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Optimizing Inpatient Blood Utilization Using Real-Time Clinical Decision Support

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Abstract

Background Red blood cell (RBC) transfusion is a common medical procedure. While it offers clinical benefits for many, hemodynamically stable patients are often subjected to unwarranted transfusions, with the potential to lead to adverse consequences. We created a real-time clinical decision support (CDS) tool in the electronic health record system to address this problem and optimize transfusion practice as part of an institutional multidisciplinary, team-based patient blood management program.

Methods The real-time CDS tool incorporated the transfusion guidelines published by the AABB. The tool was deployed as a dynamic order set within the computerized provider order entry interface. Prior to implementation, extensive education and outreach to increase provider engagement were provided. The CDS tool was launched in September 2015.

Results The percentage of guideline-indicated RBC transfusions increased from a baseline of 43.6 to 54.2% while the percentage of multiunit ($\geq$ 2 units) RBC transfusions decreased from 31.3 to 22.7% between September 2014 and July 2019. The estimated minimum cost saving over the entire study period was $36,519.36.

Conclusion Our intervention increased guideline-indicated transfusions by 10.6% and reduced multiunit transfusions by 8.6%. The adoption of a dynamic order set for the CDS tool, as opposed to an interruptive alert that displays static alert messages, allowed for more customized and tighter control of RBC orders, leading to a sustained improvement in our transfusion practice.

Keywords

- decision support systems
- clinical
- blood transfusion
- medical informatics
- blood banks
- quality improvement

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Background and Significance

Blood transfusion is the most common procedure performed during hospitalizations in the United States.[1] Since 1997, the rate of hospitalization with blood transfusion has more than doubled.[1] It is estimated that as much as 60% of allogeneic transfusions for hemodynamically stable inpatients were inappropriate and unlikely to improve patient outcomes.[2] Judicious use of blood products protects the well-being of our patients by preventing unwarranted transfusion reactions and transmissible infections. Accumulating data has identified transfusion to be an independent risk factor for adverse patient outcomes. Multiple studies have demonstrated a strong dose-dependent association between red blood cell (RBC) transfusion and adverse events such as increased in-hospital mortality, intensive care unit admissions, duration of hospital stays, and hospital-acquired complications.[3–6]

In addition to the concern for patient safety and adverse outcomes, the issue of resource overutilization, amplified by high administrative costs associated with RBC transfusion, contributes to the financial stress of health care systems. The activity-based cost model, devised by the Cost of Blood Consensus Conference, calculated that a single unit RBC transfusion costs between $522 and $1,183 (mean: $761 $\pm$ $294) when clerical tasks and additional resource consumption are accounted, exceeding acquisition costs by 3.8- to 4.8-fold.[7] As the U.S. health spending is projected to grow at an average rate of 5.5% per year for the next decade and to reach almost $6.0 trillion by 2027, organizations have an urgent need to develop novel strategies for containing the costs incurred from acquisition, maintenance, and administration of blood products.[8,9]

Optimization of blood utilization is best accomplished through patient blood management (PBM). PBM is a multidisciplinary patient-oriented, evidence-based approach that drives appropriate blood utilization to improve patient outcomes and achieve cost savings in clinical settings.[10] Integral to the successful execution of a PBM program is ensuring effective coordination among hospital leadership, clinical champions, ordering providers, and transfusionists. Clinical champions serve as the control center for these programs by communicating the improved patient outcomes and cost benefits expected from the PBM program to hospital administrators. In addition to gaining support from hospital and clinical leadership, clinical champions provide education and feedback on individual and department-level transfusion practice to gain buy-in for the program. Accordingly, implementing a PBM program is a complex process that requires substantial human and financial resources. This task, however, can be simplified by utilizing an information technology (IT)-driven approach.

We created and implemented a clinical decision support (CDS) tool in the institutional electronic health record (EHR) to enhance RBC utilization as one component of a PBM program (Epic System, Verona, Wisconsin, United States). We have hypothesized that the use of a CDS tool to promote restrictive transfusion guidelines would lead to an overall and sustained decrease in the number of RBC transfusions and subsequent cost savings.

Objectives

The aim of this study was to (1) standardize inpatient transfusion practice across the health system; (2) avoid transfusion at hemoglobin concentration $\geq$ 8.0 g/dL in hemodynamically stable patients; and (3) reduce routine multiunit RBC orders without intervening hemoglobin assessment.

