Clin. Lab. 2023;69:XXX-XXX

ORIGINAL ARTICLE

The Implementation of Patient Blood Management in a Tertiary Hospital: a 9-Year Retrospective Study of Blood Transfusion Practice

Dongmei Yang [*], Chunxia Chen [*], Fu Cheng, Bing Han, Li Qin, Bin Tan

[*] *Dongmei Yang and Chunxia Chen contributed equally to this article*
Department of Transfusion Medicine, West China Hospital, Sichuan University, Chengdu, P.R. China

SUMMARY

Background: **To analyze the changes in clinical transfusion practice and explore the exact benefits after the implementation of patient blood management (PBM).**
Method: **The retrospective study included transfusion practice data from West China Hospital of Sichuan University during the years 2009 - 2018. The data of surgical patients in 2010 were taken as the baseline (pre-PBM), and the data of surgical patients from 2012 to 2018 (post-PBM) were compared with the baseline. Outcome measures were the change in transfusion practice, patient outcomes, and economic benefits pre/post-PBM.**
Results: **Compared with pre-PBM, the rapid growth of clinical red blood cell (RBC) consumption was curbed, the total units of red blood cells (RBCs) transfused was 65,322 units pre-PBM and was 51,880.5 units in 2011. The transfusion rate per 1,000 surgical patients post-PBM was lower, and the mean units of intraoperative transfusion and surgery transfusion represented a 50% reduction. According to the product-acquisition cost, PBM had saved 46.58 million Renminbi (RMB) in 2012 - 2018. The proportion of ambulatory surgery and interventional surgery increased, the proportion of Hb transfusion trigger was significantly lower than that in 2010, and the average length of stay (ALOS) was improved.**
Conclusions: **Properly implementing a PBM program had the potential to reduce unnecessary transfusions and the related risks and costs.**
(Clin. Lab. 2023;69:xx-xx. DOI: 10.7754/Clin.Lab.2023.230127)

Correspondence:
Li Qin
Department of Transfusion Medicine
West China Hospital
Sichuan University
Chengdu 610041
Sichuan
P.R. China
Phone: + 86(028)85422523
Fax: + 86(028)85422523
Email: qinli7@126.com

Manuscript accepted February 23, 2023

KEYWORDS

patient blood management, blood transfusion, surgery, blood consumption

INTRODUCTION

In the past two decades, the gap between blood supply and demand was prominent around the world [1], while the situation was particularly concerning in China [2,3]. Ling Shi suggested that we should take efforts to control the sharp increase in clinical demand for blood, such as implementing patient blood management [4]. Based on the risks associated with transfusion and blood shortages throughout our country, there is an impending demand for us to reconsider the rationality of clinical transfusion practice and seek a new method to optimize blood utilization [5,6]. Since the Joint Com-

mission and the American Medical Association-Convened Physician Consortium for Performance Improvement pointed out in 2012 that blood transfusion was one of the most common overused treatment measures [7], various studies have focused on patient blood management (PBM) for reducing the overuse of blood products [8-11].
PBM, evidence-based clinical practice that focuses on the implementation of transfusion guidelines, perioperative blood conservation, and anemia management, has attracted considerable attention [12]. It was first proposed by the Society for the Advancement of Blood Management (SABM), committing to the improvement of patients' prognosis and the reduction of inappropriate use of blood components and medical costs [12]. According to the concept of PBM, there were three main pillars: the optimization of RBC mass, reduction of blood loss and bleeding, and optimization of the patient's physiological tolerance toward anemia [13-15]. To date, improved outcomes have been reported in the developed countries that adopt the implementation of PBM, leading to the reduction of blood product use and medical costs and furthermore improving patient outcomes [14,16-18]. However, the successful implementation of PBM has rarely been reported in developing countries, and we do not know the exact benefits after the implementation of PBM.
This retrospective observational study demonstrated the changes in clinical transfusion practice pre/post-PBM in West China Hospital of Sichuan University, giving us a general understanding of blood consumption and providing evidence for further research on the establishment of a prediction model of perioperative risk. Meanwhile, this study explored transfusion practices in terms of surgery, including the management of preoperative anemia, intraoperative blood conservation, and the control of transfusion guidelines, which helped to determine the key points of PBM and provided evidence for the implementation of PBM.

