Improved blood utilization using real-time clinical decision support

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BACKGROUND: We analyzed blood utilization at Stanford Hospital and Clinics after implementing real-time clinical decision support (CDS) and best practice alerts (BPAs) into physician order entry (POE) for blood transfusions.

STUDY DESIGN AND METHODS: A clinical effectiveness (CE) team developed consensus with a suggested transfusion threshold of a hemoglobin (Hb) level of 7 g/dL, or 8 g/dL for patients with acute coronary syndromes. The CDS was implemented in July 2010 and consisted of an interruptive BPA at POE, a link to relevant literature, and an "acknowledgment reason" for the blood order.

RESULTS: The percentage of blood ordered for patients whose most recent Hb level exceeded 8 g/dL ranged at baseline from 57% to 66%; from the education intervention by the CE team August 2009 to July 2010, the percentage decreased to a range of 52% to 56% ($p = 0.01$); and after implementation of CDS and BPA, by end of December 2010 the percentage of patients transfused outside the guidelines decreased to 35% ($p = 0.02$) and has subsequently remained below 30%. For the most recent interval, only 27% (767 of 2890) of transfusions occurred in patients outside guidelines. Comparing 2009 to 2012, despite an increase in annual case mix index from 1.952 to 2.026, total red blood cell (RBC) transfusions decreased by 7186 units, or 24%. The estimated net savings for RBC units (at $225/unit) in purchase costs for 2012 compared to 2009 was $1,616,750.

CONCLUSION: Real-time CDS has significantly improved blood utilization. This system of concurrent review can be used by health care institutions, quality departments, and transfusion services to reduce blood transfusions.

Blood management has been defined as "the appropriate use of blood and blood components, with a goal of minimizing their use."[1] This goal has been motivated historically by: 1) known and unknown blood risks, 2) preservation of the national blood inventory, and 3) constraints from escalating blood costs.[2] Known risks of blood include transmissible infectious disease, transfusion reactions, and potential effects of immunomodulation (e.g., postoperative infection or tumor progression). Unknown risks include emerging pathogens transmissible by blood (e.g., new variant Creutzfeldt-Jakob disease and West Nile virus).[3-5] Additionally, several studies have linked allogeneic blood transfusions with occurrence of unfavorable outcomes including morbidity and mortality.[6-8] Taken together, these support implementation of blood management to improve the clinical outcomes of the patients. Preventative strategies are emphasized: to identify, evaluate, and manage anemia[9-11] (e.g., pharmacologic therapy[12] and reduced iatrogenic blood losses from diagnostic testing);[13] to optimize hemostasis (e.g., pharmacologic therapy[14] and point-of-care testing[15]); and to establish decision thresholds (e.g., guidelines) for the appropriate administration of blood therapy.[6,16] Blood management

ABBREVIATIONS: BPA(s) = best practice alert(s); CDS = clinical decision support; CE = clinical effectiveness; EMR(s) = electronic medical record(s); POE = physician order entry; SHC = Stanford Hospital and Clinics.

