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# 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

Hyeon Ju Shin[1] | Jong Hun Kim[2] | Yujin Park[3] | Ki Hoon Ahn[4] | Jae Seung Jung[5] | Jong Hoon Park[6] | Korea University Bloodless Medicine Center Scientific Committee

[1]Department of Anesthesiology and Pain Medicine, Korea University College of Medicine, Seoul, South Korea

[2]Division of Infectious Diseases, Department of Internal Medicine, Korea University College of Medicine, Seoul, South Korea

[3]Bloodless Medicine Center, Korea University Anam Hospital, Seoul, South Korea

[4]Department of Obstetrics and Gynecology, Korea University College of Medicine, Seoul, South Korea

[5]Department of Thoracic and Cardiovascular Surgery, Korea University College of Medicine, Seoul, South Korea

[6]Department of Orthopedic Surgery, Korea University College of Medicine, Seoul, South Korea

**Correspondence**
Ki Hoon Ahn, Department of Obstetrics and Gynecology, Korea University College of Medicine, 73 Inchon-ro, Seongbuk-gu, Seoul 02841, South Korea.
Email: akh1220@hanmail.net

**Present address**
Jong Hun Kim, Division of Infectious Diseases, Department of Internal Medicine, CHA Bundang Medical Center, CHA University, Seongnam, South Korea

## Abstract

**Background:** Patient blood management (PBM) programmes minimise red blood cell (RBC) transfusion and improve patient outcomes worldwide. This study evaluated the effect of a multidisciplinary, collaborative PBM programme on the appropriateness of RBC transfusion in medical and surgical departments at a hospital level.

**Methods/Materials:** In 2018, the revised PBM programme was launched at the Korea University Anam Hospital, a tertiary hospital with 1048 hospital beds and the first Asian institution where a new computer PBM programme was implemented. Monthly RBC usage and adequacy were analysed from January 2018 to December 2019. The trend of adequacy over time was assessed.

**Results:** A total of 2 201 021 patients were hospitalised and visited an outpatient clinic. The number of RBC units transfused per 10 000 patients decreased from 139.8 for 2018 to 137.3 for 2019. The proportion of patients with Hb <7 g/dL receiving RBC transfusion increased significantly: 29.1%, 34.5%, 40.4% and 40.6% for periods 1, 2, 3 and 4, respectively ($p < 0.001$). The appropriateness of RBC transfusion significantly increased for medical (35.2%, 41.5%, 49.6% and 74.3% for periods 1, 2, 3 and 4, respectively [$p < 0.001$]) and surgical (37.8%, 33.3%, 45.5% and 71.1% for periods 1, 2, 3 and 4, respectively [$p < 0.001$]) departments.

**Conclusion:** Implementation of a PBM programme through a multidisciplinary clinical community approach increased the appropriateness of RBC transfusion in medical and surgical departments. Therefore, expanding publicity and PBM education to health care providers is important to maintain the appropriateness of blood transfusion.

KEYWORDS
appropriateness, feedback programme, patient blood management, transfusion

## 1 | INTRODUCTION

Patient blood management (PBM) is a patient-centred multidisciplinary, multimodal, individualised approach with evidence-based medical and surgical interventions designed to minimise red blood cell

Hyeon Ju Shin and Jong Hun Kim authors contributed equally to this work.

  

(RBC) transfusion and maintain patients' own blood mass with the goal of improving patient outcomes.[1,2] PBM relies on three pillar approaches to detect and treat perioperative anaemia, minimise surgical blood loss and optimise physiological tolerance of anaemia.[3,4] A hospital-wide system is required for the assessment of the three-pillar approach,[5] including the development of an electronic clinical decision support system for blood product ordering supported by education and physician feedback and improvement in compliance with the recommended restrictive transfusion guidelines.[6]

The World Health Organization proposed the implementation of the PBM programme in 2010 and suggested a new paradigm to maintain the quality and safety of blood transfusion (WHA63.12).[7] Implementing a health system-wide PBM programme resulted in the reduction of allogeneic RBC transfusions with savings of blood acquisition cost.[8,9] PBM has been integrated into the regulatory criteria. For example, the Joint Commission set the PBM standards, which have been employed to create the performance measures for PBM programmes since 2005 in the United States.[10,11] In about two-thirds of European countries, PBM has been incorporated into routine practice in 2012.[1] In Asia, only a few countries, hospitals and medical staff introduced the PBM programme,[12] and the possibility of over-utilisation of allogeneic RBC may be high compared with the amount of blood collected. Some studies reported that the transfusion appropriateness of Southeast Asia is lower than that in Western countries.[13,14]

In Korea, 2 million units of packaged RBCs had been used every year,[15] 30%–40% of which were used during the perioperative period.[16]

The difference in the clinical policy and urgency of clinical settings between the perioperative period and the general medical situation can be experienced by physicians in the medical department and those in the surgical department. Koren et al[17] reported that physicians in the medical departments are more familiar with the restrictive blood transfusion policy than surgeons. However, a majority of RBC transfusions were performed in the non-surgical departments.[17] This study aimed to investigate the impact of our PBM monitoring and feedback programme on allogeneic RBC transfusion and evaluate the RBC transfusion appropriateness between the medical department and surgical department at a hospital level.

