JCS
Journal of Chest Surgery
https://doi.org/10.5090/jcs.23.160
pISSN: 2765-1606 eISSN: 2765-1614
J Chest Surg. 2024;57(4):390-398

Check for updates

Clinical Research

Improvement of Transfusion Practice in Cardiothoracic Surgery Through Implementing a Patient Blood Management Program

Hee Jung Kim, M.D., Ph.D.[1,*], Hyeon Ju Shin, M.D., Ph.D.[2,*], Suk Woo Lee, M.D.[2], Seonyeong Heo, M.D.[1], Seung Hyong Lee, M.D.[1], Ji Eon Kim, M.D.[1], Ho Sung Son, M.D., Ph.D.[1], Jae Seung Jung, M.D., Ph.D.[1]

Departments of [1]Thoracic and Cardiovascular Surgery and [2]Anesthesiology and Pain Medicine, Korea University College of Medicine, Seoul, Korea

ARTICLE INFO
Received November 9, 2023
Revised January 15, 2024
Accepted January 26, 2024

Corresponding author
Jae Seung Jung
Tel 82-2-920-6400
E-mail heartistcs@korea.ac.kr
ORCID
https://orcid.org/0000-0002-8848-4112

[*]These authors contributed equally to this work as the first authors.

Background: In this study, we examined the impact of a patient blood management (PBM) program on red blood cell (RBC) transfusion practices in cardiothoracic surgery.
Methods: The PBM program had 3 components: monitoring transfusions through an order communication system checklist, educating the medical team about PBM, and providing feedback to ordering physicians on the appropriateness of transfusion. The retrospective analysis examined changes in the hemoglobin levels triggering transfusion and the proportions of appropriate RBC transfusions before, during, and after PBM implementation. Further analysis was focused on patients undergoing cardiac surgery, with outcomes including 30-day mortality, durations of intensive care unit and hospital stays, and rates of pneumonia, sepsis, and wound complications.
Results: The study included 2,802 patients admitted for cardiothoracic surgery. After the implementation of PBM, a significant decrease was observed in the hemoglobin threshold for RBC transfusion. This threshold dropped from 8.7 g/dL before PBM to 8.3 g/dL during the PBM education phase and 8.0 g/dL during the PBM feedback period. Additionally, the proportion of appropriate RBC transfusions increased markedly, from 23.9% before PBM to 34.9% and 58.2% during the education and feedback phases, respectively. Among the 381 patients who underwent cardiac surgery, a significant reduction was noted in the length of hospitalization over time ($p<0.001$). However, other clinical outcomes displayed no significant differences.
Conclusion: PBM implementation effectively reduced the hemoglobin threshold for RBC transfusion and increased the rate of appropriate transfusion in cardiothoracic surgery. Although transfusion practices improved, clinical outcomes were comparable to those observed before PBM implementation.

Keywords: Patient blood management, Transfusion, Cardiothoracic surgery

Introduction

Cardiothoracic surgery is associated with increased perioperative bleeding and the need for allogeneic blood transfusion due to anemia and changes in the coagulation system. These alterations include hyperfibrinolysis, consumption of coagulation factors, platelet dysfunction, thrombocytopenia, and hemodilution [1,2]. Allogeneic blood transfusion is associated with relatively high mortality and morbidity rates. It is also linked to an elevated incidence of acute kidney injury, thromboembolic events such as myocardial infarction and cerebrovascular accident, and transfusion-related immunomodulation, which can lead to infections and sepsis in patients undergoing cardiothoracic surgery [3-5].

Blood conservation strategies represent a key element of cardiothoracic surgery. Cardiovascular operations display the highest rate of red blood cell (RBC) transfusion among surgical procedures, accounting for 10%–15% of RBC transfusions in the United Kingdom and the United States [6,7]. Despite the publication of blood conservation strategy guidelines in 2007, blood product utilization has increased for all cardiac procedures [6].

Patient blood management (PBM) involves the timely

Copyright © 2024, The Korean Society for Thoracic and Cardiovascular Surgery
This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/4.0) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

application of evidence-based medical and surgical concepts designed to optimize hemoglobin concentration, maintain hemostasis, minimize blood loss, and bolster a patient's physiological reserves against anemia. Consequently, this strategy reduces the need for allogeneic blood products and improves patient outcomes [8]. We previously reported that the introduction of a multidisciplinary PBM program at our hospital, developed in 2018, led to more appropriate use of RBC transfusion in the medical and surgical division [9]. However, the impact on individual departments was not examined. Therefore, our objective was to assess the impact of our PBM program on transfusion practices within the cardiothoracic surgery department by comparing the proportions of appropriate RBC transfusions, the hemoglobin levels at which transfusion was triggered, and the clinical outcomes of admitted patients.