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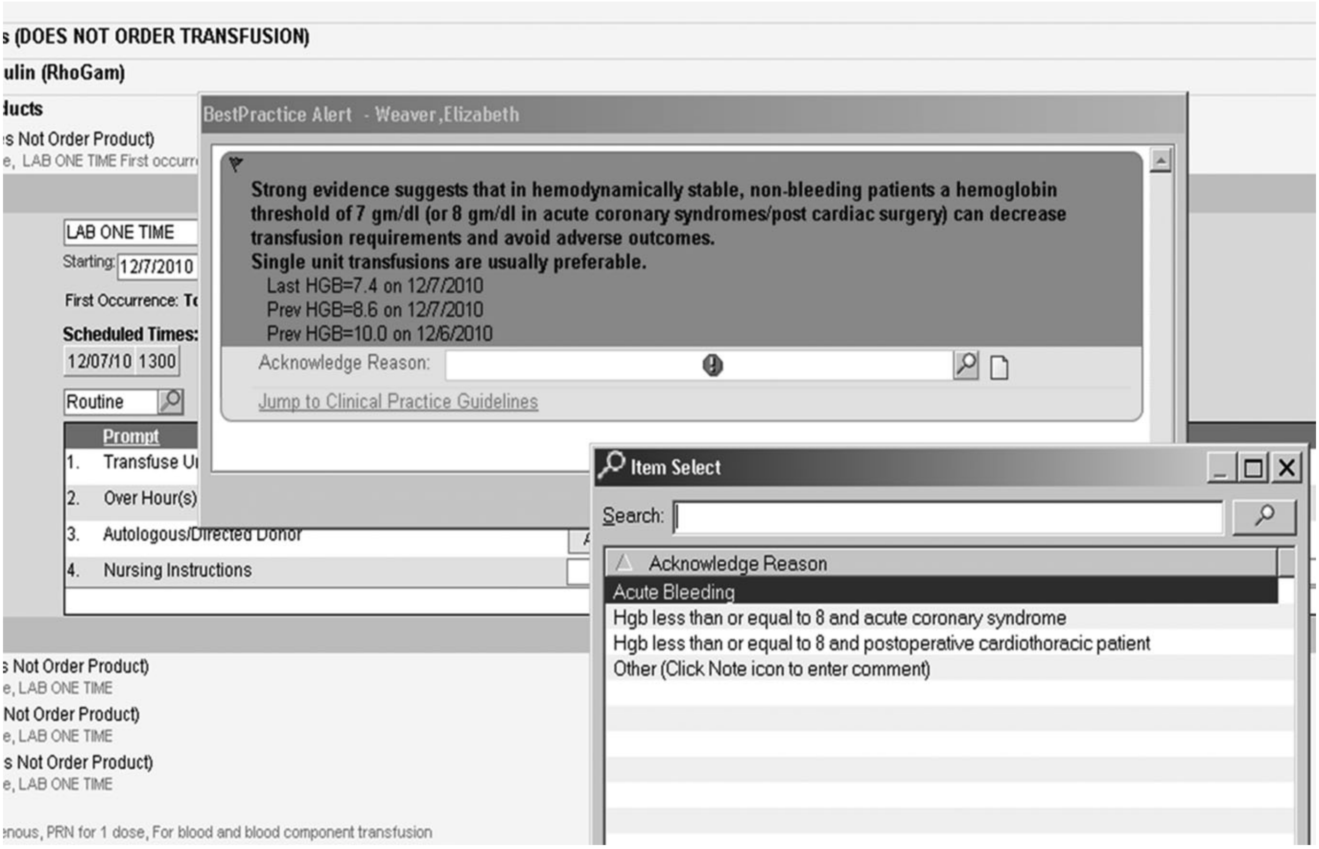

Fig. 1. BPA. Screenshot from an electronic POE for blood transfusion at SHC illustrates an "interruptive alert" as a reminder for the merits of a restrictive transfusion practice versus liberal transfusion practice. An acknowledgment field requires the physician to indicate the reason for transfusion: Hb level, change in vital signs, bleeding, or other.

has been cited as one of the 10 key advances in transfusion medicine over the past 50 years.[17]

To achieve these goals, health care institutions and accreditation and regulatory agencies have focused on improved blood utilization and improved patient safety. The Joint Commission developed patient blood management performance measures and placed these performance measures in their topic library where they are to be used as additional patient safety activities and/or quality improvement projects by provider institutions as accreditation goals.[18] One of these seven Joint Commission performance indicators is to monitor "red blood cell (RBC) transfusion indication."[19] Here we report improved blood utilization at Stanford Hospital and Clinics (SHC) by utilizing a strategy of providing real-time clinical decision support (CDS) with best practice alerts (BPA) into physician order entry (POE) for blood transfusions in our electronic medical records (EMRs) system.

