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Reducing intraoperative red blood cell unit wastage in a large academic medical center

Gina M. Whitney¹, Marcella C. Woods², Daniel J. France¹, Thomas M. Austin¹, Robert J. Deegan¹, Allison Paroskie³, Garrett S. Booth³, Pampee P. Young³, Roger R. Dmochowski⁴, Warren S. Sandberg¹, and Michael A. Pilla¹

¹Department of Anesthesiology, Vanderbilt University, Nashville, Tennessee

²Program for Quality, Safety, and Risk Prevention, Vanderbilt University, Nashville, Tennessee

³Department of Pathology, Microbiology, and Immunology, Vanderbilt University, Nashville, Tennessee

⁴Department of Urologic Surgery, Vanderbilt University, Nashville, Tennessee

Abstract

BACKGROUND—The wastage of red blood cell (RBC) units within the operative setting results in significant direct costs to health care organizations. Previous education-based efforts to reduce wastage were unsuccessful at our institution. We hypothesized that a quality and process improvement approach would result in sustained reductions in intraoperative RBC wastage in a large academic medical center.

STUDY DESIGN AND METHODS—Utilizing a failure mode and effects analysis supplemented with time and temperature data, key drivers of perioperative RBC wastage were identified and targeted for process improvement.

RESULTS—Multiple contributing factors, including improper storage and transport and lack of accurate, locally relevant RBC wastage event data were identified as significant contributors to ongoing intraoperative RBC unit wastage. Testing and implementation of improvements to the process of transport and storage of RBC units occurred in liver transplant and adult cardiac surgical areas due to their history of disproportionately high RBC wastage rates. Process interventions targeting local drivers of RBC wastage resulted in a significant reduction in RBC wastage ($p < 0.0001$; adjusted odds ratio, 0.24; 95% confidence interval, 0.15–0.39), despite an increase in operative case volume over the period of the study. Studied process interventions were then introduced incrementally in the remainder of the perioperative areas.

CONCLUSIONS—These results show that a multidisciplinary team focused on the process of blood product ordering, transport, and storage was able to significantly reduce operative RBC wastage and its associated costs using quality and process improvement methods.

Address reprint requests to: Michael A. Pilla, MD, Department of Anesthesiology, Vanderbilt University School of Medicine, 1301 Medical Center Drive, 4648 TVC, Nashville, TN 37232-5614; michael.a.pilla@vanderbilt.edu.

CONFLICT OF INTEREST

The authors have disclosed no conflicts of interest.

With an increasing focus on the value of health care received by patients, emphasis has predictably shifted toward eliminating costs and resource utilization that does not result in improved clinical outcomes. Blood products represent an expensive and labor-intensive resource, accounting for approximately 1% of hospital expenditures.¹ External wastage occurs when blood products are not returned to the blood bank within a time or temperature range that allows for their safe return into inventory. The standards set forth by the AABB dictate that the temperature of red blood cell (RBC) units must be maintained between 1 and 6°C to be available for issue.² Due to the difficulty in monitoring the temperature of RBC units after they leave the blood bank, many transfusion services have adopted a standard allowance of 30 minutes for the return of blood products.^{3,4} If RBCs are returned to the blood bank within 30 minutes of issue, it is thought that they may be safely returned to inventory, often in the absence of local time and temperature data. The wastage of blood products during the normal course of hospital operations represents a direct cost to health care organizations and is the result of process deficiencies in inventory blood product ordering, transport, and storage. The annual direct cost of intraoperative RBC wastage at Vanderbilt University Medical Center (VUMC) amounted to approximately \$249,314 in 2010, using an estimated direct cost of \$225.42 per unit of leukoreduced RBCs.⁵ This figure does not account for the overhead costs associated with the procurement, management, storage, and issue of these products. In addition to the financial cost associated with RBC wastage, the presence of RBC units outside of the blood bank that are not actively being transfused introduces additional potential for mistransfusion as they are out of the direct control of both the blood bank and the intended transfusionist.

The high-acuity nature of the perioperative area occasionally requires immediate availability of large volumes of RBCs resulting in a tendency to order and store blood products “just in case” of clinical need, likely contributing to RBC wastage. After previous provider education and reminder-based efforts at this institution failed to result in sustained reductions in perioperative RBC wastage, we hypothesized that RBC wastage in the operative environment could be reduced by 50% using process and quality improvement methods.