Methods

The study protocol for the present research was reviewed and approved by the institutional review board (IRB) of Korea University Anam Hospital (approval no., 2021AN0118). The requirement for informed consent was waived by the IRB.

Patient blood management program

Our institution, Korea University Anam Hospital—a tertiary regional center with 1,070 beds—established a minimal blood transfusion task force team (TFT) in January 2018. In April 2018, the TFT updated the blood transfusion management program in accordance with the Korean Transfusion Guidelines [10]. In line with the updated guidelines, the program provided strict indications for the transfusion of blood products. To continue the concerted efforts to improve blood transfusion management, a Bloodless Medicine Center was established at Anam Hospital, and the TFT was renamed the PBM committee in October 2018.

The committee's core activities are those that promote education and understanding of PBM. Initially, we formed a multidisciplinary team dedicated to PBM, invited experts for collaborative study, and developed a proprietary education program. Subsequently, the committee rolled out the PBM program to physicians and trainees (interns and residents), providing training on the necessity of PBM across 18 hospital departments starting in November 2018.

In May 2019, an intervention program was developed to facilitate prospective auditing and feedback regarding blood transfusions. If a physician prescribed more than 10 units of inappropriate transfusion in a month, the program would alert the physician and notify the PBM committee via email and short message service. In July 2019, the PBM program was integrated with the institution's order communication system (OCS) to establish a clinical decision support system (CDSS) for transfusion. This program requires physicians to verify that a transfusion is appropriately indicated by clicking on a pop-up window, which details the transfusion guidelines established by the PBM committee (Fig. 1).

Appropriate and inappropriate transfusion

Appropriate transfusion was defined as an RBC transfu-

1. Acute blood loss
☐ 1.1 Acute blood loss >1,500 mL
☐ 1.2 Acute blood loss of 750 mL−1,500 mL of patients with Hb <10 g/dL
☐ 1.3 Acute blood loss of 750 mL−1,500 mL in patients with cardiovascular disease or pulmonary disease
☐ 1.4 Acute blood loss during postpartum period (vaginal delivery: blood loss ≥500 mL; cesarean section: blood loss ≥1,000 mL)
2. Anemia with Hb <7 g/dL
☐ 2.1 Hb <7 g/dL
3. Clinical condition considered for RBC transfusion with Hb from ≥7 g/dL to <10 g/dL
☐ 3.1 Infant ≤6 months
☐ 3.2 Pulmonary disease with SaO_2 <90%
☐ 3.3 Cardiovascular disease including coronary artery disease, congestive heart failure, and acute myocardial infarction
☐ 3.4 Cerebrovascular disease including stroke
☐ 3.5 Peripheral vascular disease
☐ 3.6 Bone marrow dysfunction
☐ 3.7 Sepsis
4. Solid organ transplantation, pre-deposit transfusion prior to heart surgery
☐ 4.1 Liver transplantation
☐ 4.2 Heart transplantation
☐ 4.3 Lung transplantation
☐ 4.4 Pre-deposit transfusion prior to heart surgery
5. Massive transfusion protocol
☐ 5.1 Patient prescribed with massive transfusion protocol

Fig. 1. Indications for appropriate transfusion. Hb, hemoglobin; RBC, red blood cell.

sion conducted in accordance with the indications described above. In contrast, inappropriate RBC transfusion was characterized as a transfusion conducted outside of the authorized indications.

The indications for authorized blood transfusion, based on the established guidelines, are depicted in Fig. 1. In this study, the process for determining the appropriateness of RBC transfusion involved several steps: (1) the use of a computerized transfusion audit system, programmed with an algorithm that aligned with the guidelines, to identify appropriate RBC transfusions through a retrospective review of medical records; (2) calculations regarding appropriate RBC transfusions identified by the audit, which were performed by staff; and (3) the confirmation of appropriate RBC transfusions by the director of the Bloodless Medicine Center and a physician from the department of laboratory medicine. A pop-up window was implemented to enable the selection of an authorized RBC transfusion indication from the English-language guidelines at the Bloodless Medicine Center. The algorithm and CDSS for appropriate RBC transfusion were detailed in a previously published paper [9].

Patients and materials

We conducted a retrospective review of electronic medical records from the Department of Thoracic and Cardiovascular Surgery at Korea University Anam Hospital, spanning January 2017 to December 2020. The enrolled cases were categorized into 3 groups based on their timing with respect to PBM implementation: the pre-PBM, PBM education, and PBM feedback program periods.

(1) The pre-PBM period (January 2017 to December 2017) represented the interval prior to PBM implementation. (2) During the PBM education period (January 2018 to June 2019), the primary focus was on establishing the Bloodless Medicine Center, assembling an academic committee, and providing education to physicians and trainees. (3) During the feedback program period (July 2019 to December 2020), a multidisciplinary team was assembled. Its members actively provided feedback to physicians who prescribed inappropriate transfusions, while developing a CDSS in the OCS. The CDSS utilized pop-up alerts and check-ups in accordance with rigorous center guidelines (Fig. 2).