MATERIALS AND METHODS

A blood utilization clinical effectiveness (CE) team was formed beginning July 2009 by members of the SHC Department of Quality and Information Technology. The CE team was composed of members representing key clinical services and constituencies: medicine, surgery, critical care, the operating room, trauma and emergency services, and transfusion medicine. The CE team reviewed the evidenced-based literature on indications for blood transfusion[20] and reached a consensus among the medical and surgical services for including real-time CDS as part of an educational initiative to improve blood use. An EMR (Epic Systems Corp., Verona, WI)-based BPA was developed with a suggested transfusion threshold hemoglobin (Hb) level of 7 g/dL, for stable medical and surgical inpatients who were not bleeding (patients in the operating room, patients receiving blood for hemorrhage or bleeding, and patients with ICD-9 discharge diagnoses coded as bleeding or hemorrhage were excluded). For medical or surgical patients identified to be status after a cardiothoracic procedure or have an acute coronary syndrome, the consensus was a Hb threshold of 8 g/dL.

CDS intervention (Fig. 1) consisted of an interruptive alert at the time of POE. The alert was designed to only trigger for practice outside of SHC guidelines based on documented diagnoses (acute coronary syndrome, status

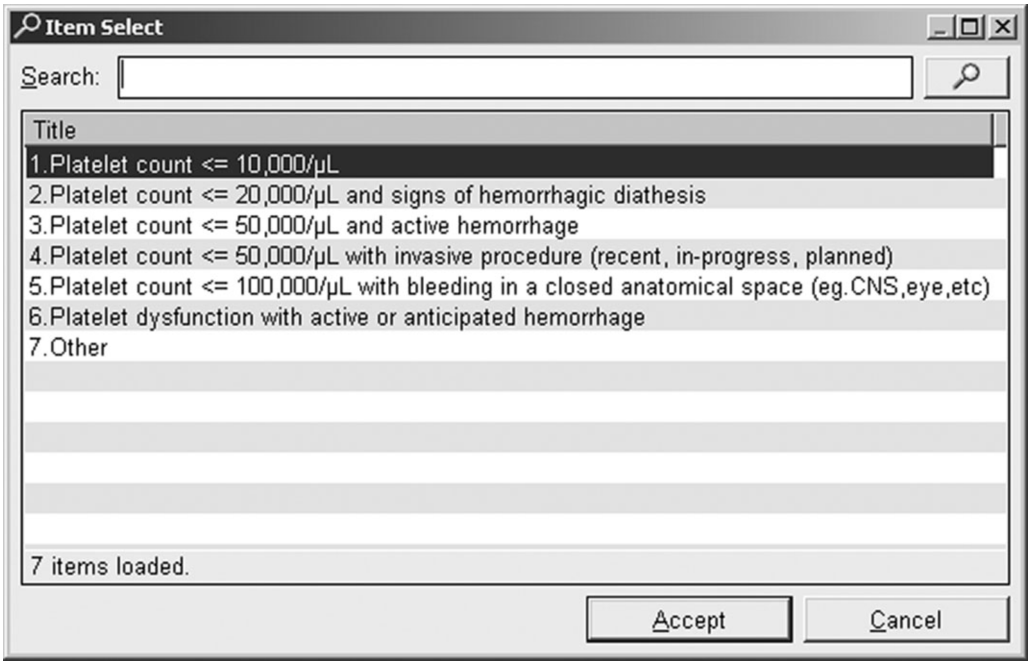

Fig. 2. PLT acknowledgment field. Screenshot from EMRs, showing POE with the PLT acknowledgment fields, which are required before completing an order for PLT transfusion.

after cardiothoracic procedure, hemorrhage, or hemodynamic instability) recorded in the problem list and the last recorded Hb. The alert provided a reminder that single-unit transfusions are usually preferable,[21] and the most recent laboratory results for Hb concentration for the patient, before the order for blood transfusion. Additionally, there was an "acknowledgment reason" drop-down query that required the ordering physician to provide an answer as to why the blood transfusion was ordered: Hb value, bleeding, or other. Finally, a link was provided to literature relevant to the BPA.

The BPA was implemented in July 2010 after a series of presentations by members of the CE team to obtain approvals by the clinical services and clinical divisions. While there was no CDA or BPA for platelet (PLT) and plasma transfusions, an acknowledgment query was implemented at the same time, for PLT orders (Fig. 2).