Methods

Setting

The University of California, Los Angeles (UCLA) Health is a tertiary care health system comprised of two academic teaching hospitals where approximately 28,000 units of RBCs are transfused annually in the inpatient and outpatient settings. Two transfusion services support two tertiary care academic medical centers: Ronald Reagan UCLA Medical Center, a 520-bed level 1 trauma center, and Santa Monica UCLA Orthopedic Medical Center, a 281-bed full-service hospital. In 2019, 58% of the RBCs units ordered are inpatient transfusions, not including the operating rooms or emergency department. RBC transfusion orders are placed via order sets and order panels in the computerized provider order entry (CPOE) system; the EHR system does not permit ad hoc orders. The ordering interface prevents duplicate orders by performing a retrospective review of pending and processing orders, but no mechanism exists to determine whether an RBC transfusion order is clinically indicated. The decision to transfuse a patient is made based on a patient's hemoglobin level, the patient's clinical condition, and providers' usual ordering habits. RBC orders are placed through the EHR order panels and order sets, which are predefined groups of orders and pretransfusion medications that are often ordered together.

Design

A multidisciplinary team, comprised of subject matter experts from hospital medicine, critical care, surgery, IT, physician informaticists, nursing, and transfusion medicine, was formed in June 2014. RBC administration records from March 2013 to June 2014 were extracted from the institutional EHR system to validate data, determine the feasibility of implementing a CDS tool, and demonstrate the potential benefits that could be derived from this RBC utilization initiative for its patients and health system. The team conducted a literature review of IT-driven blood management strategies practiced in a tertiary care academic medical center of comparable scale with a similar EHR configuration. We reviewed the designs of interventions that were implemented at Stanford Hospitals and Clinics and University of California San Diego (UCSD) Health by Goodnough et al and Jenkins et al, respectively.[11,12] We adapted their interventions due to the anticipated compatibility with our EHR system.

Our CDS tool was designed to issue active alerts for RBC units ordered outside of recommended guidelines in the CPOE system. The window included a display of the patient's most recent hemoglobin concentration with informational guideline text that changed based on the patient's hemoglobin concentration as well as relevant orderables such as 15-minute

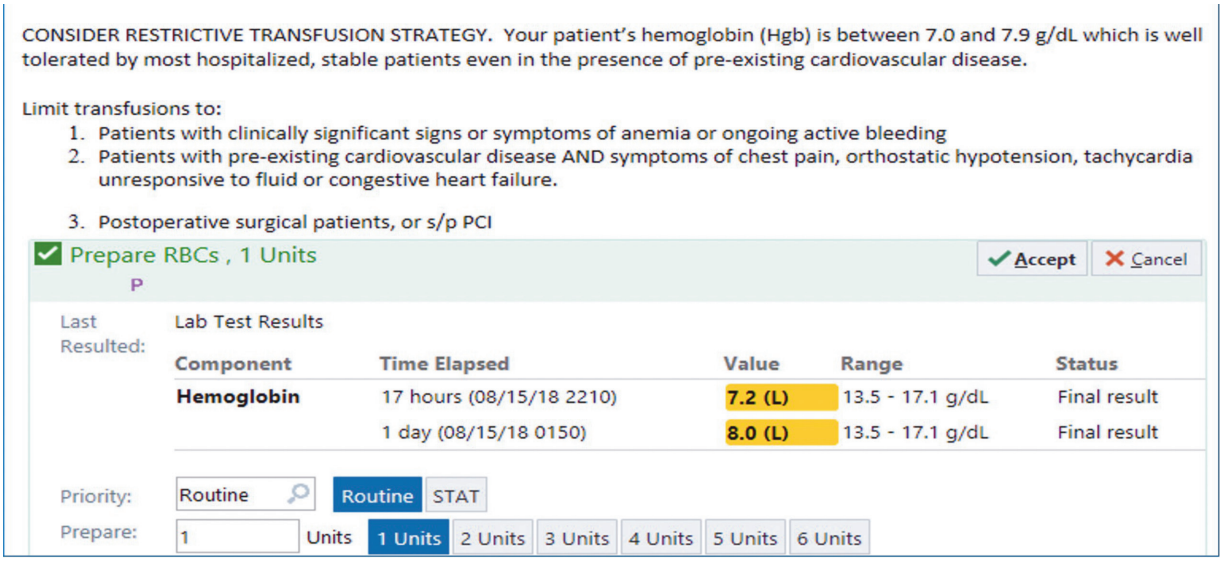

Fig. 1 Hemoglobin between 7.0 and 7.9 g/dL (© 2020 Epic Systems Corporation. Used with permission).

posttransfusion hemoglobin concentration (►Figs. 1–3). The dynamic display of guideline text ensured that the educational impact of the CDS tool was maximized to achieve a long-term improvement in guideline-indicated transfusion and reduction of unwarranted multiunit transfusions without intervening hemoglobin assessment. The build specifications are shown in ►Table 1. The CDS tool examined the most recent hemoglobin concentration in the patient chart and the presence of cardiovascular disease as documented in the patient medical record as an International Classification of Diseases (ICD) diagnosis. The ordering provider was prompted to determine if the RBC transfusion was indicated based on the presented restrictive guidelines and, if appropriate, proceed with placing the order. Prior to the implementation, education to increase provider engagement was provided through eLearning modules and presentations at meetings, supplemented by on-demand assistance from roaming trainers and clinical superusers.