Two parallel analyses were conducted. Initially, all patients admitted to the cardiothoracic surgery department (N=2,802) were included and evaluated regarding pretransfusion hemoglobin levels (in an examination of trigger hemoglobin levels) and the rate of appropriate transfusion across study periods. Subsequently, the subset of patients who underwent cardiac surgery (coronary artery bypass grafting [CABG] or heart valve surgery, n=381) was evaluated for clinical outcomes such as 30-day mortality, the durations of intensive care unit (ICU) and hospital stays, and the incidence of pneumonia, sepsis, and wound complications. This enabled the assessment of changes in clinical outcomes following PBM implementation.

Statistical analysis

Categorical variables, presented as counts and percentages, were compared using the chi-square test. The distributions of continuous variables, such as trigger hemoglobin level, transfusion volume, and durations of ICU and hospital stays, were assessed with the Shapiro-Wilk normality

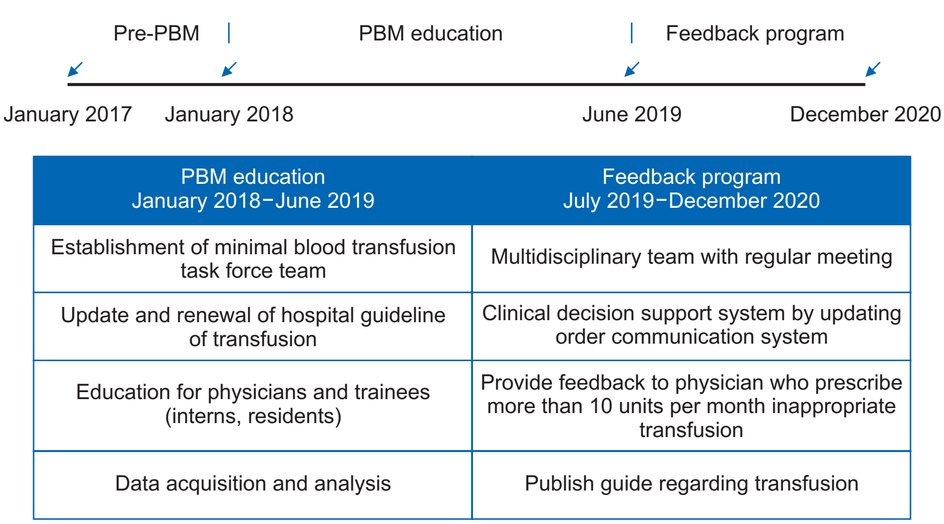

Fig. 2. Study categories based on timing in relation to implementation of patient blood management (PBM). The enrolled cohort was divided into 3 categories based on the development of PBM: pre-PBM, PBM education, and feedback program periods. A multidisciplinary team was formed to provide active feedback to physicians who prescribed inappropriate transfusions. Additionally, the team developed a clinical decision support system within the order communication system, which utilized pop-ups and check-ups in strict accordance with center guidelines.

test. Variables that did not follow a normal distribution are expressed as either the median with interquartile range (IQR) or the mean with standard deviation. These variables were evaluated using the Mann-Whitney test or the Kruskal-Wallis test.

All reported p-values were 2-tailed, and p-values less than 0.05 were considered to indicate statistical significance. Statistical analyses were performed using IBM SPSS ver. 20.0 (IBM Corp., Armonk, NY, USA) and R ver. 3.6.0 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Analysis of the overall cohort regarding appropriate transfusion

During the study period, a total of 2,802 patients were admitted to the Department of Thoracic and Cardiovascular Surgery, and 2,351 of these patients received general anesthesia. In total, 2,199 units of RBCs were transfused to 485 patients, representing 17.2% of the admitted patients. The patients who received transfusions had undergone various procedures, including isolated CABG, valve surgery, aortic surgery, esophageal surgery, lung surgery, and other operations (including interventions for cardiac tumors, transplantation, decortication for pleural conditions, and trauma), or had received medical care, including chest tube management (Table 1).

The hemoglobin threshold for initiating RBC transfusion was increased following implementation of the PBM program. The median hemoglobin levels were 8.7 g/dL (IQR, 7.8–9.6 g/dL) in the pre-PBM period, 8.3 g/dL (IQR, 7.5–9.0 g/dL) during the PBM education period, and 8.0 g/dL (IQR, 7.4–9.0 g/dL) for the PBM feedback phase ($p<0.001$). The mean hemoglobin values with standard deviations were 8.7±1.85 g/dL, 8.38±1.43 g/dL, and 8.29±1.53 g/dL, respectively. Fig. 3 illustrates the mean transfusion trigger hemoglobin levels, with 95% confidence intervals, for each period. Additionally, the proportion of RBC transfusions administered at hemoglobin levels higher than 10 g/dL decreased from 17.4% in the pre-PBM period to 11% during the PBM education and feedback phases ($p<0.001$), as shown in Table 2.