MATERIALS AND METHODS

PBM program

In March 2011, PBM was implemented in West China Hospital of Sichuan University. Leadership was critical in PBM implication. The Blood Transfusion Administration Committee of West China Hospital with the hospital president as director first made the determination to reduce over-transfusion of RBCs. The Blood Transfusion Administration Committee carried out a series measures to put PBM forward, including enactment and revision of the Blood Transfusion Management Protocols of West China Hospital, defying the roles of Clinic Department and Blood Transfusion Department in blood transfusion management, adoption of a Blood Consumption Notice and Scoring System, which publishes monthly notifications of blood volume usage per ward/per doctor and per doctor's prescription of transfusion trigger. To guarantee the effectiveness of these strategies, regular inspection and evaluation of the implementation and amendments are made when necessary.
Based on the three pillars of PBM, the major action taken by clinician to reduce unnecessary RBC transfusion was achieved mainly by 1) A strict control of transfusion indication for RBCs, 2) Encouragement for the implementation of autotransfusion and other strategies for blood conservation, such as the transformation of surgery type, and 3) Education and governance. The teaching sessions of PBM guidelines were made every year to guarantee the effectiveness of these strategies. The Blood Transfusion Administration Committee was responsible for the overall governance of the PBM, while unreasonable blood transfusion would be considered and discussed.

Study objects and data source

The study was approved by the Institutional Review Board and Medical Ethics Committee of West China Hospital of Sichuan University (No. 2021/516). The requirement for written informed consent was waived because of the retrospective design of the study.
To analyze the effect of PBM, the data of surgical patients in 2010 were taken as the baseline (pre-PBM), and the data of surgical patients in 2012 - 2018 (post-PBM) were compared with the baseline.
Worksheets of RBC consumption were generated by the hospital's laboratory information system (LIS) to perform a retrospective review from 2009 to 2018, and the data were summarized yearly to form the annual RBC consumption.
Other data of the surgical patients who were admitted to the hospital from 2010 to 2018 included in this study were derived from the hospital information system (HIS), including the following data on patient characteristics and outcomes: medical record number, gender, age, admission date, discharge date, operation date, diagnosis, surgery types, hospital length of stay, unit of RBC transfused per surgery, transfusion date, value of hemoglobin (Hb) of each patient before, during, and after the surgery, patient outcomes, etc.
Autotransfusion data were extracted from the anesthesia information system (AIS), and all types of autotransfusion were intraoperative blood salvage (IBS).

Variable definitions

Preoperative Hb was defined as Hb value closest to the surgical date within 7 days before the surgery (excludeing the surgery day). For example, if the surgery date of a patient was 2014/10/13, and there were measurements of Hb separately in 2014/10/13, 2014/10/12 and 2014/10/10, the Hb value measured on 2014/10/12 was selected as the preoperative Hb.
Postoperative Hb referred to the Hb value closest to the surgical date within 7 days after the surgery (excluding the surgery day).

Table 1. Surgical patient characteristics and clinical outcomes compared between the two periods.