For evaluation of blood components transfused, transfusion outcomes and all inpatient admissions and discharges at Stanford University hospital were analyzed and included. These data were collected from the laboratory information systems: SafeTrace Tx and Sunquest, which feed the laboratory data repository (Rhodes Clinical Repository). For analysis of the percentage of the subset of stable medical and surgical ward patients transfused at Hb thresholds greater than 8 g/dL, the SHC EPIC (EPIC Systems Corp.) database was utilized. To exclude actively bleeding patients, ICD-9 CM-based algorithms were used to categorize the patient population into "bleeders" and "nonbleeders." Patients in procedural areas (operating rooms and catheterization labs) were excluded. A database (Microsoft Access, Microsoft Corp., Redmond, WA) was used to merge the transfusion data from Rhodes with the ICD-9 CM diagnoses and procedure data from Midas (a proprietary database that contains Health Information Management–Coded data) to derive the additional data elements for developing the patient data set. Pretransfusion blood work was not available for 2.9% of RBC transfusions. Data were compared for three intervals: I, a pre-education interval (September 1, 2008-July 30, 2009); II, posteducation intervention interval (August 1, 2009-June 30, 2010); and III, post-BPA intervention interval (July 1, 2010-December 31, 2012). A two-sample t test with equal variances was performed for comparisons with each period.

RESULTS

The percentage of blood transfusions administered to inpatients (medical and surgical units without discharge diagnosis of hemorrhage or bleeding) at SHC from September 2008 to October 2012 is illustrated in Fig. 3. Blood utilization improved after the CE team instituted the EMR-based CDS in July 2010. The percentage of blood transfusions ordered for patients whose last Hb level exceeded 8 g/dL ranged from 57% to 66% from September 1, 2008, through June 30, 2009; after the formation of the CE team and the educational intervention, from August 1, 2009, until implementation of the CDS in July 2010, the percentage of blood transfusions in patients with Hb levels greater

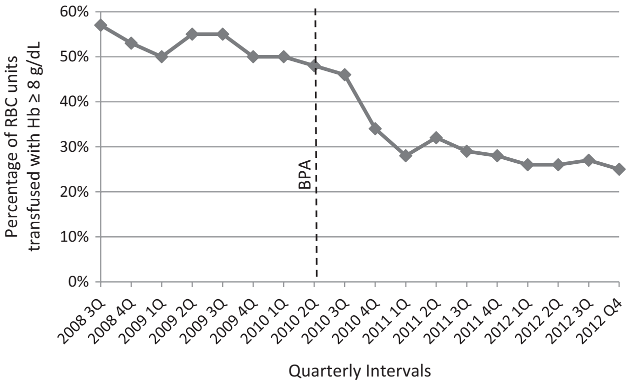

Fig. 3. Percentage of RBC transfusions administered to patients with Hb levels of more than 8 g/dL. Blood utilization at SHC improved after a CE team instituted physician education (August 1, 2009-June 30, 2010) and EMRs-based CDS in July 2010. Vertical axis = percentage of total RBC transfusions for inpatients on medical-surgical units (excluding patients with a discharge diagnosis of hemorrhage and patients in the operating room and catheterization labs) at SHC whose last recorded Hb level was greater than 8 g/dL; horizontal axis = quarterly intervals, October 2008 to December 2012. The BPA was implemented in July 2010.

than 8 g/dL decreased to a range of 52% to 56% ($p < 0.001$). After July 2010, the percentage of transfusions in patients with an Hb level greater than 8 g/dL decreased to 35% by end of December 2010 ($p < 0.001$) and has remained below 30% subsequently through December 2012 ($p < 0.001$ compared to baseline interval September 1, 2008-June 30, 2009).

The volumes of allogeneic blood components transfused at SHC from 2006 to 2012 are shown in Table 1. Blood components transfused increased yearly from 2006 to 2009. From 2009 to 2012, total RBC transfusions at SHC decreased by 24%; plasma, by 10%; and PLTs, by 12%. Transfusions of all blood components decreased by 19% over this interval.