## 2 | MATERIALS AND METHODS

### 2.1 | Implementation of blood transfusion management programme

A computerised blood transfusion management program at the Korea University Anam Hospital, Seoul, Republic of Korea, was developed in September 2013. However, the programme was not widely utilised due to a lack of proper monitoring, which led to the establishment of a minimal blood transfusion task force team in January 2018. The task force team revised the blood transfusion management programme with updates based on the guidelines[18] in April 2018. The updated guidelines[18] supported restrictive transfusion practices, and the guidelines[18] provided the detailed transfusion indications for blood products, including RBC transfusion indication, which was incorporated into both the education and intervention programmes as authorised transfusion indications. Dissemination of the updated blood transfusion guidelines by the task force team was performed via educational programmes at the workshops held within the Anam Hospital in 2018. From March to July in 2018, there were six separate sessions of workshops providing the education programmes to the physicians at the hospital, approximately over 500 personnel. The education programme employed evidence-based approaches using the data from the guidelines and clinical trials for physicians to acquire updated knowledge and information on key points of the guideline to minimise unnecessary blood transfusions in the medical and surgical departments. For continuation of concerted efforts of improving blood transfusion management, a Bloodless Medicine Center was established at the Anam Hospital in October 2018. From November 2018 to February 2019, the enhanced educational blood transfusion programme was presented at conferences for the departments of surgery and medicine at the Anam Hospital. Moreover, individual education sessions on the blood transfusion programme were provided to the new resident physicians as a part of the orientation programme in March 2019. In May 2019, five medical staff members from the Bloodless Medicine Center completed the short-term on-site training of the Bloodless Medicine Program at the Englewood Hospital, New Jersey, United States, to learn advanced features and practices of blood management for further improvement of the education programme.

After the successful administration of the blood transfusion education programme, an intervention programme on prospective audit and feedback for blood transfusion was implemented in May 2019. The intervention programme was designed to alert health care providers regarding the systemic method of administering blood transfusions and to provide feedback. If a prescribing physician was found to have ordered more than 10 cases of unnecessary or improper blood transfusion per month based on the guidelines,[18] then an email with evaluations of appropriateness of blood transfusion will be sent to the prescribing physician by staff at the Bloodless Medicine Center. Furthermore, a clinical decision support advisory model was implemented in a computerised provider order entry system in July 2019. The model required an additional step to order blood transfusion before a physician could proceed with the task of blood transfusion, in which the prescribing physician needed to click a pop-up window and choose one of the authorised blood transfusion indications based on the guidelines (Figure 1). This feature was implemented to provide educational information to the prescribing physicians and to increase adherence to the PBM programme. Additional educational programmes reflecting the newly incorporated model were presented at the conferences held at the Anam Hospital in November and December 2019 for further dissemination of the programme.

### 2.2 | Patient population and definitions

A hospital-based retrospective study was conducted at the Korea University Anam Hospital, Seoul, Republic of Korea, which is classified as