The rate of appropriate transfusion improved following implementation of the PBM program, rising from 23.9% in

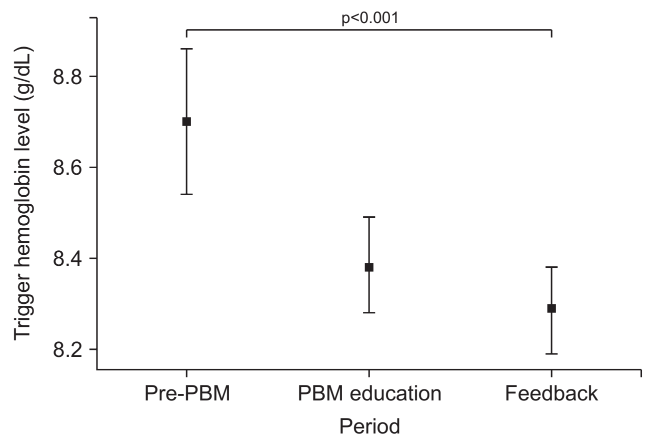

Fig. 3. Mean hemoglobin level triggering transfusion by patient blood management (PBM) implementation period. The mean hemoglobin level triggering transfusion was significantly lower for the feedback period compared with the pre-PBM phase (mean levels: pre-PBM, 8.7±1.85 g/dL; PBM education, 8.38±1.43 g/dL; PBM feedback, 8.29±1.53 g/dL). The bar plot shows the mean value with its 95% confidence interval.

Table 1. Profiles of patients receiving RBC transfusion admitted to the cardiothoracic surgery department

Variable	Pre-PBM (January–December 2017)	PBM education (early 2018–mid-2019)	PBM feedback (mid-2019–end of 2020)
No. of patients	132	175	178
Isolated CABG	20 (15.2)	42 (24.0)	35 (19.7)
Valve surgery	39 (29.5)	60 (34.3)	28 (15.7)
Aortic surgery	14 (10.6)	5 (2.9)	23 (12.9)
Esophageal surgery	1 (0.8)	14 (8.0)	14 (7.9)
Lung surgery[a]	16 (12.1)	15 (8.6)	10 (5.6)
Other surgery[b]	26 (19.7)	26 (14.9)	40 (22.5)
Medical care[c]	16 (12.1)	13 (7.4)	18 (10.1)
No. of RBC transfusions	535	701	963
No. of appropriate transfusions	128	245	561
Ratio of appropriate transfusion (%)	23.9	35.0	58.3

Values are presented as number or number (%).
RBC, red blood cell; PBM, patient blood management; CABG, coronary artery bypass grafting.
[a]Lung surgery refers to lung resection. [b]Other surgery included procedures for cardiac tumors, transplantation, and heart injury. [c]Medical care encompassed observation and chest tube management.

https://doi.org/10.5090/jcs.23.160

Table 2. Hemoglobin level triggering red blood cell transfusion according to PBM period

Period	Hemoglobin <7 g/dL	7 g/dL≤ hemoglobin <10 g/dL	Hemoglobin ≥10 g/dL	Total units
Pre-PBM	78 (14.6)	364 (68.0)	93 (17.4)	535 (100.0)
PBM education	90 (12.8)	537 (76.6)	74 (10.6)	701 (100.0)
PBM feedback	128 (13.3)	731 (75.9)	104 (10.8)	963 (100.0)

Values are presented as number (%).
PBM, patient blood management.

2017 to 68.4% in 2020 (p<0.001). Regarding the PBM timeline, the appropriate transfusion ratio increased from 23.9% in the pre-PBM period to 58.2% during the feedback period (Fig. 4).

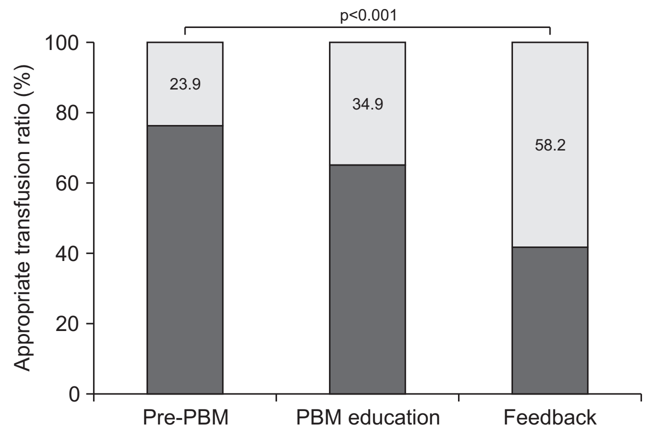

Fig. 4. Proportion of appropriate red blood cell transfusions. The appropriate transfusion ratio increased from 23.9% in the pre-patient blood management (PBM) phase to 58.2% during the feedback period.