An analysis of trends in blood utilization at SHC from January 2008 through June 2013, when corrected for volumes of patient discharges over this time, is illustrated in Fig. 4; overall, blood component transfusions at SHC increased in 2008 to 2009, but this trend has been reversed since the CDS or BPA for RBC was initiated in July 2010. Of note, plasma and PLT components have also shown a trend for decline in transfusion volumes. The estimated net savings for RBC units (at $225/unit) in purchase costs for 2012 compared to 2009 was $1,616,750.

The annual case mix indexes for all inpatients for the years 2008 to 2012 were 1.952, 1.985, 1.952, 2.017, and 2.026, respectively. To determine whether decreased blood utilization could be explained by other factors such as a decrease in surgical cases, we reviewed selected procedures: total hip and knee replacements, spinal fusions, aortic valve replacement, isolated coronary artery bypass, and heart and lung transplant cases. The totals of these cases from 2008 through 2012 were 1557, 1688, 1656, 1863, and 1993, respectively.

DISCUSSION

Of the estimated 39 million discharges in the United States in 2004, 5.8% (2.3 million) were associated with blood transfusion.[22] Blood transfusion occurred in over 10% of all hospital stays that included a procedure and was the most frequently performed procedure in 2009. The rate of blood transfusion more than doubled from 1997 to 2009.[23] For the 4-year period 2005 to 2008, 212 fatalities reported to the Food and Drug Administration[24] were deemed to be transfusion related. The leading causes of death were transfusion-related acute lung injury (n = 114), hemolytic transfusion reactions (n = 46), transfusion-associated sepsis (n = 18), transfusion-associated cardiac overload (n = 17), and babesiosis (n = 10). A far greater number of patients potentially had worse clinical outcomes (increased morbidity and mortality) due to inherent risks of blood[19] that were associated with unnecessary transfusions.[25] Increased provider awareness of the costs associated with blood transfusion[4] and recognition of the potential negative outcomes have stimulated multidisciplinary, institution-based approaches to patient blood management.

Guidelines and recommendations[6,26-37] for blood transfusion attest to the increasing interest and importance of appropriate blood utilization for health care institutions. The targeting of discrete Hb levels as "triggers" for transfusion is controversial, and the recommendations acknowledge the necessity of considering other more physiologic criteria.[27] It is generally agreed that transfusion is not of benefit when Hb levels are greater than 10 g/dL and are beneficial when Hb levels are less than 6 g/dL.[28,33] The variability in transfusion outcomes in patients such as those undergoing cardiothoracic surgery continues to persist even after adjusting for patient- and institution-related factors.[38,39] A survey[40] of anesthesiologists from more than 1000 US and Canadian institutions found that while more than three-quarters of anesthesiologists and two-thirds of surgeons had read the Society of Thoracic Surgeons and Society of Cardiovascular Anesthesiologists guidelines,[33] only 20% reported an institutional discussion, and 14% reported an institutional monitoring group. The poor impact factor for guidelines in this setting has been attributed to limited published Class A evidence, some problems inherent to interpretation of clinical trials (e.g., low participation rate for eligible patients, treatment off-protocol), and the use of Hb level as a surrogate indicator for impaired oxygen delivery and oxygen consumption.[41]

TABLE 1. Allogeneic blood components transfused at SHC 2008 to 2012*

	Year									
Component	2008		2009		2010		2011		2012	
RBCs	14,972	14,500	15,182	15,012	13,547	11,757	11,378	11,758	11,235	11,773
Plasma	7,574	7,297	6,358	6,612	7,216	5,595	5,539	4,761	5,332	4,776
PLTs	3,688	4,192	4,326	4,086	4,507	3,848	4,084	4,202	3,747	3,651
Cryoprecipitate	3,808	3,470	3,682	4,609	4,013	3,532	3,525	3,252	3,803	4,235
Total	30,382	29,701	29,753	30,451	29,410	24,841	24,600	24,101	24,176	24,498

* 6-month intervals.

