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Improvements in red blood cell transfusion utilization following implementation of a single-unit default for electronic ordering

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Abstract

BACKGROUND—The prevention of excessive allogeneic red blood cell (RBC) transfusion is an important component of Patient Blood Management initiatives. In this investigation, changes in transfusion behaviors following modification of computerized physician order entry (CPOE) procedures for RBC transfusions to a single-unit default quantity were assessed.

STUDY DESIGN AND METHODS—This is an observational cohort study of adults for whom non-emergency allogeneic RBC transfusions were ordered in the two years before and two years after the date of modification of the CPOE system to a single unit default (June 18th, 2015). Changes in the frequency of single versus multi-unit RBC transfusion orders and other transfusion metrics were compared between pre-intervention and post-intervention cohorts.

RESULTS—A total of 52,773 unique transfusion orders for 61,989 RBC units were included, of which 60,045 (96.9%) were transfused. Single unit orders increased annually, from 10,404 (74.1%) in the first year to 11,645 (88.6%) in the last year, while multi-unit orders decreased by more than half ($p < 0.0001$). The number of RBC units transfused decreased by 13.9% from 32,528 in the pre-intervention cohort to 27,497 in the post-intervention cohort ($p < 0.0001$) with an estimated reduction in transfusion-related expenditures of nearly \$4 million. The percentage of transfusions associated with a post transfusion hemoglobin < 10 g/dL decreased by 34.5% ($p < 0.0001$).

CONCLUSION—Modification of the CPOE process such that non-emergency RBC transfusion orders were defaulted to a single unit was associated with decreased rates of multi-unit RBC transfusion orders, lower transfusion volumes, and substantial cost savings.

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INTRODUCTION

Red Blood Cell (RBC) transfusion has traditionally been perceived as an effective and acceptably safe intervention for patients with anemia.^{1–3} However, over the past two decades, questions have been raised regarding both the efficacy and safety of this intervention in the absence of acute hemorrhage or clear anemia-related physiological compromise.⁴ In addition to a paucity of evidence suggesting clinical improvement with more liberal RBC transfusion strategies, there is growing recognition of the numerous underappreciated risks of blood transfusion, including life-threatening complications such as Transfusion-Related Acute Lung Injury (TRALI) and Transfusion-Associated Circulatory Overload (TACO).^{5–7} Moreover, transfusion associated health care costs are astounding, having been estimated to exceed \$1 billion in the US for RBC transfusions alone.^{8,9}

Patient Blood Management (PBM) programs aim to optimize the care of patients at risk for blood transfusion through evidence-based, multi-faceted, and multidisciplinary approaches. A seemingly important activity employed by successful PBM programs has been an effort to reduce the number of multi-unit RBC transfusion orders in non-emergent transfusion circumstances. In this investigation, we sought to better understand the impact of a specific Computerized Physician Order Entry (CPOE) intervention for RBC transfusions, where the unit quantity for non-emergency RBC transfusion orders was defaulted to a single unit, on relevant transfusion-related outcomes. We hypothesized that changing the default order quantity for elective RBC transfusions to a single unit would be associated with improvements in healthcare resource utilization.

MATERIALS AND METHODS

We conducted a historical observational cohort study utilizing a before-and after study design under the approval of the Mayo Clinic Institutional Review Board (IRB). The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were utilized in the design and conduct of the study, as well as the reporting of results.¹⁰

Study Population

Patients included in this study were assigned to one of two cohorts based upon the relationship between the date of their RBC transfusion order and the implementation date (June 18th, 2015) for defaulting elective RBC transfusion order quantities to a single unit. The pre-intervention cohort (June 18th, 2013 to June 17th, 2015) was chosen to represent elective allogeneic RBC orders and transfusions before the change in default electronic ordering, while the post-intervention cohort included patients from June 18th, 2015 to June 17th, 2017. All adults (age 18 years or older) receiving one or more non-emergent allogeneic RBC transfusion order(s) at one of two hospitals (Mayo Clinic Hospital, Saint Mary's Campus, 1,265 beds; Mayo Clinic Hospital, Methodist Campus, 794 beds) who had not rescinded the right to use their medical record for research were included in this study. RBC orders placed in the emergency department or in procedural locations (e.g. operating suites, procedural environments) were excluded as RBC transfusions in these environments were not ordered through the same electronic ordering system.