Analysis of clinical outcomes following patient blood management implementation in the cardiac surgery cohort

During the study period, 381 patients underwent CABG or heart valve surgery, with a mean age of 66.44±10.22 years and 35.2% of the patients being female. No significant difference in baseline characteristics was observed among the 3 groups categorized by PBM period. CABG was the predominant surgical procedure during the PBM period, in contrast to the pre-PBM and education periods (Table 3).

The proportion of patients requiring RBC transfusion appeared to diminish over time across the study periods. Additionally, the mean numbers of RBC units transfused during the PBM education and feedback periods were lower compared to the pre-PBM interval. A gradual but statistically significant reduction was noted in the length of hospitalization (p<0.001). However, no significant changes were observed in 30-day mortality, ICU stay duration, or the incidence of pneumonia, sepsis, or wound complications (p>0.05) (Table 4).

Discussion

This study demonstrated that the implementation of a PBM program led to an increase in the rate of appropriate transfusion and a reduction in transfusion volume within the cardiothoracic surgery department. Among patients undergoing cardiac surgery, gradual decreases were noted in the duration of ICU and hospital stays over the study period. The institution in this study, an Asian regional tertiary hospital, successfully conserved RBCs through systematic PBM and exhibited improved clinical parameters.

Our efforts to establish PBM have centered on education and feedback for trainees and physicians across all departments. The PBM committee has provided updated hospital transfusion guidelines and organized conferences for trainees and physicians at our hospital. As part of the feedback program, we implemented a mandatory pop-up checkbox in the order communication system, requiring physicians to review transfusion guidelines when administering blood to patients. Additionally, we offered feedback to physicians and trainees who administered blood contrary to the guidelines (deemed inappropriate transfusion) for more than 10 units per month. Following implementation of the PBM strategy, transfusion practices in the thoracic and cardiovascular surgery department demonstrated improvement compared to the period before PBM was introduced. The threshold for hemoglobin levels triggering transfusion was lowered, the proportion of appropriate transfusions (those meeting hospital guidelines) increased, and the average number of RBC transfusions per patient decreased. This PBM program was successfully implemented in the thoracic and cardiovascular surgery department at our hospital. Despite the increase in the rate of appropriate transfusion during the study period, the overall proportion of these transfusions remained low, at approximately 50%. The primary reason for this low rate was the selection of incorrect indications for transfusion, often made by train-

Table 3. Baseline characteristics of the cardiac surgery cohort

Characteristic	Pre-PBM	PBM education	PBM feedback	p-value
No. of patients	75	146	160	
Age (yr)	65.62±9.61	64.99±10.28	68.25±9.86	0.127
Female	31 (41.3)	55 (37.7)	48 (30.0)	0.172
Body mass index (kg/m^2)	24.5±3.51	23.90±3.88	24.91±3.26	0.07
Hypertension	13 (17.3)	42 (28.8)	51 (31.9)	0.064
Diabetes mellitus	38 (50.7)	69 (47.3)	80 (50.0)	0.851
Hyperlipidemia	8 (10.7)	26 (17.8)	26 (16.2)	0.376
Stroke	9 (12.0)	16 (11.0)	17 (10.6)	0.951
Hemoglobin (mg/dL)	12.68±2.02	12.37±1.92	12.55±2.18	0.451
Coronary artery bypass grafting	38 (50.7)	70 (47.9)	110 (68.6)	0.001
Valve surgery	39 (52.0)	86 (58.9)	59 (36.9)	<0.001

Values are presented as number, mean±standard deviation, or number (%).
PBM, patient blood management.

Table 4. Clinical outcomes according to PBM implementation period in cardiac surgery cohort

Variable	Pre-PBM	PBM education	PBM feedback	p-value
No. of patients	75	146	160	
Patients undergoing transfusion	51 (68.0)	100 (68.5)	64 (40.0)	<0.001
Mean no. of RBC transfusions per patient	2.71±7.25	1.63±2.81	1.61±1.88	<0.001
Mortality (≤30 day)	3 (4.0)	10 (6.8)	9 (5.6)	0.687
Intensive care unit stay (day)	2.52±6.77	1.82±3.00	1.66±1.98	0.302
Hospital stay (day)	13 (11–18)	12 (10–16)	11 (10–15)	<0.001
Pneumonia	5 (6.8)	26 (17.8)	12 (7.5)	0.065
Sepsis	2 (2.7)	13 (8.9)	9 (5.6)	0.320
Wound complication	7 (9.3)	15 (10.3)	8 (5.0)	0.522

Values are presented as number, number (%), mean±standard deviation, or median (interquartile range).
PBM, patient blood management; RBC, red blood cell.

ees or physicians via the pop-up element. Therefore, enhancing education on proper transfusion practices for trainees and physicians may further improve the rate of appropriate transfusion.

