predicted versus observed transfusion rate. The predicted risk of transfusion was calculated by Alghamdi and colleagues' Transfusion Risk Understanding Scoring Tool (9). Patients were grouped by the predicted risk of transfusion. The areas of the circles are proportional to the number of patients in each group: The circles in the legend represent 50 patients. The vertical distance from the diagonal line to the center of the circle represents patients in that particular risk group who avoided a predicted red blood cell transfusion.

were practicing alike. Our indications for transfusion continue to evolve in our ongoing initiative and we will continue to thoroughly evaluate patient outcomes and adjust our protocols as needed to ensure a safe practice.

Low utilization of blood products during cardiac surgery has not impaired our patient outcomes. We make a concerted effort to perform surgery on an elective basis to optimize a patient's RBC mass. We have found that blood transfusion is rarely an emergency and it is not necessary to

have blood products readily available for patients undergoing open heart surgery. Most of our patients who receive a transfusion do so in the postoperative setting, where they can be evaluated in a more stable state.

Our largest challenge has been the reluctance of practitioners to change their practice and continue to reduce transfusion rates. Complacency in 2002 led to higher transfusion rates. This was overcome by continuing education and reporting of results to our staff. Ongoing data collection and review with practitioners is an important way to support their practice changes. Cardiologists, consulting physicians, and patients also need to be educated about our blood conservation program and the effects of postoperative anemia.

The perfusionist's role in blood transfusion reduction is essential and changes at our facility were achieved without difficulty and without additional cost. Immediate reduction in transfusion rates can be achieved with standardization and creative perfusion techniques. However, a comprehensive blood conservation program also requires a physician champion, a multidisciplinary collaboration, an effective BCC, and an institutional commitment to reduce blood utilization.

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