Data Collection

The CDS tool targeted elective inpatient RBC transfusions given to adults aged 18 and above. We excluded RBC transfusions originating in operating rooms and the emergency department, including those dispensed for massive bleeding. Our study included inpatient RBC transfusions only since outpatient transfusions are largely protocol-based and do not usually require input from providers. The study period spanned from September 1, 2014 to July 31, 2019. We designated September 1, 2014 to August 30, 2015 as the preintervention baseline period. Extensive user testing of the CDS tool was conducted in the EHR test environment during this time.

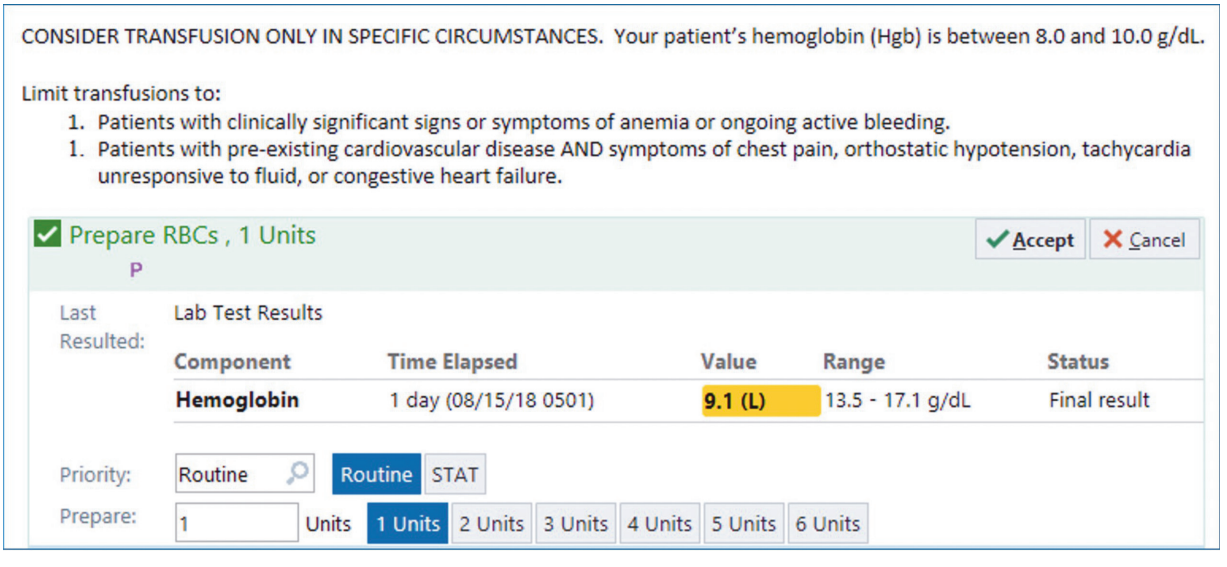

Fig. 2 Hemoglobin between 8.0 and 10.0 g/dL (© 2020 Epic Systems Corporation. Used with permission).