Description of CPOE RBC Ordering System

Before implementation of the intervention, the electronic ordering system allowed providers to input the desired quantity of RBC units via free-text entry for each unique RBC transfusion order. For more detailed information regarding the CPOE order entry system, please see the Supplemental Figure. With the change in CPOE settings, the default RBC order quantity for elective allogeneic RBC transfusions was defaulted to one unit. Providers still maintained the ability to modify the order quantity via free text entry for the number of units. Concurrent with this change, additional institutional PBM efforts were underway starting in 2014 and continued through the study period and beyond, including efforts focused on educating providers regarding the risks and benefits of transfusion therapies as well as identifying appropriate transfusion triggers for RBCs.

Data Collection

We retrieved information relating to transfusion therapies using our institutional Transfusion DataMart, which is an automated data warehouse that facilitates extraction of information related to transfusion therapies, including blood products administered, location and timing of blood product administration, and pre- and post- transfusion laboratory values (i.e. hemoglobin values nearest to the time of transfusion within 24 hours). The Transfusion DataMart, part of a larger Acute Care DataMart, has been validated extensively at the study institution.^{11,12} All non-emergent RBC transfusion orders and units transfused were extracted from June 18th, 2013 to June 17th, 2017. RBC orders and transfusions were assessed annually and by cohort (i.e. pre- vs. post-intervention).

Outcomes

Outcomes focused on RBC utilization, including: 1) Total number of RBC orders; 2) Total number of RBC units transfused; 3) Frequency and proportion of single unit vs. multi-unit RBC transfusion orders; 4) Pre-transfusion and post-transfusion hemoglobin values; and 5) Proportion of RBC transfusion orders accompanied by a post-transfusion hemoglobin greater than or equal to 10 g/dL, as a potential marker of over-transfusion. Additionally, we assessed transfusion-related expenditures between the pre- and post-intervention cohorts utilizing a previously published activity-based cost of \$761 for each RBC unit.⁸

Statistical Approach

Laboratory values and transfusion characteristics are summarized and presented as mean (standard deviation) or frequencies (%) for continuous or categorical data elements, respectively. Chi-squared analyses and two-sample T-tests or Wilcoxon rank sum tests (non-parametric data) were utilized to compare outcomes between the pre- and post-intervention cohort for categorical and continuous outcome measures, respectively. A p-value < 0.05 was used for statistical significance.

RESULTS

A total of 16,861 unique patients were transfused with RBCs and included in the investigation (8,381 transfused pre-intervention; 736 transfused both pre-intervention and post-intervention; 7,744 transfused post-intervention), representing 52,773 unique non-

emergent RBC transfusion orders for 61,989 RBCs units, of which 60,045 (96.9%) units were actually transfused. A total of 33,318 RBC units were ordered in the pre-intervention cohort through 27,157 unique orders, which was significant higher than the 28,671 units ordered through 25,616 unique orders in the post-intervention cohort (13.9% decrease; $p < 0.0001$). The number of RBC units transfused was similarly distributed with a total of 32,548 units transfused in the pre-intervention cohort compared to 27,497 in the post-intervention cohort (15.5% decrease; $p < 0.0001$). This corresponded to mean (SD) 3.7 (5.3) units per transfused patient in the pre-intervention cohort versus 3.4 (4.7) in the post-intervention cohort ($p = 0.0003$), with median (IQR) values of 2 (1, 4) in both cohorts (Wilcoxon rank sum $p < 0.0001$). When including all patients treated at the study institution at risk for transfusion during the study period of interest (128,849 unique hospitalized patients pre-intervention, 132,411 post-intervention) the mean RBC units transfused per patient was 0.80 (3.2) pre-intervention, which was greater than 0.69 (2.7) units per patient post-intervention ($p < 0.0001$), with median values of 0 (0, 0) in both cohorts (Wilcoxon $p < 0.0001$). Median Charlson comorbidity index scores for hospitalized patients at risk for transfusion were lower pre-intervention, suggesting less severe comorbid disease than in the post-intervention cohort [3 (1, 6) vs. 4 (1, 6), respectively ($p < 0.0001$)].