MATERIALS AND METHODS

Setting

VUMC is a tertiary care center with 1019 licensed beds, 72 operating rooms (ORs), and with a volume of approximately 52,400 cases annually.

Human subjects protection

This work was reviewed by the VUMC Institutional Review Board and deemed to be exempt quality improvement work.

Planning the intervention

A multidisciplinary team was established whose membership was composed of individuals from the Department of Anesthesiology; the Division of Transfusion Medicine; the Center for Quality, Safety, and Risk Prevention; and the Center for Research and Innovation in

Systems Safety. The initial project work focused on determining key drivers of operative RBC wastage.

Assessment of perioperative blood wastage

We completed a process map based on interviews with OR personnel and through direct observations of the ordering, transport, and storage of blood products during surgery.⁶ The resulting process map was supplemented with time and temperature data to identify particular processes associated with an increase in RBC unit temperature (Table 1). Based on the time and RBC temperature data as well as input from frontline providers, a failure mode and effects analysis was conducted in which potential process failures were considered for frequency and likelihood of increasing RBC wastage.⁷

Time and temperature of RBC units (n =20) were recorded at various time points over a 1-month period: 1) the blood products' removal from blood bank refrigeration, 2) insertion into the pneumatic tube or cooler, 3) arrival at the OR tube station, 4) checking of the transfusion administration record by two providers, and 5) transfusion of each unit observed. Transit times from the blood bank to the tube station or OR were recorded. In the event that an RBC unit was not transfused, time and RBC unit temperature were recorded upon receipt in the blood bank. If an RBC unit was returned to the blood bank and it was unable to be returned to inventory, that was noted. Qualitative measures were also noted to create a general understanding of the delivery process, including the clinical role of the people responsible for ordering, transporting, or receiving of blood products. Infrared thermometers were validated against the VUMC blood bank thermometers before the study.

Returned blood products were inspected and determined acceptable for reissue if the following criteria were met: the bag was not entered, temperature of the RBC unit was maintained below 6°C, at least one sealed segment of integral donor tubing remained attached, and the product had not expired. If any of the required criteria were not met, then the unit was discarded. The criteria for the determination of RBC wastage were unchanged during the baseline and intervention time periods.

A reliable means of electronically tracking RBC wastage events was developed using the VUMC blood bank's internal computer information system (SoftBank II, SCC Soft Computer, Clearwater, FL). This date and time of RBC issue was then cross-referenced with the Vanderbilt Peri-operative Information Management System (VPIMS) database to determine the type of operation and the patient's location at the time that the blood product was issued. Additionally, during the implementation phase, all wastage events resulted in follow-up contact by one of the project team members (MP) with the appropriate providers to identify factors contributing to specific wastage events in the perioperative area.

Development of improvement interventions

Interventions were developed based on three key drivers of ongoing RBC wastage identified during failure modes and effects analysis: 1) RBC delivery via pneumatic tube system, 2) failure to store RBC units in coolers in the OR, and 3) lack of feedback regarding RBC wastage events in high-wastage areas (Fig. 1).

Data demonstrated that the temperature of RBC units exceeded standards once out of the blood bank refrigerators for 8 minutes. Delivery of the RBC unit to the OR via a pneumatic tube system was associated with significant increases in RBC temperature and subsequent wastage when compared to delivery in a blood bank–validated cooler. As a result, our intervention required that any order exceeding a single unit of RBCs was delivered using a validated cooler. In the event that the clinician believed that the cooler transport of RBC delivery would delay the delivery of blood products, he or she was advised to bypass cooler transport and use the pneumatic tube system.

Data demonstrated that improper packing or shifting of the bag of wet ice inside the cooler during transport and storage in the OR likely resulted in increased wastage. Because variability in RBC product packing was contributing to RBC wastage, the cooler was redesigned to utilize stationary cold packs at the perimeter (Fig. 2). This redesigned cooler was validated to maintain RBC unit temperature below 6°C for 8 hours.

During the intervention phase of this work in the cardiac ORs, it was discovered that some RBC wastage was attributable to storage of RBC and thawed fresh-frozen plasma (FFP) units within the same cooler. As FFP is thawed in a warm water bath, its temperature is significantly greater than that of RBCs at the time of issue. It was determined that packaging RBCs and thawed FFP into separate coolers reduced warming of RBC products stored within transport coolers.