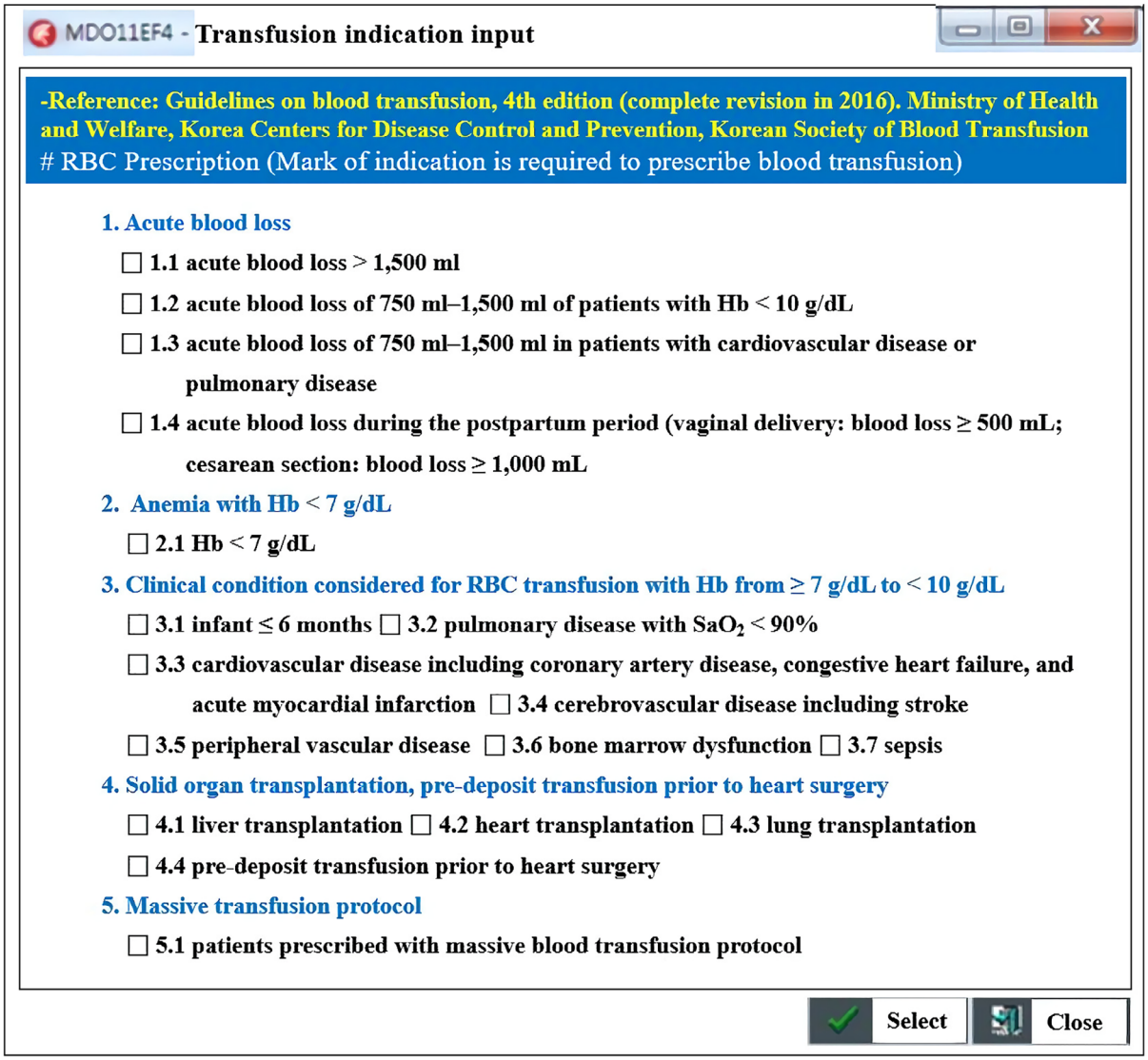


**FIGURE 1** A pop-up window to choose one of the authorised red blood cell transfusion indications based on the guidelines (English version) [Color figure can be viewed at wileyonlinelibrary.com]

a tertiary care hospital with 1048 hospital beds. All patients who received RBC transfusion at the hospital, including outpatients, inpatients and emergency room patients, between January 2018 and December 2019 were reviewed by the staff at the Bloodless Medicine Center and enrolled in the study. Transfusion-related data, including the number of RBC transfusion in units, haemoglobin (Hb) concentrations and related clinical conditions incorporated in the clinical decision support advisory model before RBC transfusion, were collected.

As shown in Figure 1, the authorised blood transfusion indications based on the guideline[18] were as follows: (1) acute blood loss: 1.1 acute blood loss >1500 ml, 1.2 acute blood loss of 750–1500 ml in patients with Hb < 10 g/dL, 1.3 acute blood loss of 750–1500 ml in patients with cardiovascular disease or pulmonary disease and 1.4 acute blood loss during the postpartum period (vaginal delivery: blood loss ≥500 ml; caesarean section: blood loss ≥1000 ml); (2) anaemia with 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 and 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 and 4.4 pre-deposit transfusion prior to heart surgery; and (5) massive transfusion protocol. The appropriateness of RBC transfusion was calculated from the following process: (1) identification of appropriate RBC transfusion by the computerised transfusion audit programme with the algorithm in accordance with the guideline[18] (Figure 2) from a retrospective review of medical records, (2) calculation of identified appropriate RBC transfusion from results of the computerised transfusion audit programme by the staff at the