RBC transfusion has been associated with increased morbidity and mortality in thoracic and cardiovascular surgery [3,11,12]. Despite the implementation of guidelines aimed at reducing blood transfusions as well as overall PBM programs, the volume of transfusions has continued to rise in cardiothoracic surgery, in contrast to other surgical fields such as orthopedic surgery, vascular surgery, and neurosurgery [6,13]. This trend can be attributed to the fact that patients undergoing thoracic and cardiovascular surgery are often older, have comorbidities, are taking antiplatelet agents, and undergo complex surgical procedures. However, despite the relatively high risk of transfusion in cardiothoracic surgery, PBM has not been as widely adopted in Asian countries as it has been in Europe [14,15]. In an effort to conserve blood and enhance the quality of care, our institute has made a concerted effort to introduce a PBM program to all healthcare workers in our hospital.

In 2011, the Society for Thoracic Surgeons (STS) released an updated clinical practice guideline document that outlined blood conservation strategies. These strategies were designed to minimize bleeding and blood loss, thereby improving outcomes for patients undergoing cardiac surgery [16,17]. The guidelines recommended blood conservation methods, including the use of intraoperative cell salvage and antifibrinolytics to reduce perioperative bleeding. However, a 2011 update on blood conservation strategies by the STS and the Society of Cardiovascular Anesthesiologists did not lead to a reduction in the rate of blood transfusions among patients undergoing cardiac surgery [16]. This was attributed to the low rate of guideline implementation by physicians [6,18]. The 2017 European guidelines on PBM for adult cardiac surgery provided practical advice for physicians specializing in PBM within this surgical field [19].

Our committee focused on education and feedback via the use of a CDSS. We developed and implemented a guideline-based protocol for appropriate RBC transfusion in our OCS. Consequently, every physician and trainee was required to evaluate the protocol for appropriate transfusion with each RBC prescription. The committee also monitored prescriptions and issued warnings to physicians who administered inappropriate transfusions to patients. The efficacy of CDSS usage for PBM has been demonstrated in previous studies [20,21]. Butler et al. [22] revealed that the implementation of a CDSS improved compliance with restrictive transfusion practices in hematology. Our institute integrated an electronic CDSS into the OCS, which facilitated the monitoring of appropriate RBC prescriptions and the provision of feedback to doctors. This is a crucial factor in the successful implementation of PBM. The improved outcomes were consistent across other medical and surgical departments within our hospital [9].

The 3 pillars of PBM are optimizing erythropoiesis, minimizing iatrogenic blood loss, and improving physiological reserve [23]. The first pillar involves detecting and managing anemia; patients with anemia should be diagnosed and treated with appropriate medications before and after surgery. The second pillar focuses on minimizing blood loss by assessing bleeding risk, minimizing phlebotomy, ensuring meticulous hemostasis, utilizing cell saver technology, and preventing coagulopathy. The third pillar emphasizes the importance of accurately assessing a patient's capacity to tolerate blood loss and enhancing cardiopulmonary function to support restrictive transfusion strategies. Efforts to reduce the use of blood products are grounded in this 3-pillar matrix of blood management. First, the committee recommends that patients with anemia scheduled for surgery should undergo consultation with hematology to boost erythropoiesis and address underlying causes. Second, during surgery, meticulous control of bleeding, coagulation factor testing (including thromboelastography, thromboelastometry, and rotational thromboelastometry), and the administration of antifibrinolytic agents are strongly advised. Third, after surgery, it is recommended to restrict transfusions based on hemodynamic stability and hemodilution conditions. All 3 processes should be conducted in accordance with available recommendations [10,24].

Limitations

This study had limitations due to its retrospective design. The characteristics of patients included in each period (pre-PBM, education, and feedback) may have varied due to a range of diagnoses and surgical profiles. Our focus was on evaluating the impact of PBM implementation on hospital-level outcomes. Consequently, we selected the entire cohort of patients admitted to the cardiothoracic surgery department. This resulted in a study cohort with diverse patient diagnoses and surgical profiles, each with different transfusion thresholds. These included patients undergoing pulmonary resection, cardiac surgery, thoracostomy, and medical treatment. We reviewed the hospital guidelines for RBC transfusion, which are not specific to any disease group. As such, distinct transfusion guidelines exist for certain disease groups, including myocardial infarction, stroke, and conditions with unstable hemodynamics. For patients undergoing cardiac surgery, adherence to these detailed recommendations is necessary [7,25-27].