Shared ownership and data transparency of RBC wastage events

Initial RBC wastage data identified that liver transplant and cardiac surgical operative areas accounted for 50.7% of all operative RBC wastage. We designed and tested changes in blood product delivery and storage in the liver transplant ORs beginning in April 2013. RBC orders of more than 1 unit were delivered and stored in a blood bank-approved cooler intraoperatively, avoiding the use of the pneumatic tube system. This cooler was returned immediately upon case conclusion and directly to the blood bank. Anesthesia and nursing personnel in the liver transplant area received education regarding the factors found to contribute to RBC wastage and its associated cost. Rare RBC wastage events that continued to occur after implementation of these process changes were reviewed with anesthesia and nursing providers to identify remaining process deficiencies or barriers to implementation. Aggregated RBC wastage data were shared with local OR providers. The identical process changes were then implemented in the cardiac surgical area in June 2013. Local wastage data were shared on a monthly basis with anesthesiology and nursing staff meetings for the purpose of reinforcing process improvements, facilitating discussion of barriers to implementation, and acknowledging the positive impact of their efforts. Changes to RBC transport processes were phased in throughout the perioperative areas during the following year.

Statistical analysis

Enumerative statistics—Statistical analyses were performed using computer software (SAS, Version 9.3, SAS Institute, Inc., Cary, NC). Population characteristics were examined using Pearson's chi-square test, Fisher's exact test, or Wilcoxon rank sum test, as

appropriate for the distribution of the data. Simple logistic regression was used to determine the effect of RBC utilization on wastage. To further analyze the effect of the process intervention, a multiple logistic regression was performed with wastage of at least 1 RBC unit per surgical procedure as the response variable and total number of RBCs ordered, intervention, and surgery type included as explanatory variables. A p value of less than 0.05 was considered significant.

Statistical process control—Shewhart charts (individual/moving range charts) were generated to evaluate the impact of process improvement interventions on RBC unit wastage. Because monthly RBC wastage is inherently variable over time, calculation of upper and lower confidence limits (± 3 sigma) were used to identify data points outside the bounds of variability of the baseline data contained in the individual chart. The moving ranges chart displays the difference in RBC unit wastage from one month to the next and allows for the monitoring of substantial shifts in RBC unit wastage likely to process improvements.

RESULTS

All surgical procedures requiring RBC transfusion that occurred at VUMC during the period July 1, 2011, to May 31, 2014, were included in this analysis. These procedures were grouped into preintervention and postintervention cohorts based on surgical date with April 1, 2013, and June 1, 2013, set as the intervention dates within the liver transplant and cardiac surgical areas, respectively. For all other surgical areas, an intervention date of June 1, 2013, was used for analysis. During this period, 25,952 units of RBCs were utilized and 833 units were wasted, resulting in an overall RBC wastage rate of 3.4%. In the preintervention cohort, 749 units of RBCs were wasted out of 18,600 units utilized (4.0%) while 162 units of RBCs were wasted out of 8082 units utilized (2.0%) in the postintervention cohort. This difference yielded a p value of less than 0.0001 on univariate analysis (Table 2) and a relative risk reduction of 50.4%.

The majority of intraoperative RBC wastage was attributable to adult cardiac and liver transplant areas, which accounted for 39.9 and 10.8%, respectively, of total RBC units wasted. For adult cardiac surgeries, 310 units of RBCs were wasted out of 3726 units utilized (8.3%) in the preintervention cohort while 42 units of RBCs were wasted out of 1492 units utilized (2.8%) in the postintervention cohort ($p < 0.0001$). In the liver transplant area, 89 units of RBCs were wasted out of 2159 units utilized (4.1%) in the preintervention cohort while 6 units of RBCs were wasted out of 797 units utilized (0.8%) in the postintervention cohort ($p < 0.0001$). We did note a substantial decrease in RBC utilization during the time period of the study that was likely the result of hospital-wide efforts to improve RBC transfusion practices (Fig. 3).