Bloodless Medicine Center and (3) verification of appropriate RBC transfusion by the director of the Bloodless Medicine Center and the laboratory physician from the department of laboratory medicine. Therefore, RBC transfusion deemed to be performed according to the indication above was classified as an appropriate RBC transfusion. Inappropriate RBC transfusion was defined as RBC transfusion that was performed out of the authorised indications. Since the blood transfusion management programme has been implemented with significant updates and expansion of educational activities semi-annually from 2018 to 2019, the appropriateness of RBC transfusion was assessed in four periods (period 1: January–June 2018, period 2: July–December 2018, period 3: January–June 2019 and period 4: July–December 2019) stratified according to the department where the procedure was performed (surgical and medical). The medical departments included the Department of Internal Medicine, Cancer Center, Department of Emergency Medicine, Department of Rehabilitation, Department of Family Medicine and Department of Pediatrics. The surgical departments included the Department of General Surgery, Department of Orthopedic Surgery, Department of Neurosurgery, Department of Oral and Maxillofacial Surgery, Department of Plastic Surgery, Department of Urology and Department of Obstetrics and Gynecology. This study was approved by the Institutional Review Board (IRB) at the Korea University Anam Hospital (IRB number: 2020AN0256).

### 2.3 | Statistical analysis

Data were recorded using Microsoft Excel (Microsoft Corp, Redmond, WA) and analysed using SPSS software, version 18.0 for Windows (SPSS Inc., Chicago, IL). Dichotomous variables were compared using the Pearson $\chi^2$ test or Fisher's exact test. The trend of the RBC transfusions in four periods was analysed using the Mantel-Haenzsel test for trend. A $p$ value of <0.05 was considered statistically significant.

## 3 | RESULTS

A total of 2 201 021 patients were hospitalised and visited an outpatient clinic during the study period (1 094 105 patients in 2018 and 1 106 916 patients in 2019). A total of 15 300 units of RBCs were transfused in 2018 and 15 193 units in 2019. The number of RBC transfusions in units per 10 000 patients decreased over the study period: 139.8 in 2018 and 137.3 in 2019. The proportion of patients with Hb <7 g/dL receiving RBC transfusion significantly increased over the study period: 29.1%, 34.5%, 40.4% and 40.6% for periods 1, 2, 3 and 4, respectively ($p < 0.001$). However, the proportion of patients with 7 g/dL ≤ Hb < 10 g/dL receiving RBC transfusion decreased over the study period: 64.4%, 60.2%, 53.8% and 54.1% for periods 1, 2, 3 and 4, respectively ($p < 0.001$). Of note, the proportion of patients with Hb ≥10 g/dL receiving RBC transfusion was different over the study period: 6.5%, 5.3%, 5.8% and 5.4% for periods 1, 2, 3 and 4, respectively ($p = 0.004$) (Table 1). The rate of appropriate RBC transfusions gradually increased from January 2018 to May 2019. However, the rate has significantly increased after the implementation of an intervention programme on prospective audit and feedback for blood transfusion in May 2019. As shown in Figure 3 and Table 2, the appropriateness of RBC transfusion significantly increased over the study period: 36.0%, 39.2%, 48.5% and 73.2% for periods 1, 2, 3 and 4, respectively ($p < 0.001$).