Characteristic		Period 1 (pre-PBM)	Period 2 (post-PBM)						
		2010	2012	2013	2014	2015	2016	2017	2018
Age, mean (SD)		42.7 (21.95)	44.2 (22.32)	44.3 (22.65)	45.4 (22.15)	46.1 (21.78)	46.5 (21.79)	46.9 (21.73)	47.2 (21.63)
0 - 14 years (%)		14.3	14.3	14.9	13.3	12	11.8	11.5	11.4
15 - 64 years (%)		68.2	65.8	64.8	65.9	66.9	66.6	66.2	66
≧ 65 years (%)		17.5	19.9	20.3	20.8	21.1	21.6	22.3	22.6
Gender	female (%)	42.7	44.7	44.1	45	45.5	46	46.1	46.4
	male (%)	57.3	55.3	55.9	55	54.5	54	53.9	53.6
Preoperative Hb, mean (SD)		130.2 (20.11)	132.5 (20.43)	132.3 (20.17)	132.8 (20.76)	131.9 (20.94)	131.8 (20.73)	131.4 (20.57)	132.3 (20.67)
< 9 g/dL (%)		7.63	6.93	6.6	6.82	7.88	7.81	7.98	8.14
9 - 12 g/dL (%)		28.03	22.86	24.92	25.36	26.19	27.16	27.07	26.13
> 12 g/dL (%)		64.34	70.21	68.48	67.82	65.93	65.03	64.95	65.73
Hb trigger †, mean (SD)		118.6 (24.16)	116.4 (26.32)	115.6 (26.1)	114.3 (25.88)	113.5 (26.01)	113.5 (25.94)	113.5 (25.7)	112.7 (26.86)
< 9 g/dL (%)		15.64	22.79	20.43	22.13	22.92	23.96	23.98	24.96
9 - 12 g/dL (%)		34.21	29.82	35.29	36.4	34.2	37.38	36.35	35.83
> 12 g/dL (%)		50.15	47.39	44.28	41.47	42.78	38.66	39.68	39.21
Post-surgery Hb, mean (SD)		111.8 (20.59)	111.7 (21.72)	112 (21.57)	112.3 (21.64)	112 (21.65)	112.3 (21.5)	113.1 (21.8)	113.6 (21.88)
< 9 g/dL (%)		13.64	15.46	15.52	15.23	15.56	14.91	14.45	14.37
9 - 12 g/dL (%)		52.1	47.94	49.73	49.53	50.4	50.54	49.53	47.91
> 12 g/dL (%)		34.26	36.6	34.75	35.24	34.04	34.55	36.02	37.72
Discharged Hb, mean (SD)		125.1 (21.53)	125.8 (22.61)	125.6 (22.34)	125.5 (22.79)	125.2 (22.73)	124.9 (22.5)	125 (22.04)	126.4 (22.08)
< 9 g/dL (%)		13.51	14.83	14.69	14.38	14.79	14.47	14	14.08
9 - 12 g/dL (%)		52.59	48.88	50.42	50.14	51.07	51.21	49.97	48.42
> 12 g/dL (%)		33.9	36.29	34.89	35.49	34.14	34.32	36.03	37.5

Hb = haemoglobin.
Hb trigger † means the Hb transfusion trigger, which was based on the last measured Hb value pre-surgery.

Discharged Hb referred to the Hb value closest to the surgical date within 7 days before discharge (including the day of discharge).
Intraoperative transfusion referred to the total units of RBCs transfused in the first 24 hours of the surgery.
Surgical transfusion, referred to all the units of RBCs transfused per surgery, was defined as the sum of all RBCs transfused during the period from the day of surgery to discharge.
The three types of surgery in the hospital were elective surgery, emergency surgery, and others. Ambulatory surgery and interventional surgery were included in the other subgroup.

Statistical analysis
Statistical analysis was performed by Excel v.14.1.0 (Microsoft Inc., Redmond, WA, USA), JMP v.9.0.0 (SAS Institute, Cary, NC, USA) and GraphPad Prism 8.0. ANOVA and the chi-squared test were used to analyze the data under specific conditions. The Kruskal-Wallis test was used to compare the nonparametric data. The data were expressed as the mean ± SD. A p-value of less than 0.05 was considered significant.

RESULTS

Surgical patient characteristics pre/post-PBM
There were 779,581 inpatients involved. The mean age of the surgical patients was 45.7 ± 22 years old, and 54.5% of them were male. A total of 3.92% (30,526/779,581) of surgical patients had intraoperative transfusions, and the total units of RBCs was 117,205 U, while surgical transfusions accounted for 5.24% (40,820/779,581), with 194,821 U.