For adult cardiac and liver transplant cases during the entire study period, an increase in RBC utilization was associated with increased wastage ($p < 0.0001$; odds ratio, 1.07; 95% confidence interval [CI], 1.05–1.09). In addition, RBC utilization significantly decreased in these cases after implementation of the process intervention (4.8 units/case vs. 3.7 RBC units/case, $p < 0.0001$). To account for the effects of surgical type, total number of RBC units

used per surgical procedure, and intervention on RBC wastage rate, a multiple logistic regression was performed with wastage of at least 1 RBC unit per case as the response variable. Liver transplant and adult cardiac surgery cases were compared to each other in this analysis. After controlling for total number of RBC units transfused and surgical type, the process intervention resulted in a decrease of RBC wastage over the entire study period ($p < 0.0001$; adjusted odds ratio, 0.24; 95% CI, 0.15–0.39; Table 2). Of note, total number of utilized RBC units ($p < 0.0001$; adjusted odds ratio, 1.08; 95% CI, 1.05–1.10; Table 2) and adult cardiac procedures ($p = 0.0419$; adjusted odds ratio, 1.62; 95% CI, 1.02–2.59; Table 2) relative to liver transplants both increased the likelihood of wasted RBCs per case. Although there was a reduction in RBC utilization over this time period, most of the wastage reduction was due to the process intervention since this had approximately a fourfold greater effect size on wastage than RBC utilization according to the multiple logistic model.

DISCUSSION

The wastage of blood products represents a significant cost to medical centers as they attempt to reduce unnecessary expenditures that do not result in improved clinical outcomes. On a national level, the Q-Tracks program, the quality tracking mechanism of the College of Pathology, uses blood product wastage as a quality indicator. Data are submitted annually by more than 100 institutions and analyzed to identify and model characteristics of high-quality organizations. Q-Tracks received data concerning more than 2 million units of blood products and identified 35,000 units of in-date wastage (1.75%). Heitmiller and colleagues⁸ detailed efforts to reduce RBC wastage in the operative environment used a Lean Six Sigma methodology to define the extent of RBC wastage, implement process changes, and then measure the impact of these interventions. Locally, previous attempts to reduce perioperative RBC wastage had focused on the use of education and reminders. Despite our repeated efforts, RBC wastage continued unabated within the ORs. Our approach to addressing RBC wastage in the perioperative environment focused on developing an in-depth understanding of processes of RBC unit transport and storage and revealed drivers of RBC wastage that are unlikely to be unique to our organization.

To effectively reduce the wastage of blood products in the perioperative environment, we decided to change our approach to this work and to incorporate quality improvement method as a means of understanding the processes underlying blood product ordering, storage, and transport and their common failure modes. This shift in focus from repeated provider education to understanding and modifying processes of care acknowledged the relatively transient involvement of multiple types of providers (who were being continually reeducated and reminded) in the overall process of ordering and transport of blood products in the operative environment.

Our initial work was designed to develop an in-depth understanding of the process of blood product ordering, transport, storage, and utilization within our operative environment. After process mapping and failure modes and effects analysis, key drivers of RBC wastage were identified. Because the Food and Drug Administration and the AABB require that RBC units be maintained at an internal temperature between 1 and 6°C to be available for reissue in the event that they are not used, the process map was supplemented with time and

temperature data. These findings allowed the development of a strategic and targeted approach to the reduction in RBC wastage. We hypothesized that using process improvement methods, perioperative RBC wastage could be reduced by 50% using targeted interventions.

Underlying the success of this effort was the belief that RBC wastage was at its core a “process” problem and not the result of error or inadequacy on the part of in-room nursing and physician providers. The challenge then became one of focusing on process improvements and developing a sense of “shared ownership” of RBC wastage events when they occurred. Implementation of process changes, particularly changes in the process for blood delivery, was coupled with the sharing of real-time wastage data to individual providers within 24 hours of a wastage event. The availability of aggregate data to front-line staff in the OR established a collaborative relationship between the improvement team and local groups of providers. Review of ongoing wastage events at regular meetings with physician and nursing staff has encouraged continued awareness of blood product ordering, transport, and storage processes resulting in sustained reductions in wastage.

Barriers to implementation of these process changes were relatively manageable. We did identify some element of “improvement fatigue” on the part of frontline providers as well as concern for increasing the workload on busy frontline staff members. Early in the design of our interventions, we did make a deliberate effort to design process changes that did not result in automated “reminders” or substantially increase the workload on a single group of staff members. One additional barrier to implementation of process changes was the concern of anesthesiologists that using coolers for delivery of RBC units would result in significant delay. Time and temperature data obtained during the development of the process map did not support this concern for the use of the tube system. To acknowledge this concern we did specify that providers were able to revert to the preimplementation process if they felt that RBC cooler delivery would result in risk to the patient. This reversion to the preimplementation process did not occur throughout the postimplementation period. The improvement team did agree, however, that widespread simultaneous implementation could introduce delay due to a lack of available staff to transport the RBC cooler. As a result, this specific intervention was initially limited to the liver transplant and cardiac surgical ORs, with widespread implementation of this change being gradually phased in throughout the following year.