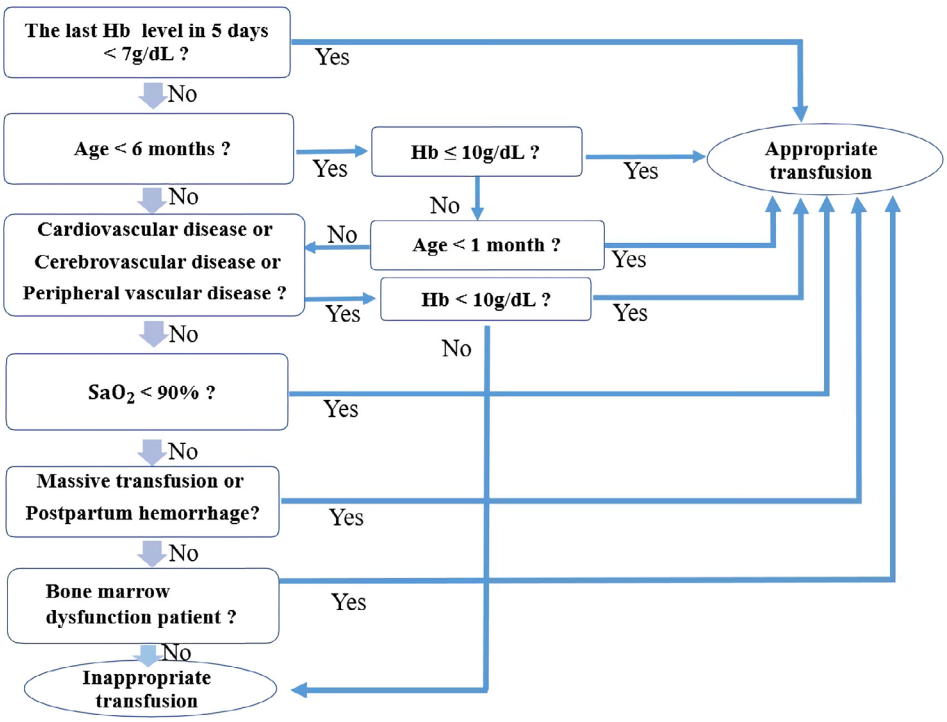


**FIGURE 2** The algorithm for determination of appropriateness of red blood cell transfusion. Hb, haemoglobin; SaO2, arterial oxygen saturation [Color figure can be viewed at wileyonlinelibrary.com]

**TABLE 1** Red blood cell transfusion in units used for the patients during the study period stratified by pre-transfusion haemoglobin levels and departments

| | Overall medical and surgical departments | | | |
|---|---|---|---|---|
| | **Haemoglobin < 7 g/dL** | **7 g/dL ≤ Haemoglobin < 10 g/dL** | **Haemoglobin ≥ 10 g/dL** | **Total (units)** |
| January–June 2018 (n=) | 2317 (29.1%) | 5128 (64.4%) | 517 (6.5%) | 7962 (100.0%) |
| July–December 2018 | 2606 (34.5%) | 4549 (60.2%) | 398 (5.3%) | 7553 (100.0%) |
| January–June 2019 | 3073 (40.4%) | 4099 (53.8%) | 440 (5.8%) | 7612 (100.0%) |
| July–December 2019 | 3128 (40.6%) | 4167 (54.1%) | 414 (5.4%) | 7709 (100.0%) |
| | **Medical departments** | | | |
| | **Haemoglobin <7 g/dL** | **7 g/dL ≤ Haemoglobin <10 g/dL** | **Haemoglobin ≥10 g/dL** | **Total (units)** |
| January–June 2018 | 1573 (28.8%) | 3540 (64.8%) | 346 (6.3%) | 5459 (100.0%) |
| July–December 2018 | 1854 (35.2%) | 3171 (60.2%) | 241 (4.6%) | 5266 (100.0%) |
| January–June 2019 | 2321 (41.7%) | 2933 (52.7%) | 313 (5.6%) | 5567 (100.0%) |
| July–December 2019 | 2303 (44.8%) | 2591 (50.4%) | 251 (4.9%) | 5145 (100.0%) |
| | **Surgical departments** | | | |
| | **Haemoglobin <7 g/dL** | **7 g/dL ≤ Haemoglobin <10 g/dL** | **Haemoglobin ≥10 g/dL** | **Total (units)** |
| January–June 2018 | 744 (29.7%) | 1588 (63.4%) | 171 (6.8%) | 2503 (100.0%) |
| July–December 2018 | 537 (25.9%) | 1378 (66.5%) | 157 (7.6%) | 2072 (100.0%) |
| January–June 2019 | 752 (36.8%) | 1166 (57.0%) | 127 (6.2%) | 2045 (100.0%) |
| July–December 2019 | 825 (32.2%) | 1576 (61.5%) | 163 (6.4%) | 2564 (100.0%) |