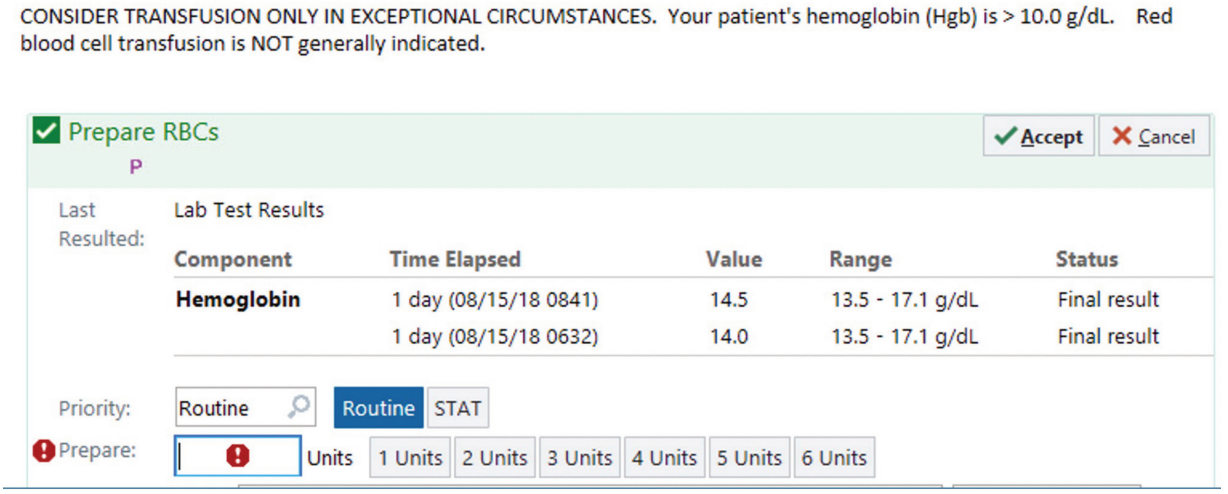

Fig. 3 Hemoglobin greater than 10.0 g/dL (© 2020 Epic Systems Corporation. Used with permission).

Table 1 Build specifications

• Display patient's most recent hemoglobin result • Add defaulted hemoglobin laboratory order if no result found within past 48 hours • Display transfusion guidelines based on most recent hemoglobin concentration result • Default RBC order to 1 unit if current hemoglobin concentration is 7.0–10.0 g/dL • Measure hemoglobin concentration 15 minutes after first RBC unit has been transfused

Abbreviation: RBC, red blood cell.

Table 2 Criteria for appropriate red blood cell transfusion

First unit • No coronary artery disease and most recent hemoglobin concentration is < 7.0 g/dL • Coronary disease and most recent hemoglobin concentration is < 8.0 g/dL Second and subsequent units • No coronary artery disease and most recent hemoglobin concentration is < 6.0 g/dL • Coronary disease and most recent hemoglobin is concentration < 7.0 g/dL

Measures

The overall effectiveness of the program was evaluated by two postintervention metrics: (1) percentage of orders that adhere to appropriate evidence-based guidelines (►Table 2)[13,14] and (2) percentage of multiunit (≥ 2 units) RBC orders. We also constructed a statistical process control (SPC) chart to monitor process variables over time. An SPC chart enables visual detection of variation that is not explained by chance but caused by factors that are extrinsic to the core process.[15] The upper and lower control limits were set ± 3 standard deviations from the mean—less than 0.2% probability that any individual data point would fall outside the limits due to random chance alone. Chi-square test was used to compare the aggregate order data between the preintervention and postintervention periods. We created the control charts and conducted the statistical analysis with JMP Pro 15 (SAS Institute Inc., Cary, North Carolina, United States).

Cost Analysis

To quantify the financial impact of our intervention, we conducted a cost analysis based on the number of RBC orders. We assumed that the reduction of a single multiunit transfusion order led to at least one fewer unit transfused. We compared the preintervention rate of multiunit transfusions to the postintervention rate. We designated September 2014 to August 2015 and September 2015 to July 2019 as the pre- and postintervention periods, respectively. We assumed that the difference in the number of RBC orders corresponded to the number of transfusions that would have been avoided due to the intervention. This quantity was multiplied by the cost of a unit of RBC calculated by Shander et al's activity-based costing model.[7] The number of RBC units transfused during this period was not used for calculation due to the concern that RBC utilization may be influenced by multiple factors including but not limited to changes in hospital demographics, hospital census, and transplant volume. This model factored in the indirect cost of RBC transfusion including resource consumption such as materials, labor, capital, and third-party services, to provide a comprehensive cost estimate. Mean cost of a single RBC unit transfusion was estimated to be $760.82 (range: $522.45–$1183.32).

Results

Within the preintervention period (September 2014–August 2015), 7,126 discrete RBC orders placed by UCLA's providers resulted in 18,622 RBC units transfused. Of these orders, 43.6% were deemed inappropriate by the restrictive transfusion criteria (►Table 2). Thirty percent of the RBC orders were directed to patients with a hemoglobin concentration greater than 8.0 g/dL.