Every RBC wastage event was also reviewed by members of the multidisciplinary improvement team to identify and mitigate barriers to full implementation and to detect shortcomings of the revised process. Limitations of this effort include multiple simultaneous interventions that were implemented based on the findings of the initial process mapping effort or the possibility that reductions in RBC wastage were attributable to unforeseen factors outside of the scope of this effort. Multiple simultaneous changes limits the ability to assess the independent effect of any single intervention, although this approach did improve the efficiency and reduce the complexity of staged implementation. We did, however, choose to test the implementation of the set of process changes in a single high-wastage area (liver transplant) to further refine the process before dissemination to the cardiac surgical area. Additionally, the effort to reduce RBC wastage in the OR did coincide with institution-

wide efforts to improve RBC transfusion practice that resulted in significant reductions in RBC utilization across the institution. For this reason, logistic regression was utilized to assess for the impact of reduced RBC utilization on perioperative RBC wastage. However, RBC wastage as a percentage of products issued by the blood bank was significantly reduced, even as operative case volume increased.

In conclusion, blood product wastage represents a significant expenditure within health care organizations and represents an opportunity for substantial reductions in cost while maintaining high-quality care. This effort showed that a multidisciplinary team focused on the process of blood product ordering, transport, and storage, and in collaboration with engaged front-line staff, was able to significantly reduce RBC wastage and its associated costs. Creating a process of shared accountability and “sensitivity to operations” among those in the operative environment distinguished this effort from previous unsuccessful efforts at RBC wastage reduction in this institution. A shift in focus from broad-based education efforts to targeted process improvement with active engagement of frontline staff resulted in a sustained reduction in RBC wastage.

Acknowledgments

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ABBREVIATIONS

OR(s)	operating room(s)
VUMC	Vanderbilt University Medical Center

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Fig. 1.

Key driver diagram detailing the drivers of intraoperative RBC wastage in the institution and the interventions designed to mitigate them.

Fig. 2. Blood cooler was redesigned to reduce variability in packing of RBC units relative to ice. Cold packs at the perimeter of the cooler have been validated to maintain RBC unit temperature between 1 and 6°C in the OR for 8 hours.

Fig. 3. Individuals/moving range chart reflecting intraoperative RBC wastage relative to RBC ordering by month number. Implementation is denoted below the X-axis along with a change in the applicable control limits of the new process. (A) Liver transplant RBC wastage by month: before implementation of process changes in Month 23, attempts to reduce RBC wastage during liver transplant cases were education-based and were unable to produce long-term reductions in RBC wastage. Process changes in Month 23 resulted in sustained reductions in RBC wastage. (B) Adult cardiac RBC wastage by month: before introduction of process changes in Month 27, no specific effort to reduce RBC wastage was ongoing. Implementation in Month 27 resulted in sustained and significant reductions in RBC wastage.

TABLE 1

Preintervention RBC ordering, transport, and storage process

RBC unit ordered
RBC unit removed from refrigeration in blood bank
RBC unit delivered to or via pneumatic tube system or cooler
RBC unit stored in validated cooler in or if present
verification of transfusion administration record with RBC unit and patient id by two providers
RBC unit transfused
<i>or</i>
RBC unit in cooler transported to or control room
Cooler checked for proper packing of ice and RBC units
Cooler returned to blood bank
RBC unit returned to inventory
RBC unit wasted
<i>or</i>
RBC unit returned to blood bank via pneumatic tube system
RBC unit returned to inventory
RBC unit wasted

TABLE 2

Pre- and postintervention case volume and RBC wastage

Descriptors	12 months preceding intervention	12 months after intervention
Liver transplant implementation dates	April 2012–March 2013	April 2013–March 2014
Liver transplant case volume	103	129
RBC units wasted—liver	89	6
RBC units wasted per case—liver	0.86	0.04
Cardiac surgical implementation dates	June 2012–May 2013	June 2013–May 2014
Cardiac surgical case volume	1307	1345
RBC units wasted—cardiac	310	42
RBC units wasted per case—cardiac	0.24	0.03
Total RBC units wasted—or total	749	162