The number of single unit orders in the pre-intervention cohort (20,978; 77.3%) was less than the post-cohort (22,508; 87.9%; $p < 0.0001$). The number of single unit vs. multi-unit RBC transfusion orders by study year are displayed in Figure 1, with substantial decreases in multi-unit orders and increases in single-unit orders over the study period. There was no difference in the number of RBC units ordered that were actually transfused based upon single vs. multi-unit orders (96.8% vs. 97.0% of ordered units transfused, respectively; $p = 0.159$).

Hemoglobin values were available pre-transfusion and post-transfusion for 98.3% and 95.2% of transfused units, respectively. Pre-transfusion and post-transfusion hemoglobin values based upon whether the transfused units were part of a single or multi-unit order are provided for each study year in Table 1, with modestly higher pre- and post-transfusion hemoglobin values in the pre-intervention cohort. The percentage of RBC transfusions associated with a post transfusion hemoglobin ≥ 10 g/dL was greater in the pre-intervention cohort (17.1%) versus the post-intervention cohort (11.2%; $p < 0.0001$; Table 2). When considering the entire cohort, RBCs transfused as part of a multi-unit transfusion order were associated with a higher likelihood for post-transfusion hemoglobin values ≥ 10 g/dL (23.2%) when compared to single unit orders (10.5%; $p < 0.0001$). This was true in both the pre-intervention cohort (25.6% vs. 12.0% for multi-unit and single-unit orders, respectively; $p < 0.0001$) and the post-intervention cohort (18.3% vs. 9.2%; $p < 0.0001$).

Estimated activity-based RBC transfusion expenditures in the pre-intervention cohort were \$24,753,808. In the post-intervention cohort, total RBC transfusion expenditures were \$20,925,217. This corresponds to an estimated reduction in RBC-related transfusion expenditures of \$3,828,591.

DISCUSSION

This study aimed to evaluate the impact of modifying the unit order quantity for RBC transfusions to a single unit as a default for elective RBC transfusion orders at a large, tertiary care medical center. To that end, implementation of this system was associated with a significant improvement in the frequency and proportion of single unit vs. multi-unit RBC orders as well as decreases in the total number of RBCs ordered and transfused. In fact, more than 5,000 fewer units of RBCs were transfused in the post-intervention cohort, corresponding to an estimated reduction in transfusion-related expenditures of nearly \$4 million over two years despite an increase in the number of hospitalized patients and a higher burden of comorbid disease. These findings build upon the results of previous investigations that have shown a decrease in the total number of RBCs transfused with similar changes in electronic default ordering systems,^{13–17} although in a much broader scope in the current investigation given the size of the health care system.

Promoting single unit transfusion strategies has become a central component of the “Choosing Wisely” campaign of the ABIM Foundation, with the catchy slogan of “*Why give 2 when 1 will do?*”.[16] In this investigation, single-unit orders increased throughout the study period while multi-unit orders were more than cut in half. Importantly, multi-unit transfusion orders were more frequently accompanied by post-transfusion hemoglobin values greater than or equal to 10 g/dL, perhaps suggesting the presence of over-transfusion. Additionally, post-transfusion hemoglobin values exceeding 10 g/dL were more common in the pre-intervention cohort, suggesting that single-unit default RBC ordering may have a role in preventing transfusion “overshoot”; though admittedly, optimal post-transfusion hemoglobin targets remain incompletely defined. In this study, even after the intervention of interest, 11% of patients experienced post-transfusion hemoglobin values greater than or equal to 10 g/dL; hence, there is likely opportunity for continued improvement in transfusion practices.