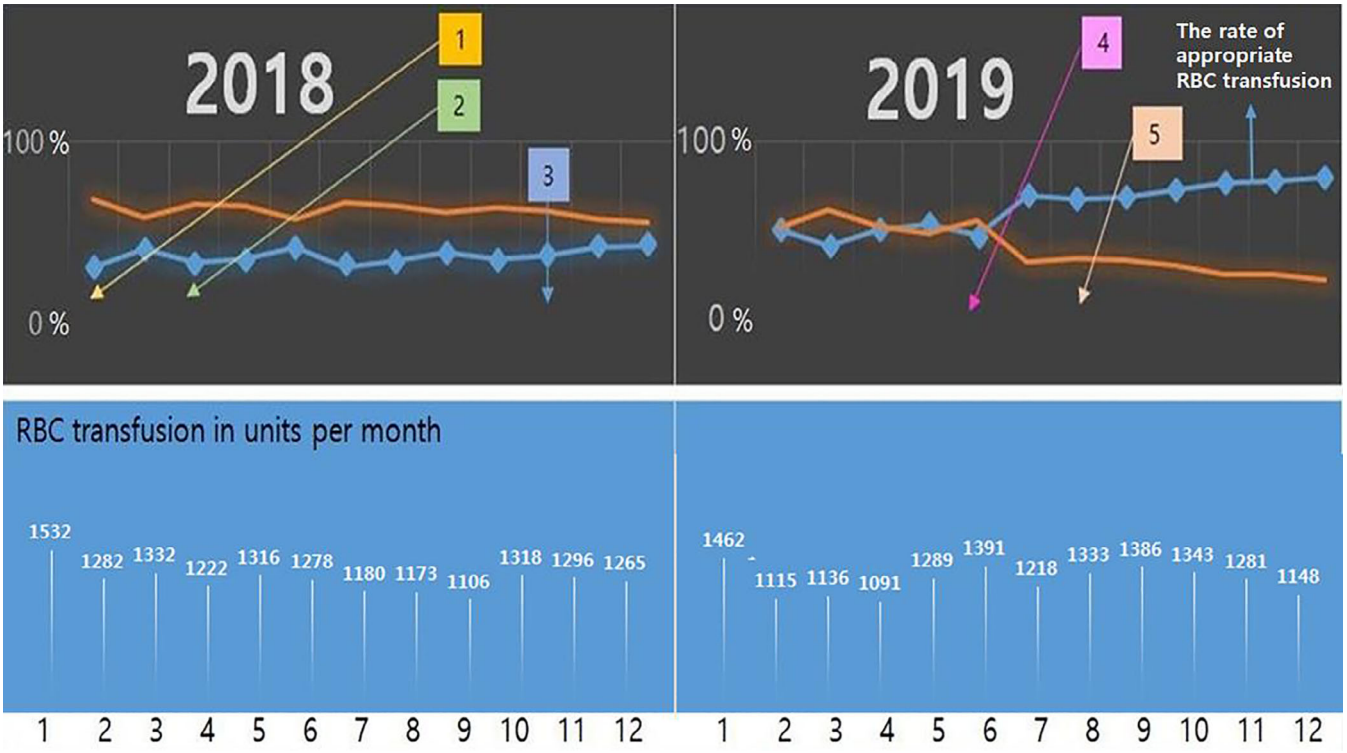


**FIGURE 3** Monthly rate of appropriate red blood cell transfusion during the study period with a series of updates in the blood transfusion programme. RBC, red blood cell, 1. The implementation of a minimal blood transfusion task force team in January 2018. 2. Revision of the blood transfusion management programme with updates based on the guidelines in April 2018. 3. The establishment of a Bloodless Medicine Center at the Anam Hospital in October 2018. 4. The implementation of an intervention programme of prospective audit and feedback for blood transfusion in May 2019. 5. The implementation of a clinical decision support advisory model in a computerised provider order entry system in July 2019 [Color figure can be viewed at wileyonlinelibrary.com]

**TABLE 2** Appropriateness of red blood cell transfusion by the study periods

| | Overall medical and surgical departments | | | | |
|---|---|---|---|---|---|
| | **Study period 1 (January–June 2018)** | **Study period 2 (July–December 2018)** | **Study period 3 (January–June 2019)** | **Study period 4 (July–December 2019)** | ***p*** |
| Inappropriate transfusion, n (units) (%) | 5105 (64.0) | 4464 (60.8) | 3923 (51.5) | 2064 (26.8) | <0.001 |
| Appropriate transfusion, n (units) (%) | 2867 (36.0) | 2874 (39.2) | 3690 (48.5) | 5645 (73.2) | |
| | **Medical departments** | | | | |
| | **Study period 1 (January–June 2018)** | **Study period 2 (July–December 2018)** | **Study period 3 (January–June 2019)** | **Study period 4 (July–December 2019)** | ***p*** |
| Inappropriate transfusion, n (units) (%) | 3539 (64.8) | 3081 (58.5) | 2808 (50.4) | 1323 (25.7) | <0.001 |
| Appropriate transfusion, n (units) (%) | 1920 (35.2) | 2185 (41.5) | 2760 (49.6) | 3822 (74.3) | |
| | **Surgical departments** | | | | |
| | **Study period 1 (January–June 2018)** | **Study period 2 (July–December 2018)** | **Study period 3 (January–June 2019)** | **Study period 4 (July–December 2019)** | ***p*** |
| Inappropriate transfusion, n (units) (%) | 1566 (62.2) | 1383 (66.7) | 1115 (54.5) | 741 (28.9) | <0.001 |
| Appropriate transfusion, n (units) (%) | 947 (37.8) | 689 (33.3) | 930 (45.5) | 1823 (71.1) | |