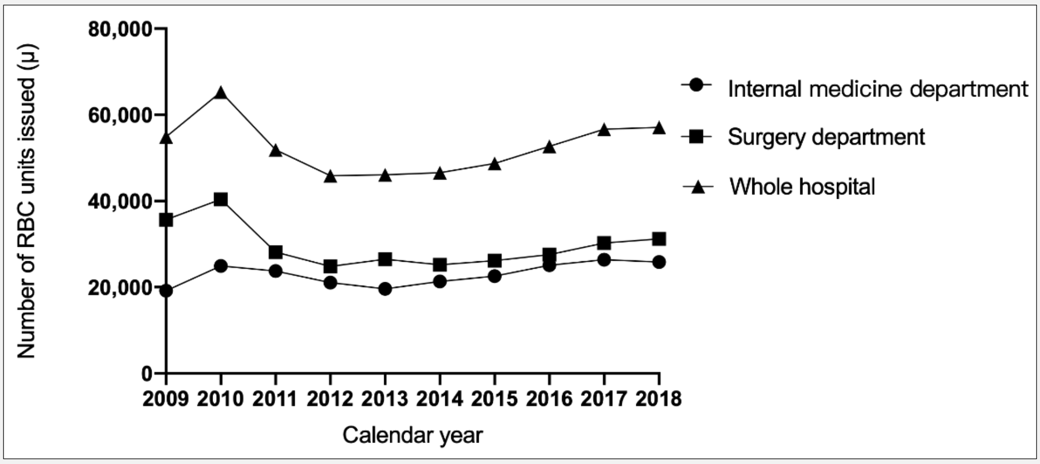

Figure 1. Changes of RBC consumption from 2009 to 2018.

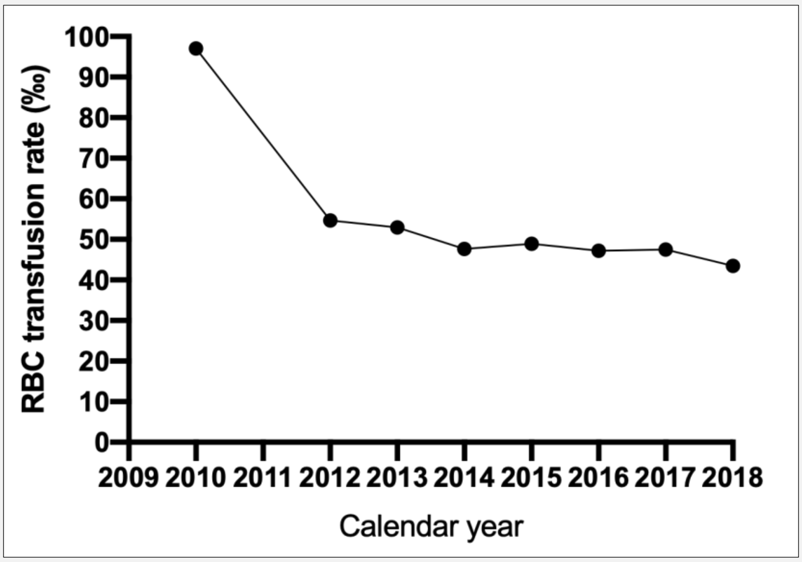

Figure 2. The RBC transfusion rate per 1,000 surgical patients pre/post-PBM.

Age distribution in transfused surgical patients pre/post-PBM

We analyzed the change in age distribution in surgical patients and transfused surgical patients. The aging distribution of surgical patients is shown in Table 1. The mean age of surgical patients in 2012 - 2018 was higher than that in 2010 ($p < 0.001$). The age distribution of surgical patients was divided into three groups: 0 - 14 years, 15 - 64 years, and ≥ 65 years. The proportion of surgical patients over 65 years old gradually increased from 17.5% in 2010 to 22.6% in 2018, and the absolute number of patients was increased by nearly 3 times