There are several limitations to the presented work. First, this is an observational study, and hence we are unable to declare that the implementation of a single-unit default for elective RBC transfusion ordering was responsible for observed changes in transfusion practice. Notably, this change in CPOE ordering occurred concurrently with other PBM activities that were initiated in 2014 and continued throughout the study time period. As one example, the proportion of single unit orders increased from 74% to 81% during the second year of the pre-intervention cohort prior to changes in default RBC ordering, a difference which was statistically significant ($p < 0.0001$). Of note, this was an absolute increase of 170 more single-unit orders in the second year. By comparison, absolute increases of 289 and 782 single-unit orders were observed, respectively, in the first two years following the intervention of interest. Similarly, the percentage of patients with a post-transfusion hemoglobin ≥ 10 g/dL decreased from 18.8% to 15.1% in the pre-intervention cohort ($p < 0.0001$), with these numbers dropping even further post-intervention. Hence, it is likely that ongoing PBM activities, initiated prior to CPOE modification, were already contributing to changes in transfusion behaviors. Second, this study was not designed to assess changes in clinical outcomes. Hence, we are not able to comment on any associated positive or negative changes in patient-important outcome measures as related to changes in transfusion

practices, though previous studies have noted improvement or stability in patient outcomes accompanying related modifications to electronic blood transfusion ordering as part of broader PBM initiatives.^{18,19} Additionally, we used estimated activity-based costs for RBC transfusion. However, it is possible that activity-based transfusion costs for each unit of RBCs may differ between single-unit and multi-unit orders. For example, pre-transfusion patient blood testing should not be required for each additional RBC unit in a multi-unit order, which could potentially decrease cost per unit. Finally, this study was conducted at a single academic medical center, and hence the generalizability of findings to other health care systems and electronic ordering environments are not guaranteed. Future investigations are clearly warranted to assess changes in both transfusion-related outcomes and clinical outcomes with the implementation of similar interventions, which are often employed as part of a larger PBM initiative.

In conclusion, implementation of a single-unit default order quantity for elective RBC transfusion orders in the CPOE system of a large tertiary care medical center as part of a broader PBM initiative was associated with substantial reductions in multi-unit transfusion orders and total units of RBCs transfused. These results suggest that single-unit defaults for elective RBC transfusion orders should be included with other institutional PBM efforts when attempting to optimize the use of blood component therapies.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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REFERENCES:

1. Kor DJ, Gajic O. Blood product transfusion in the critical care setting. *Curr Opin Crit Care* 2010;16:309–16. [PubMed: 20543684]
2. Marwaha N, Sharma RR. Consensus and controversies in platelet transfusion. *Transfus Apher Sci* 2009;41:127–33. [PubMed: 19717344]
3. Napolitano LM, Kurek S, Luchette FA, et al. Clinical practice guideline: red blood cell transfusion in adult trauma and critical care. *J Trauma* 2009;67:1439–42. [PubMed: 20009700]
4. Barr PJ, Donnelly M, Cardwell CR, Parker M, Morris K, Bailie KE. The appropriateness of red blood cell use and the extent of overtransfusion: right decision? Right amount? *Transfusion* 2011;51:1684–94. [PubMed: 21470238]
5. Clifford L, Jia Q, Yadav H, et al. Characterizing the epidemiology of perioperative transfusion-associated circulatory overload. *Anesthesiology* 2015;122:21–8. [PubMed: 25611653]
6. Clifford L, Jia Q, Subramanian A, et al. Characterizing the epidemiology of postoperative transfusion-related acute lung injury. *Anesthesiology* 2015;122:12–20. [PubMed: 25611652]
7. Administration USFaD. Fatalities Reported to FDA Following Blood Collection and Transfusion: Annual Summary for Fiscal Year 2014. . 2014.