For medical departments, the numbers of patients hospitalised and who visited an outpatient clinic over the study period were 345 246, 348 373, 353 143 and 353 089 for periods 1, 2, 3 and 4, respectively. The numbers of RBC transfusion units over the study period per 10 000 patients were 158.1, 151.2, 157.6 and 145.7 for periods 1, 2, 3 and 4, respectively. The proportion of patients with Hb <7 g/dL receiving RBC transfusion increased over the study period: 28.8%, 35.2%, 41.7% and 44.8% for periods 1, 2, 3 and 4, respectively ($p < 0.001$). However, the proportion of patients with 7 g/dL ≤ Hb < 10 g/dL receiving RBC transfusion decreased over the study period: 64.8%, 60.2%, 52.7% and 50.4% for periods 1, 2, 3 and 4, respectively ($p < 0.001$). The proportion of patients with Hb ≥10 g/dL receiving RBC transfusion was significantly different over the study period: 6.3%, 4.6%, 5.6% and 4.9% for periods 1, 2, 3 and 4, respectively ($p < 0.001$) (Table 1). Furthermore, the appropriateness of RBC transfusion significantly increased over the study period: 35.2%, 41.5%, 49.6% and 74.3% for periods 1, 2, 3 and 4, respectively ($p < 0.001$) (Table 2).

For surgical departments, the numbers of patients admitted in the hospitals and who visited the outpatient department over the study period were 193 146, 207 340, 191 342 and 209 342 for periods 1, 2, 3 and 4, respectively. The numbers of RBC units transfused over the study period per 10 000 patients were 129.6, 99.9, 106.9 and 122.5 for periods 1, 2, 3 and 4, respectively. The proportion of patients with Hb <7 g/dL receiving RBC transfusion increased over the study period: 29.7%, 25.9%, 36.8% and 32.2% for periods 1, 2, 3 and 4, respectively ($p < 0.001$). However, the proportion of patients with 7 g/dL ≤ Hb < 10 g/dL receiving RBC transfusion decreased over the study period: 63.4%, 66.5%, 57.0% and 61.5% for periods 1, 2, 3 and 4, respectively ($p = 0.001$). There was no significant difference in the proportion of patients with Hb ≥10 g/dL receiving RBC transfusion over the study period: 6.8%, 7.6%, 6.2% and 6.4% for periods 1, 2, 3 and 4, respectively ($p = 0.277$) (Table 1). However, the appropriateness of RBC transfusion significantly increased over the study period: 37.8%, 33.3%, 45.5% and 71.1% for periods 1, 2, 3 and 4, respectively ($p < 0.001$) (Table 2).

## 4 | DISCUSSION

This study showed that the appropriateness of RBC transfusion significantly increased over the study period in both medical and surgical departments. In addition, the number of RBC transfusions per patient decreased after the application of PBM. Thus, a reduction in the proportion of patients receiving RBC transfusion was likely a result of an increase in the appropriateness of transfusion through the PBM and feedback programme. Several studies have shown that the incidence of over-utilisation of blood products was reduced through the implementation of PBM.[8,19-22] As Frank et al[8] pointed out, the three important factors in the implementation of this PBM are physician leadership, project management support and data analytics, and these three are the reasons why our organisation is successfully implementing them.[8] In particular, the implementation of an intervention programme on prospective audit and feedback for blood transfusion was very effective, which is similar to the reports of other recent study.[23] In a prospective, interventional cohort study by Mehra

et al,[23] the PBM monitoring and feedback programme was applied. They reported that, within the first year of introduction, transfusion of all allogeneic blood products per 1000 patients was reduced by 27%. The number of blood products transfused per patient was also significantly reduced. The introduction of our PBM monitoring and feedback programme reduced the transfusion probability by 14% (odds ratio: 0.86, confidence interval [CI]: 0.82–0.91, $p < 0.001$).

Although a previous study[17] reported that neither medical nor surgical doctors had a high level of knowledge on transfusion in non-operative-related matters, our study showed that PBM could be applied to medical physicians and surgical physicians to increase the appropriateness of blood transfusion. Thus, our study results reaffirm the effectiveness of improving appropriateness of blood transfusion through the implementation of monitoring and feedback programmes. In addition, this is the first study to analyse the medical and surgical sectors separately through the hospital-level PBM. However, a previous study[24] evaluated the application of PBM in the intensive care unit. Among the critically ill patients, PBM can be particularly effective given the extremely high prevalence of anaemia, variable and unjustified transfusion practices, high frequency of coagulation disorders and avoidable sources of blood loss such as unnecessary diagnostic blood draws.[24]