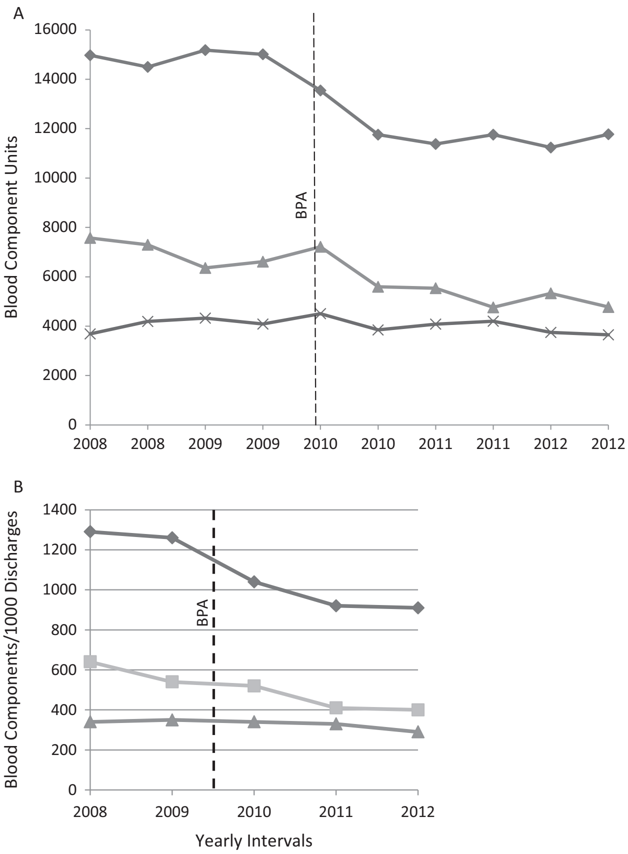

Fig. 4. Trends in blood utilization. (A) Total RBCs (—◆—), plasma (—▲—), and PLTs (—✕—) transfused for all patients at SHC from 2008 through 2012. BPA was initiated July 2010. RBC, plasma, and PLT transfusions increased in years 2008 and 2009, and after BPA, decreased subsequently in years 2010 through 2012. (B) Same as A, expressed as blood components transfused per 1000 discharges. Modified from Goodnough et al.[48]

Prospective randomized trials in patients undergoing cardiac[42] and noncardiac[43,44] surgery have each demonstrated that such patients can tolerate perioperative anemia without transfusion to Hb levels between 7 and 8 g/dL and have equivalent clinical outcomes comparable with transfusions to Hb levels of greater than 9 to 10 g/dL. An updated Cochrane meta-analysis[22] of prospective randomized trials[45] comparing "high" versus "low" Hb thresholds on more than 3700 patients found that 1) low Hb thresholds were well tolerated, 2) RBC transfusions were reduced (approx. 37%) significantly in patients randomized to the low Hb cohorts, 3) infections were reduced by 34% in patients in the low Hb cohorts, and 4) a Hb level of 7 g/dL was sufficient for the majority of patients. It is noteworthy that the recently published FOCUS trial found that elderly (mean, >80 years of age) high-risk (factors for coronary artery disease) patients who have undergone hip fracture surgery tolerate a Hb trigger as low as 8 g/dL (or higher if symptomatic).[44] This randomized controlled trial of 2016 elderly patients with history or risk factors of cardiovascular disease who underwent hip surgery demonstrated that mortality rates, inability to walk independently, and in-hospital morbidity rates were similar in liberal- versus restrictive-transfused patients, despite significant fewer transfusions in the restrictive group. Compared with higher Hb thresholds, a Hb threshold of 7 or 8 g/dL is associated with fewer RBC units transfused without adverse patient events when analyzed for mortality, cardiac morbidity, functional recovery, or length of stay.[46]

Both our pediatric[47] and our adult[48] hospitals at Stanford University Medical Center have been able to significantly reduce blood transfusions through educational initiatives (for SHC, third quarter 2009 through second quarter 2010) preceding implementation of the real-time CDS. The Hb threshold for blood transfusions can be seen to decrease after CE teams instituted physician education and then even more substantially after implementation of the CDS via an interruptive alert coupled with electronic POE. This model of concurrent review via the electronic health records at POE can be extended to peer-reviewed activities, to include further analysis of patient outliers within departments or clinical service lines, in which peer-performance executive committees can scrutinize cases selected as outliers, to satisfy accreditation requirements.[49,50]