To assess changes in clinical outcomes during the study period following the implementation of PBM, we examined early outcomes such as 30-day mortality, durations of ICU and hospital stays, and incidence rates of pneumonia, sepsis, and wound complications. We observed no significant differences in these early outcomes throughout the study period. Further research is necessary to evaluate the relationship between the PBM protocol and clinical outcomes.

Conclusion

The implementation of a PBM program successfully reduced the hemoglobin threshold for RBC transfusion and increased the rate of appropriate transfusion in cardiothoracic surgery. Although transfusion practices improved, clinical outcomes were comparable to those observed before the PBM program was put in place. The integration of an electronic CDSS and feedback program, overseen by a multidisciplinary committee, may contribute to the successful adoption of PBM for trainees and physicians.

Article information

ORCID

Hee Jung Kim: https://orcid.org/0000-0001-5254-1405
Hyeon Ju Shin: https://orcid.org/0000-0003-3150-6840
Suk Woo Lee: https://orcid.org/0000-0001-7478-3755
Seonyeong Heo: https://orcid.org/0000-0003-4857-7100
Seung Hyong Lee: https://orcid.org/0000-0002-9839-6431
Ji Eon Kim: https://orcid.org/0000-0002-1938-6412
Ho Sung Son: https://orcid.org/0000-0003-2766-1186
Jae Seung Jung: https://orcid.org/0000-0002-8848-4112

Author contributions

Conceptualization: Shin HJ, Kim HJ. Data curation: Kim HJ. Formal analysis: Kim HJ. Investigation: Kim HJ, Shin HJ, Lee SW, Kim JE, Heo S, Lee SH, Son HS Jung JS. Methodology: Kim HJ. Validation: Jung JS. Writing–original draft: Kim HJ, Shin HJ, Lee SW, Kim JE, Heo S, Lee SH, Son HS, Jung JS. Approval of final manuscript: all authors.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Funding

This research was supported by grant from Patient-Centered Clinical Research Coordinating Center (PACEN) funded by the Ministry of Health & Welfare, Republic of Korea (grant No. HC23C0104).

Acknowledgments

The authors would like to extend their gratitude to R.N. Mi Kyung Lee at the Bloodless Medicine Center.

References

1. Karkouti K, Wijeysundera DN, Yau TM, et al. The independent association of massive blood loss with mortality in cardiac surgery. Transfusion 2004;44:1453-62. https://doi.org/10.1111/j.1537-2995.2004.04144.x
2. Ranucci M. Hemostatic and thrombotic issues in cardiac surgery. Semin Thromb Hemost 2015;41:84-90. https://doi.org/10.1055/s-0034-1398383
3. Murphy GJ, Reeves BC, Rogers CA, Rizvi SI, Culliford L, Angelini GD. Increased mortality, postoperative morbidity, and cost after red blood cell transfusion in patients having cardiac surgery. Circulation 2007;116:2544-52. https://doi.org/10.1161/CIRCULATIONAHA.107.698977
4. Bjursten H, Dardashti A, Ederoth P, Bronden B, Algotsson L. Increased long-term mortality with plasma transfusion after coronary artery bypass surgery. Intensive Care Med 2013;39:437-44. https://doi.org/10.1007/s00134-012-2723-9
5. Spiess BD, Royston D, Levy JH, et al. Platelet transfusions during coronary artery bypass graft surgery are associated with serious adverse outcomes. Transfusion 2004;44:1143-8. https://doi.org/10.1111/j.1537-2995.2004.03322.x
6. Robich MP, Koch CG, Johnston DR, et al. Trends in blood utilization in United States cardiac surgical patients. Transfusion 2015;55:805-14. https://doi.org/10.1111/trf.12903
7. Murphy GJ, Pike K, Rogers CA, et al. Liberal or restrictive transfusion after cardiac surgery. N Engl J Med 2015;372:997-1008. https://doi.org/10.1056/NEJMoa1403612
8. Frank SM, Thakkar RN, Podlasek SJ, et al. Implementing a health system-wide patient blood management program with a clinical community approach. Anesthesiology 2017;127:754-64. https://doi.org/10.1097/ALN.0000000000001851
9. Shin HJ, Kim JH, Park Y, et al. Effect of patient blood management system and feedback programme on appropriateness of transfusion: an experience of Asia's first Bloodless Medicine Center on a hospital basis. Transfus Med 2021;31:55-62. https://doi.org/10.1111/tme.12754
10. Ministry of Health and Welfare; Korea Centers for Disease Control and Prevention. Guidelines on blood transfusion. 4th ed. Ministry of Health and Welfare; 2016.
11. Ranucci M, Baryshnikova E, Castelvecchio S, Pelissero G; Surgical and Clinical Outcome Research (SCORE) Group. Major bleeding, transfusions, and anemia: the deadly triad of cardiac surgery. Ann Thorac Surg 2013;96:478-85. https://doi.org/10.1016/j.athoracsur.2013.03.015
12. Kidane B, Jacob N, Bruinooge A, et al. Postoperative but not intraoperative transfusions are associated with respiratory failure after pneumonectomy. Eur J Cardiothorac Surg 2020;58:1004-9. https://doi.org/10.1093/ejcts/ezaa107
13. Mazzeffi MA, See JM, Williams B, et al. Five-year trends in perioperative red blood cell transfusion from index cases in five surgical specialties: 2011 to 2015. Transfusion 2018;58:1271-8. https://doi.org/10.1111/trf.14559
14. Shander A, Van Aken H, Colomina MJ, et al. Patient blood management in Europe. Br J Anaesth 2012;109:55-68. https://doi.org/10.1093/bja/aes139
15. Abdullah HR, Ang AL, Froessler B, et al. Getting patient blood management Pillar 1 right in the Asia-Pacific: a call for action. Singapore Med J 2020;61:287-96. https://doi.org/10.11622/smedj.2019037
16. Society of Thoracic Surgeons Blood Conservation Guideline Task Force; Ferraris VA, Brown JR, et al. 2011 Update to the Society of Thoracic Surgeons and the Society of Cardiovascular Anesthesiologists blood conservation clinical practice guidelines. Ann Thorac Surg 2011;91:944-82. https://doi.org/10.1016/j.athoracsur.2010.11.078
17. Society of Thoracic Surgeons Blood Conservation Guideline Task Force; Ferraris VA, Ferraris SP, et al. Perioperative blood transfusion and blood conservation in cardiac surgery: the Society of Thoracic Surgeons and the Society of Cardiovascular Anesthesiologists clinical practice guideline. Ann Thorac Surg 2007;83(5 Suppl):S27-86. https://doi.org/10.1016/j.athoracsur.2007.02.099
18. Likosky DS, FitzGerald DC, Groom RC, et al. Effect of the perioper-