With regard to the surgical department, a recent meta-analysis of 17 studies comprising 235 779 surgical patients showed that a comprehensive PBM programme addressing all three PBM pillars (comprehensive anaemia management, minimisation of iatrogenic [unnecessary] blood loss and harnessing and optimisation of the patient-specific physiological tolerance of anaemia) is associated with the reduced need for RBC transfusion, lower complication and mortality rate and subsequent improvement in clinical outcomes.[25] In the meta-analysis, implementation of PBM significantly reduced the transfusion rates by 39% (risk ratio [RR]: 0.61, 95% CI: 0.55–0.68, $p < 0.00001$), 0.43 RBC units per patient (mean difference: −0.43, 95% CI: −0.54 to −0.31, $p < 0.00001$), hospital length of stay (mean difference: −0.45, 95% CI: −0.65 to −0.25, $p < 0.00001$), total number of complications (RR: 0.80, 95% CI: 0.74–0.88, $p < 0.00001$) and mortality rate (RR: 0.89, 95% CI: 0.80–0.98, $p = 0.02$).

The method of building the PBM programme has been reported before; however, this is the first study to report the results of the systemically implemented PBM programme incorporated in the electronic medical record system at a hospital level in Asia. It is also the first study to report the appropriateness of transfusion by separating the medical and surgical systems. As interest in proper blood transfusions is relatively low in Asia compared with that in Western countries, and the overuse of blood transfusions is expected to be relatively high, this study is meant to increase interest in terms of the proper utilisation of blood products in Asia, which accounts for more than half of the world's population, and to discuss timely topics because blood donations are expected to decrease gradually. However, our study has some limitations. First, the present study did not use plasma and platelet transfusion as part of the measurement of appropriate transfusion due to a shortage of data. Although our PBM programme has focused on RBC transfusion, we expect to expand the scope of the program to control plasma and platelet transfusion in the future, which will lead to a more comprehensive assessment of the program. Nonetheless, the most frequently performed transfusion in the hospital setting is RBC transfusion. Thus, we believe that our data analysis using RBC transfusion likely reflects the trend of transfusion, which may well serve as the measurement of appropriate transfusion. Second, there might have been information bias due to the retrospective nature of our study. In addition, confounding effects from unmeasured variables such as possible changes in types of surgeries or patients' demographics over the study period might have affected our analyses. However, we used consistent definitions for data collection to minimise potential bias. Third, our study and PBM programme have been based on the Korean guideline,[18] which recommends different RBC transfusion thresholds for patients with Hb ≥7 g/dL and pre-existing cardiovascular disease compared to other guidelines, such as the American Association of Blood Banks (AABB)[26] (the Korean guideline Hb from ≥7 g/dL to <10 g/dL vs. the AABB Hb 8 g/dL). Thus, the degree of effectiveness of the PBM programme might vary, especially for patients with Hb ≥7 g/dL and pre-existing cardiovascular disease, depending on the clinical settings and interpretation of the adopted guidelines. Fourth, the computerised provider order entry system may need improvement to further increase the appropriateness of RBC transfusion. Some physicians were noted to bypass the system by selecting the incorrect transfusion indication in the computerised provider order entry system for ordering RBC transfusion, which might have contributed to the inappropriateness of RBC transfusion in our study. Fifth, there might have been some seasonality component to the transfusion data as there was a higher rate of RBC transfusion among patients with Hb ≥ 10 g/dL in periods 1 and 3. Certain medical conditions that may predispose to requiring blood transfusions, such as cerebral haemorrhage, acute aortic syndrome and fracture from fall, are well known to occur more frequently in winter months, particularly from January to February in Korea.[27-29] Although a time series analysis would be helpful in uncovering such trends, our results of the benefits of the PBM programme over four separate 6-month periods can still be useful for demonstrating the impact of the PBM programme.

An analysis of cost saving, such as return on investment, is necessary in the future. As all blood donations have been made by voluntary blood donors, and the blood supply for transfusions is managed by the Blood Management Act in Korea,[30] the price of RBC is lower in Korea than in other countries.[31] However, a low birth rate and aging population in Korea will likely contribute to a decrease in blood donations, resulting in a risk of a shortage of blood products.[27] Thus, judicious use of blood products, particularly RBC, through the implementation of the PBM programme will be of great benefit for the safety of patients.

In conclusion, we observed that the appropriateness of transfusion increased after PBM implementation. In addition, publicity of PBM programme and its education for medical staff may play an important role. In particular, when the guidelines for appropriate transfusion were individually provided to the clinical workforce, the appropriateness of transfusion increased significantly. Therefore, expanding publicity and PBM education to health care providers is important to maintain the appropriateness of blood transfusion in the hospital.

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## CONFLICT OF INTEREST

The authors have no competing interests.

## ORCID

*Ki Hoon Ahn* https://orcid.org/0000-0002-6314-4621
*Jae Seung Jung* https://orcid.org/0000-0002-8848-4112

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