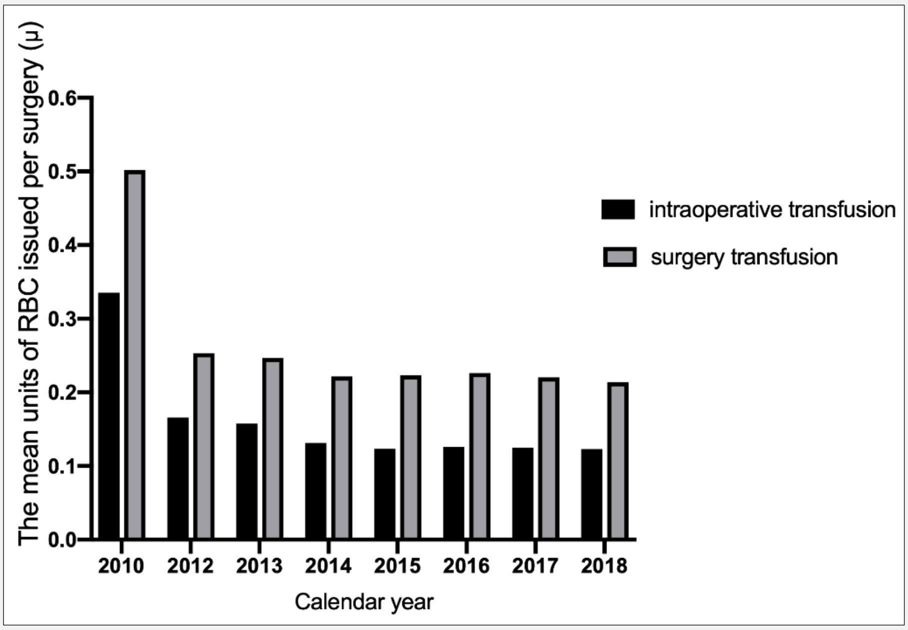

Figure 3. The mean units of RBC transfused per surgery pre/post-PBM.

intraoperative transfusion referred to the total amount of the RBC issued in the first 24 hours of the surgery; surgery transfusion referred to all the units of RBC transfused per surgery, was defined as the sum of all RBC transfused during the period from the day of surgery to discharge.

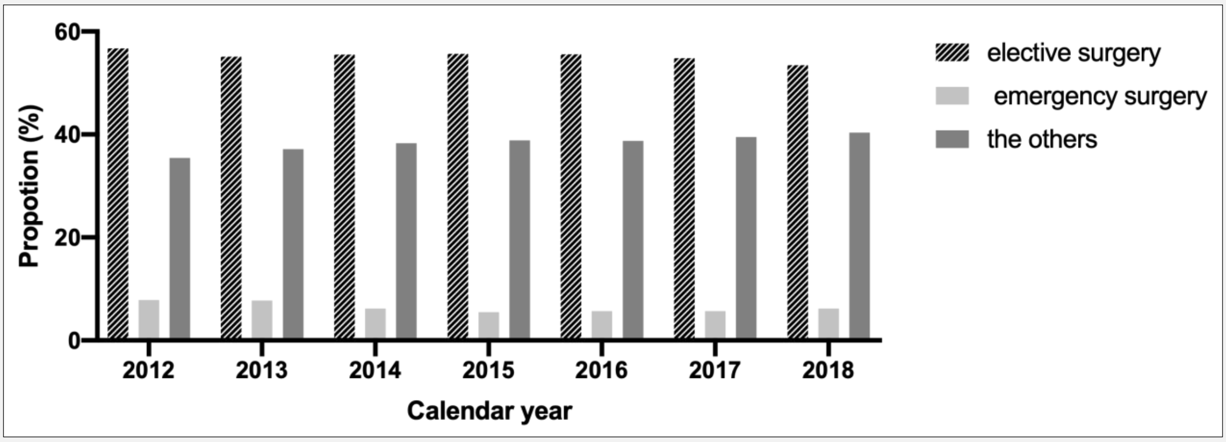

Figure 4. The change in surgery type from 2012 to 2018 (post-PBM).