ative blood transfusion and blood conservation in cardiac surgery clinical practice guidelines of the Society of Thoracic Surgeons and the Society of Cardiovascular Anesthesiologists upon clinical practices. Anesth Analg 2010;111:316-23. https://doi.org/10.1213/ANE.0b013e3181e329f1
19. Task Force on Patient Blood Management for Adult Cardiac Surgery of the European Association for Cardio-Thoracic Surgery (EACTS) and the European Association of Cardiothoracic Anaesthesiology (EACTA); Boer C, Meesters MI, et al. 2017 EACTS/EACTA Guidelines on patient blood management for adult cardiac surgery. J Cardiothorac Vasc Anesth 2018;32:88-120. https://doi.org/10.1053/j.jvca.2017.06.026
20. Rothschild JM, McGurk S, Honour M, et al. Assessment of education and computerized decision support interventions for improving transfusion practice. Transfusion 2007;47:228-39. https://doi.org/10.1111/j.1537-2995.2007.01093.x
21. Main C, Moxham T, Wyatt JC, Kay J, Anderson R, Stein K. Computerised decision support systems in order communication for diagnostic, screening or monitoring test ordering: systematic reviews of the effects and cost-effectiveness of systems. Health Technol Assess 2010;14:1-227. https://doi.org/10.3310/hta14480
22. Butler CE, Noel S, Hibbs SP, et al. Implementation of a clinical decision support system improves compliance with restrictive transfusion policies in hematology patients. Transfusion 2015;55:1964-71. https://doi.org/10.1111/trf.13075
23. Isbister JP. The three-pillar matrix of patient blood management: an overview. Best Pract Res Clin Anaesthesiol 2013;27:69-84. https://doi.org/10.1016/j.bpa.2013.02.002
24. Raphael J, Mazer CD, Subramani S, et al. Society of Cardiovascular Anesthesiologists Clinical Practice Improvement Advisory for management of perioperative bleeding and hemostasis in cardiac surgery patients. J Cardiothorac Vasc Anesth 2019;33:2887-99. https://doi.org/10.1053/j.jvca.2019.04.003
25. Carson JL, Brooks MM, Abbott JD, et al. Liberal versus restrictive transfusion thresholds for patients with symptomatic coronary artery disease. Am Heart J 2013;165:964-71. https://doi.org/10.1016/j.ahj.2013.03.001
26. Tobian AA, Heddle NM, Wiegmann TL, Carson JL. Red blood cell transfusion: 2016 clinical practice guidelines from AABB. Transfusion 2016;56:2627-30. https://doi.org/10.1111/trf.13735
27. Carson JL, Brooks MM, Hebert PC, et al. Restrictive or liberal transfusion strategy in myocardial infarction and anemia. N Engl J Med 2023;389:2446-56. https://doi.org/10.1056/NEJMoa2307983