8. Shander A, Hofmann A, Ozawa S, Theusinger OM, Gombotz H, Spahn DR. Activity-based costs of blood transfusions in surgical patients at four hospitals. *Transfusion* 2010;50:753–65. [PubMed: 20003061]
9. Whitaker BIH S 2011 National Blood Collection and Utilization Survey. 2011.
10. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* 2007;370:1453–7. [PubMed: 18064739]
11. Herasevich V, Pickering BW, Dong Y, Peters SG, Gajic O. Informatics infrastructure for syndrome surveillance, decision support, reporting, and modeling of critical illness. *Mayo Clin Proc* 2010;85:247–54. [PubMed: 20194152]
12. Holtby H, Skowno JJ, Kor DJ, Flick RP, Uezono S. New technologies in pediatric anesthesia. *Paediatr Anaesth* 2012;22:952–61. [PubMed: 22967152]
13. Connor JP, Raife T, Medow JE, Ehlenfeldt BD, Sipsma K. The blood utilization calculator, a target-based electronic decision support algorithm, increases the use of single-unit transfusions in a large academic medical center. *Transfusion* 2018.
14. Ma M, Eckert K, Ralley F, Chin-Yee I. A retrospective study evaluating single-unit red blood cell transfusions in reducing allogeneic blood exposure. *Transfus Med* 2005;15:307–12. [PubMed: 16101808]
15. Heyes J, Kelly PA, Monaghan K, Lawn M, Dhesi A, Mijovic A. A single unit transfusion policy reduces red cell transfusions in general medical in-patients. *QJM* 2017;110:735–9. [PubMed: 29024964]
16. Podlasek SJ, Thakkar RN, Rotello LC, et al. Implementing a “Why give 2 when 1 will do?” Choosing Wisely campaign. *Transfusion* 2016;56:2164. [PubMed: 27624209]
17. Yang WW, Thakkar RN, Gehrie EA, Chen W, Frank SM. Single-unit transfusions and hemoglobin trigger: relative impact on red cell utilization. *Transfusion* 2017;57:1163–70. [PubMed: 28164305]
18. Gupta PB, DeMario VM, Amin RM, et al. Patient Blood Management Program Improves Blood Use and Clinical Outcomes in Orthopedic Surgery. *Anesthesiology* 2018.
19. Goodnough LT, Maggio P, Hadhazy E, et al. Restrictive blood transfusion practices are associated with improved patient outcomes. *Transfusion* 2014;54:2753–9. [PubMed: 24995770]

Figure 1.
Changes in Single-Unit and Multi-Unit RBC Transfusion Orders by Year

Table 1.
Changes in mean pre-transfusion and post-transfusion hemoglobin values over the study time frame

	Pre-transfusion			Post-Transfusion		
	All Units	1 Unit	2+ Units	All Units	1 Unit	2+ Units
Pre-Intervention						
2013-2014 [^]	7.7 (1.2)	7.9 (1.2)	7.5 (1.2)	9.0 (1.3)	8.9 (1.3)	9.3 (1.2)
2014-2015 [^]	7.5 (1.2)	7.6 (1.2)	7.2 (1.2)	8.8 (1.4)	8.6 (1.4)	9.1 (1.3)
<i>Mean</i>	7.6 (1.2)	7.7 (1.2)	7.4 (1.2)	8.9 (1.3)	8.7 (1.3)	9.2 (1.3)
Post-Intervention						
2015-2016 [^]	7.4 (1.3)	7.5 (1.3)	7.2 (1.4)	8.6 (1.5)	8.5 (1.5)	8.9 (1.4)
2016-2017 [^]	7.4 (1.3)	7.5 (1.3)	7.1 (1.3)	8.5 (1.3)	8.4 (1.3)	8.9 (1.3)
<i>Mean</i>	7.4 (1.3)	7.5 (1.3)	7.2 (1.3)	8.6 (1.4)	8.5 (1.4)	8.9 (1.3)
						<0.0001

[^] Study time frames span from June 18th to June 17th of the given years.

* P-values are for T-test comparisons utilizing mean pre-intervention and mean post-intervention hemoglobin values for “All Units” transfused.

Table 2.

Proportion of unique RBC transfusions associated with a post-transfusion hemoglobin 10 g/dL

	All Units	1 Unit	2+ Units	P*
Pre-Intervention				
2013-2014 [^]	18.8%	13.0%	27.1%	
2014-2015 [^]	15.1%	11.0%	23.5%	
<i>Total</i>	17.1%	12.0%	25.6%	
Post-Intervention				
2015-2016 [^]	11.9%	9.7%	18.9%	
2016-2017 [^]	10.6%	8.8%	17.7%	
<i>Total</i>	11.2%	9.2%	18.3%	
% Reduction[#]				
	34.5%	23.3%	28.5%	<0.0001

[^] Study time frames span from June 18th to June 17th of the given years.[#] % Reduction is comparing the percentage reduction from the “total” pre-intervention values to the “total” post-intervention values.

* P-value is for Chi-squared comparison of the total pre-intervention and the total post-intervention proportion of units transfused with a post-transfusion hemoglobin 10 g/dL for the “All Units” category.