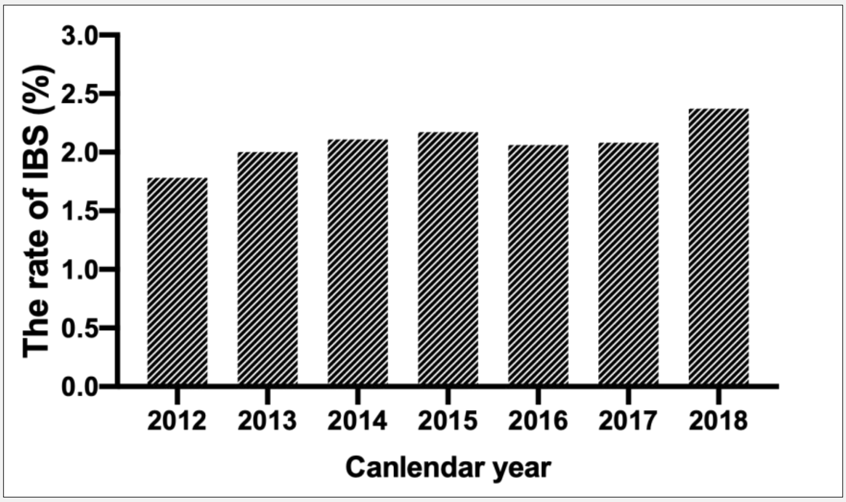

Figure 5. The rate of intraoperative blood salvage (IBS) from 2012 to 2018.

(30,101 in 2010 vs. 11,206 in 2018). In the transfused surgical patients, although the proportion of the 15 - 64 group dominated, the proportion of transfused surgical patients in the ≥ 65 years group in 2012 - 2018 increased significantly compared with that in 2010 ($p < 0.001$), from 19.12% in 2010 to 24.20% in 2018.

Hb transfusion trigger in surgical patients pre/post-PBM

As shown in Table 1, the proportion of patients with anemia post-PBM each year was lower than that pre-PBM ($p < 0.001$). Among all the surgical patients, preoperative anemia accounted for 33.6%. Pre-PBM, the proportion of preoperative anemia was the highest (35.66%), while in 2012 (post-PBM), the proportion of preoperative anemia was the lowest (29.79%). We further analyzed the Hb transfusion trigger in surgical patients, with Hb transfusion trigger of less than 9, 9 to 12, and 12 g/dL or more. In the transfused surgical patients, preoperative anemia accounted for 57.92%, and the proportion of preoperative anemia patients was significantly higher than that in 2010 ($p < 0.001$), from 48.85% in 2010 to 60.79% in 2018.

Post-surgery Hb and discharged Hb of transfused surgical patients post-PBM

Post-surgery Hb and discharged Hb could reflect changes in transfusion strategies. After the implementation of PBM, the proportion of transfused surgical patients with Hb of less than 9 g/dL was significantly higher than that in 2010 (23.32%) ($p < 0.001$, shown in Table 1).

The annual RBC products consumption pre/post-PBM

The total units of RBCs transfused by year in the hospital from 2009 to 2018 are shown in Figure 1. In 2010, the total units of RBCs transfused in the whole hospital was 65,322 units, an increase of 19.20% compared with 2009. After carrying out PBM in 2011, the consumption of RBC products was effectively curbed in the first year, and the total units of RBCs transfused were 51,880.5 units in 2011, 20.58% lower than those in 2010, and an 11.58% decline in the next year. As a result, 2012 was the lowest in the last 10 years. After the implementation of PBM, the decrease in RBC consumption in the surgery department was the most obvious.

The RBC transfusion rate per 1,000 surgical patients pre/post-PBM

The transfusion rate per 1,000 surgical patients post-PBM was significantly lower than that pre-PBM ($p < 0.001$) and tended to decline in the following years (Figure 2). The transfusion rate per 1,000 surgical patients was 97.1% in 2010, while in 2012, the transfusion rate dropped sharply to 54.7%, and the lowest reported rate was 43.4% in 2018 (Figure 2).

The mean units of RBCs transfused per surgery pre/post-PBM

The mean units of RBCs per surgery had a significant decline post-PBM (shown in Figure 3). Among transfused surgical patients pre-PBM, the mean intraoperative transfusion per surgery of 2010 was 0.335 units, while the mean surgery transfusion per surgery was 0.502

units. The years 2012 - 2018 (post-PBM) represented a decline of 50%, the mean units of intraoperative transfusion maintained a level of approximately 0.123 units, and the mean units of surgery transfusion were maintained at the level of approximately 0.222 units.