The RBC utilization CDS tool was launched in September 2015. UCLA observed significant improvements in both

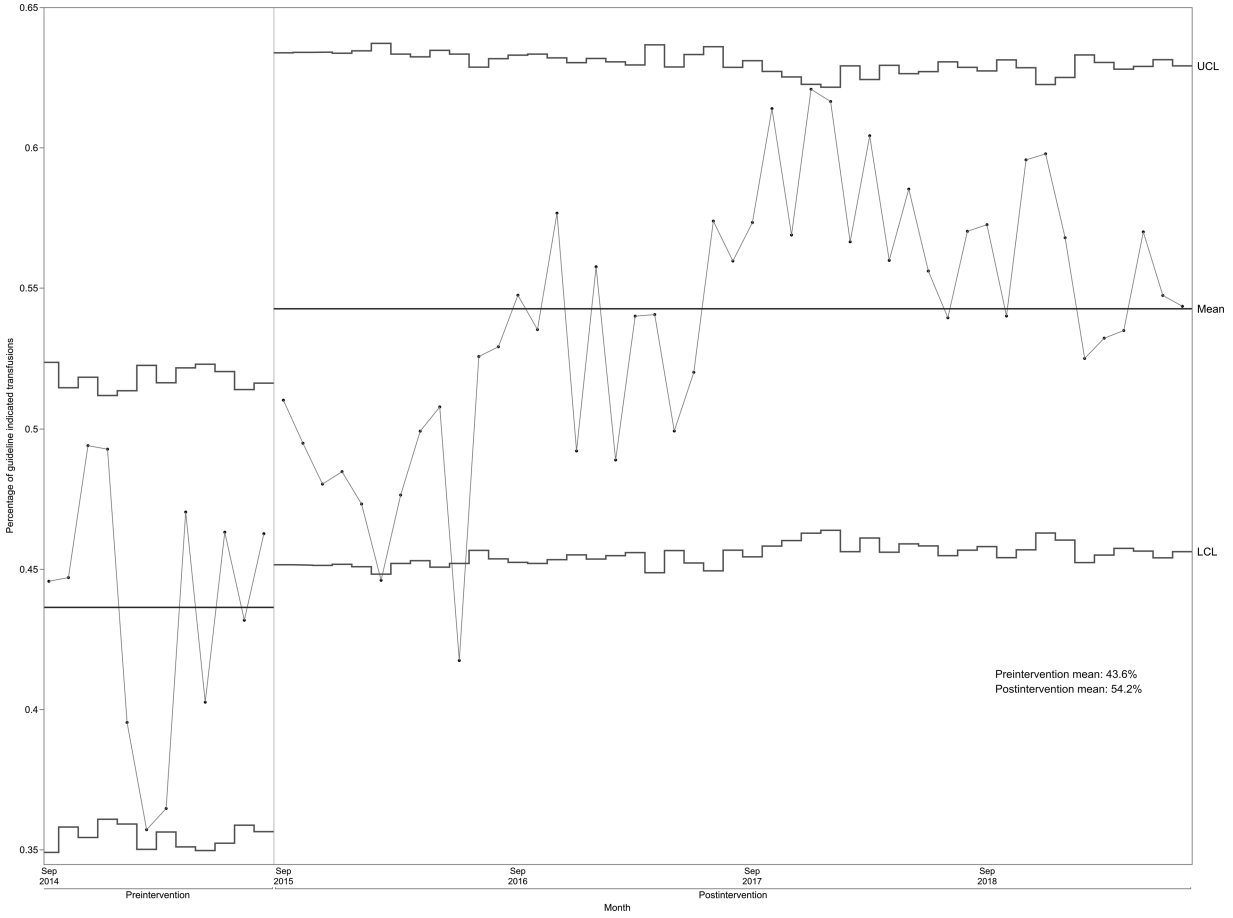

Fig. 4 Percentage of guideline-indicated inpatient transfusions between September 2014 and July 2019. *X*-axis caption: Year. *Y*-axis caption: Guideline-indicated inpatient transfusions, %. LCL, lower control limit; UCL, upper control limit.

metrics —mean percentages of orders that adhere to appropriate indications and multiunit RBC orders. Guideline-indicated transfusions increased from 43.6% during the preintervention period to 54.2% during the postintervention period ($p < 0.00001$). The percentage of multiunit RBC transfusions decreased from 31.3% during the preintervention period to 22.7% in the postintervention period ($p < 0.00001$). Control charts showing these changes are presented in ►Figs. 4 and 5. The two metrics demonstrated sustained improvement between implementation and the conclusion of the data collection period. The control chart for guideline-indicated transfusions shows two isolated data points exceeding the lower control limits in the postintervention period. The control chart for multiunit transfusion shows two large clusters that exceed the upper control limit and lower control limits from September 2015 to July 2016 and December 2017 to January 2019, respectively.

For cost analysis, we assumed that reduction by one order resulted in at least one RBC unit saved. The monthly volume of multiunit transfusion orders decreased from 190 to 136 with a net reduction of 54 units between September 2015 and July 2019. Using Shander et al's mean cost of a single RBC unit transfusion of $760.82, we estimated the cost savings over the entire study period to be at least $36,519.36.