Traditional quality indicators for blood utilization from the College of American Pathologists have included crossmatch-to-transfusion ratios, RBC unit outdate expiration rates, and RBC units wasted.[51] These are important variables for laboratory quality measures such as blood ordering policies and blood inventory management; but importantly, do not assess blood transfusion practices and blood transfusion outcomes. Furthermore, traditional models for blood utilization via retrospective peer review have also been ineffective in affecting transfusion practices.[52,53]

Process improvements to improve blood utilization through labor-intensive, concurrent, or retrospective review of blood component ordering using utilization criteria have been described.[54,55] One study reported that proportions of patients who received RBCs along with nadir and discharge hematocrit levels decreased significantly during 5-month intervals before and after modification of computerized POE.[54] Marques and colleagues[55] were able to demonstrate improved blood utilization after implementation of a plan based on education outreach; this effect is comparable to the observed improvement in blood utilization during our own educational outreach by the CE team from August 2009 to July 2010 (Fig. 3). This previous study was able to demonstrate a reduction in percentage of patients transfused and the mean number of RBC units per patient, for a series of diagnosis-related groups over 12-month intervals before and after an intense intervention of audits and educational activities.[55] Blood utilization assessed as RBC transfusions per 1000 discharges is a more direct quality indicator for hospital-wide blood transfusions, which can be corrected for annual changes in health care volumes (patient discharges).

Potential limitations of our study include the fact that this is a retrospective, single-institution experience, and that potential, unknown factors unrelated to the CDS system may have affected blood utilization, such as changes in the health care environment. However, the amount and complexity of health care delivered at our institution has remained robust; our institution has shown steady increases from 2008 to 2012 in annual patient discharge and volumes and in volumes of complex surgical cases and organ transplant cases.

The use of EMR systems[56] has allowed the opportunity to use prescriber education and audits upon POE,[54,57] similar to what we implemented in July 2010; the marked improvement in blood utilization with decreased RBC transfusions subsequent to this intervention demonstrates that not only has this been sustained over a follow-up interval of 3 years, but also with a continued decline in RBC utilization, shows evidence of continued quality improvement (Figs. 3 and 4). The impact and contributions of the individual elements of the CDS—the BPA, link to relevant literature, and/or the acknowledgment reasons—will need to be subjected to further analysis to better understand which of these components contributes to CDS affecting blood transfusion practices.

Data from the American Red Cross on national blood usage in the United States indicates an estimated annual decline of 3% over the past several years,[19] suggesting that physician behavior toward blood transfusions is undergoing change nationally. This trend is accompanied by data from the National Blood Collection and Utilization Survey,[58] which shows a progressive annual decrease in number of patients and percentage of hospitals who have canceled elective surgical procedures due to blood inventory constraints. Current initiatives in research for blood transfusions are reflected in the growing literature on adverse effects of blood storage and their possible implications for blood transfusions.[59]

In conclusion, we have been able to significantly reduce blood transfusions through an educational initiative incorporating real-time CDS. Improving blood utilization improves patient safety by reducing blood transfusions: blood transfusions carry risks and are costly, and the supply of blood is limited. Evolving evidence of a lack of benefit for blood transfusions (i.e., a restrictive transfusion approach is equally beneficial to patients compared to a more liberal transfusion approach) mandates the development of quality measures to address overuse of blood transfusion therapy.[60] Blood utilization and transfusion outcomes are therefore undergoing renewed scrutiny by health care institutions, regulatory agencies, and accreditation organizations. Professional societies are also well positioned to incorporate blood transfusion outcomes in their own guidelines and recommendations as quality indicators.[61] Health care institutions, quality departments, and transfusion services can utilize CDS to improve blood utilization, reduce costs, and improve patient safety.

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CONFLICT OF INTEREST

The authors report no conflicts of interest or funding sources.

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