Discussion

Our study highlights the benefits of a real-time CDS tool in optimizing transfusion practice. Our CDS tool successfully reduced the percentage of multiunit orders ($\geq$ 2 units) and increased the percentage of guideline-indicated RBC orders. The development of an embedded CDS tool facilitated the adoption of restrictive transfusion guidelines, which we felt to be the most critical component of the PBM program. We defined the CDS tool to encompass the following three functions: (1) educate clinicians about evidence-based RBC transfusion practice utilizing restrictive transfusion guidelines, (2) minimize provider RBC ordering practices that do not meet evidence-based guidelines, and (3) provide quantitative analytics that tangibly demonstrate the effectiveness of the PBM program for the hospital leadership.

The use of CDS tools within commercial EHR systems to improve provider adherence to restrictive transfusion guidelines has proven effective and become the norm at many academic medical centers.[16] Our project not only added to the existing body of evidence but also created a novel CDS tool that served a dual role of providing effective educational feedback and facilitating clinical decision-making. We specifically built and implemented our CDS tool in the form of a dynamic order set, which allowed for more customized and

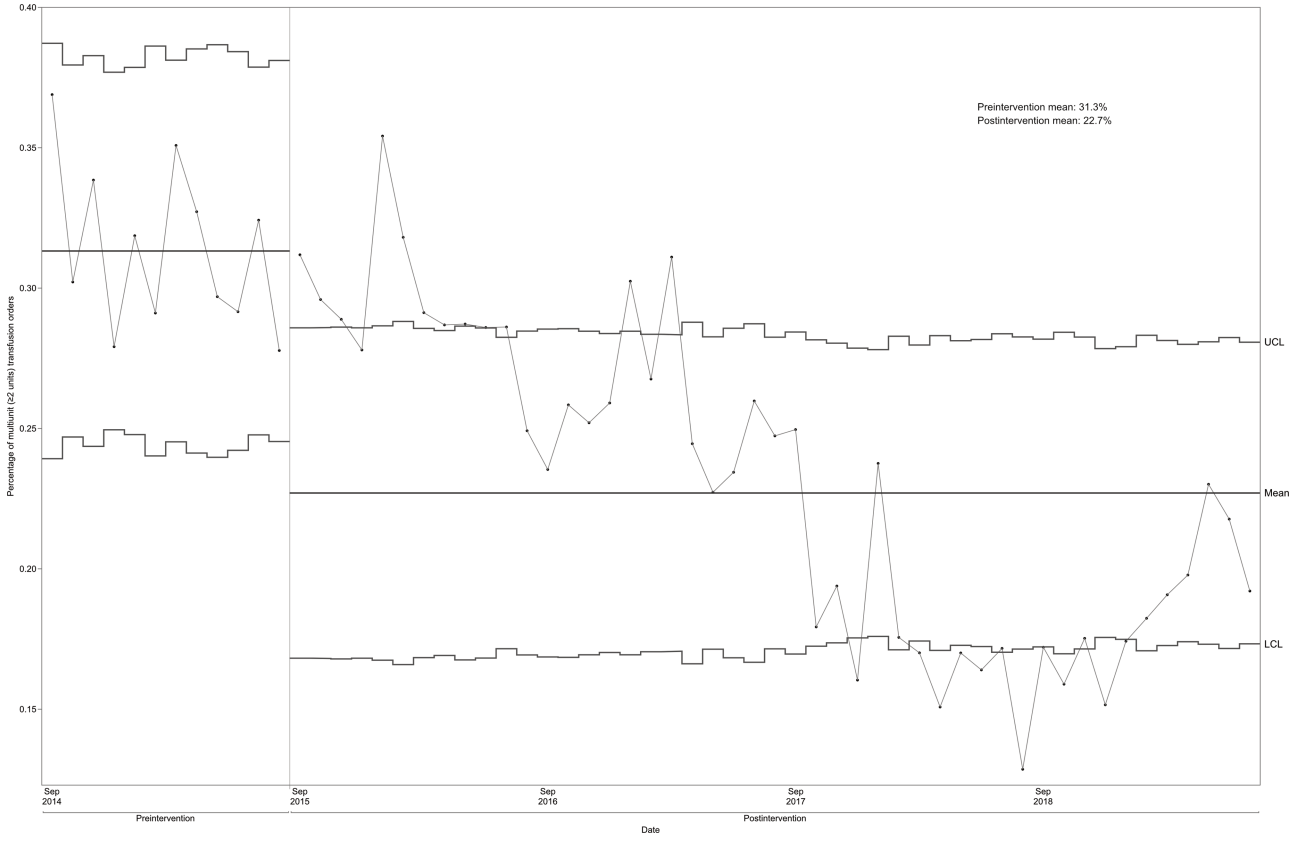

Fig. 5 Percentage of multiunit (≥ 2 units) red blood cell (RBC) orders between September 2014 and July 2019. *X*-axis caption: Year. *Y*-axis caption: Percentage of multiunit (≥ 2 units) transfusion orders. LCL, lower control limit; UCL, upper control limit.

tighter control of RBC orders. To the extent of our knowledge, prior studies, including the two that we referenced, deployed their CDS tools as interruptive alerts with static recommendation messages.[11,12,17,18] The synergistic effect of provider education and behavioral optimization achieved by the CDS tool translated to a sustained improvement of our RBC transfusion practice, as demonstrated by the 3-year postintervention data in the SPC charts.

The reduction in multiunit 2-unit RBC orders and increase of guideline-indicated RBC orders in our data are congruent with prior findings from large tertiary care academic medical centers.[11,12] In the study conducted at UCSD Health, the percentage of multiunit RBC transfusions decreased by almost 40.2% between baseline and the postintervention period and the percentage of inpatient RBC transfusion units administered for hemoglobin ≥ 7 g/dL declined by 34.3%. Similarly, in Stanford's study, the percentage of inpatient RBC transfusion units administered for hemoglobin ≥ 8 g/dL declined by approximately 20%. Although our data showed a clear improvement, the observed changes were not as significant as those seen in the two above studies. The more pronounced effects may be attributable to the following factors. First, Stanford's additional modification of bone marrow transplant admission order sets for standing transfusion orders, which defaulted the hemoglobin target to 7 g/dL, instead of the prior 8, 9, or 10 g/dL targets, was highly effective. Second, UCSD's more robust alert trigger criteria that were connected to documented diagnoses in the patient problem list may have impacted provider ordering behavior. A potential next step is to incorporate these features and further monitor our institutional metrics.

The SPC charts delineated the systemic change established by the CDS tool. In the postintervention period, the rate of guideline-indicated transfusions showed minimal fluctuation and reached a new steady state quickly. Two individual data points exceeding the lower control limits were observed during the first year. This finding may represent a lead-in period in which the providers were getting accustomed to the intervention. On the contrary, the rate of multiunit transfusions showed two large year-long clusters of data points exceeding upper and lower control limits in 2015 to 2016 and 2017 to 2018, respectively. To the extent of our knowledge, there were no special circumstances, events, or interventions that either decreased or increased the demand for RBCs in these time periods. We were unable to map these data points that went beyond the limits to specific underlying causes. Instead of creating control charts at the conclusion of a study period, we suggest that other institutions plot control charts longitudinally to enhance their ability to approach and resolve processes that prevent the interventions from achieving their desired effects.

This study has limitations. First, the PBM involved a strong nonelectronic, educational, and communicational component. Improvement in blood transfusion practice was not due to the

CDS tool alone. This finding is supported by the gradual decrease and increase in the percentage of 2-unit RBC transfusion and guideline-indicated transfusions in the 12-month baseline period. Although education and communication initiatives are necessary for a successful PBM program, these supplemental strategies may serve as confounding factors. A future project may implement a similar intervention without concurrent educational efforts to conduct a more robust impact assessment of a CDS tool. Second, the alert trigger rate may be more tightly controlled. Because the triggering condition was on the patient's hemoglobin concentration alone and did not rely on the patient problem list and stored ICD codes, the alert may have triggered more than we anticipated. However, provider dependent identification increases sensitivity and will have a higher chance of capturing orders with inappropriate indications. Third, our assessment of guideline-indicated transfusions may not have been sufficiently comprehensive. Because we relied on just two variables, hemoglobin count and presence of cardiovascular disease, to set the triggering condition of the CDS tool, we did not account for off-protocol transfusions for which neither of the two variables affected the provider's decision to transfuse.

Conclusion

Our evidence-based RBC transfusion CDS tool, which was deployed as a dynamic order set within the CPOE to allow for more customized and tighter control of RBC orders, facilitated an improved institutional PBM program at UCLA. Our implementation of a real-time CDS tool to improve blood transfusion practice illustrates the benefits of a digital approach to delivering high-quality patient-centered, cost-effective health care and paving the way for additional value-based health care.

Clinical Relevance Statement

Our case report has clinical relevance for organizations that wish to leverage an IT-driven method to achieve quality improvement and cost savings in transfusion practice.

Multiple Choice Questions

1. Which of the following is one of the critical functions of the CDS tool in this study?
   a. Cost calculation.
   b. Clinician education.
   c. Impose penalty for overutilization.
   d. Provide alternate therapeutic options.

   Correct Answer: The correct answer is option b. The CDS tool aimed to educate clinicians about evidence-based RBC transfusion practice utilizing restrictive transfusion guidelines.

2. Which of the following describes the type of CDS tool implemented by this study?
   a. Predictive analytics.
   b. Patient data summary.
   c. Dynamic order set.
   d. Intelligent/dynamic documentation template.

   Correct Answer: The correct answer is option c. The CDS tool used a set of predefined criteria to display appropriate recommendations.

Protection of Human and Animal Subjects

The institutional review board approved the project as exempt human subjects research study due to the use of deidentified aggregate data.

Conflict of Interest

None declared.

References

1 Pfuntner A, Wier LM, Stocks C. Most Frequent Procedures Performed in U.S. Hospitals, 2011: Statistical Brief #165. 2006. Accessed September 2020 at: http://www.ncbi.nlm.nih.gov/pubmed/24354027
2 Shander A, Fink A, Javidroozi M, et al;International Consensus Conference on Transfusion Outcomes Group. Appropriateness of allogeneic red blood cell transfusion: the international consensus conference on transfusion outcomes. Transfus Med Rev 2011;25 (03):232–246
3 Trentino KM, Farmer SL, Swain SG, et al. Increased hospital costs associated with red blood cell transfusion. Transfusion 2015;55 (05):1082–1089
4 Hofmann A, Farmer S, Shander A. Five drivers shifting the paradigm from product-focused transfusion practice to patient blood management. Oncologist 2011;16(Suppl 3):3–11
5 Thomson A, Farmer S, Hofmann A, Isbister J, Shander A. Patient blood management - a new paradigm for transfusion medicine? ISBT Sci Ser 2009;4(02):423–435
6 Bernard AC, Davenport DL, Chang PK, Vaughan TB, Zwischenberger JB. Intraoperative transfusion of 1 U to 2 U packed red blood cells is associated with increased 30-day mortality, surgical-site infection, pneumonia, and sepsis in general surgery patients. J Am Coll Surg 2009;208(05):931–937
7 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(04):753–765
8 The Centers for Medicare and Medicaid NHE Summary, including share of GDP, CY 1960–2018. 2019. Accessed September 2020 at: https://www.cms.gov/Research-Statistics-Data-and-Systems/-Statistics-Trends-and-Reports/NationalHealthExpendData/NationalHealthAccountsHistorical.html
9 The Centers for Medicare and Medicaid Services National Health Expenditure Projections 2018–2027 Forecast Summary. 2018. Accessed September 2020 at: https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/Downloads/ForecastSummary.pdf
10 Leahy MF, Hofmann A, Towler S, et al. Improved outcomes and reduced costs associated with a health-system-wide patient blood management program: a retrospective observational study in four major adult tertiary-care hospitals. Transfusion 2017;57 (06):1347–1358
11 Goodnough LT, Shieh L, Hadhazy E, Cheng N, Khari P, Maggio P. Improved blood utilization using real-time clinical decision support. Transfusion 2014;54(05):1358–1365
12 Jenkins I, Doucet JJ, Clay B, et al. Transfusing wisely: clinical decision support improves blood transfusion practices. Jt Comm J Qual Patient Saf 2017;43(08):389–395
13 Carson JL, Grossman BJ, Kleinman S, et al;Clinical Transfusion Medicine Committee of the AABB. Red blood cell transfusion: a clinical practice guideline from the AABB. Ann Intern Med 2012; 157(01):49–58

14 Bulger J, Nickel W, Messler J, et al. Choosing wisely in adult hospital medicine: five opportunities for improved healthcare value. J Hosp Med 2013;8(09):486–492
15 Benneyan JC, Lloyd RC, Plsek PE. Statistical process control as a tool for research and healthcare improvement. Qual Saf Health Care 2003;12(06):458–464
16 Derzon JH, Clarke N, Alford A, Gross I, Shander A, Thurer R. Restrictive transfusion strategy and clinical decision support practices for reducing RBC transfusion overuse. Am J Clin Pathol 2019;152(05):544–557
17 Kassakian SZ, Yackel TR, Deloughery T, Dorr DA. Clinical decision support reduces overuse of red blood cell transfusions: interrupted time series analysis. Am J Med 2016;129(06):636.e13–636.e20
18 Saag HS, Lajam CM, Jones S, et al. Reducing liberal red blood cell transfusions at an academic medical center. Transfusion 2017;57 (04):959–964