Hospital-wide patient outcomes pre- and post-PBM

After the implementation of the PBM program, the average length of stay (ALOS) of all inpatients showed a downward trend. The ALOS was 10.9 days in 2010 and 8.09 days in 2018.

Change in surgery type and the implementation of blood conservation post-PBM

Our results revealed that although the type of surgery was still dominated by elective surgery (53.5% - 56.7%), the proportion of the other group (ambulatory surgery and interventional surgery) was growing yearly, accounting for 35.4% in 2012 and 40.4% in 2018 (Figure 4). At the same time, our research showed that the rate of IBS increased from 1.76% (1,406/7,986) in 2012 to 2.36% (3,164/13,367) in 2018, as shown in Figure 5.

Comparison of activity-based cost of transfusion savings pre- and post-PBM

As the consumption of RBCs in 2010 (pre-PBM) was taken as the baseline, we supposed the average consumption of RBCs remained at the baseline year level, and then an additional 103,522 units of RBCs would have been transfused over the years 2012 - 2018 (post-PBM). According to the product-acquisition cost, the implementation of PBM saved 46.58 million RMB ($7.11 million) in medical expenses, converting to a save of 6.65 million RMB ($1.02 million) annually on average.

DISCUSSION

To our knowledge, this study was the first comprehensive evaluation of the associated effect of PBM in a developing country. Since the PBM program was carried out in March 2011 at West China Hospital of Sichuan University, it effectively curbed the rapid growth of clinical RBC consumption in 2011 - 2018 (post-PBM) compared with 2010 (pre-PBM), and the reduction in RBC consumption in the surgery department was the most obvious. Because RBCs were mainly issued to surgical patients, we focused on analyzing the transfusions among the surgical patients.

According to the demographic characteristics of the population, the proportion of patients over 65 years old increased year by year, which reflected the phenomenon of aging among surgical patients [19]. This aging phenomenon also appeared in transfused surgical patients. Previous studies have validated that the elderly population is more likely to receive transfusions [20]. However, despite the annual increase in RBC consumption and the phenomenon of aging, the transfusion rate per 1,000 surgical patients, the mean units of RBCs transfused per surgery, and the RBC transfusion rate per 1,000 surgical patients in the year post-PBM (2012 - 2018) decreased significantly compared with the year pre-PBM (2010), thus saving numerous medical costs.

To further investigate the influence of PBM programs pre- and post-PBM on patient outcomes, we assessed the ALOS of all inpatients and the economic benefit. The ALOS indicated that the patient outcomes presented a better medical prognosis in the year post-PBM compared with pre-PBM. Taking RBC consumption in 2010 (pre-PBM) as the baseline, our study estimated the direct savings of medical expenses in 2012 - 2018 (post-PBM). Regarding the additional cost of activities, such as materials, labor, third-party services, activity-based savings were underestimated. According to studies about activity-based costs of blood transfusion in surgical patients, the activity-based costs were 4 times higher than the product acquisition costs [21,22], which indicated that the gross savings of activity-based costs were much greater than the real product costs. Calculating the gross savings of blood costs would help the government make appropriate decisions about the health system, while incomplete accounting for blood costs has the potential to misdirect decision making by the health care system.

Due to the lack of benchmarking, it was difficult to compare the management results of PBM between different organizations. However, compared with the data of some large tertiary hospitals in Europe and the United States [21,23], we may still have some room for improvement. Australia was the first region to raise PBM to the level of national strategy. A retrospective study of patients admitted to four major adult tertiary-care hospitals between 2008 and 2014 showed that the RBC consumption increased at an annual rate of 12% pre-PBM in the year of 2008 - 2009, largely due to the rapidly growing and aging population, representing a saving of AU$18,507,092 (US$18,078,258) and between AU$80 million and AU$100 million (US$78 million and US$97 million) estimated activity-based savings [15]. The United States was another country where PBM was well developed. According to a report from Johns Hopkins Hospital of the United States in 2016, after PBM was implemented in 2014, RBC consumption decreased by 12% ($p < 0.035$), and the total cost avoided was 181,887 US dollars/year (calculated by activity cost, 582,039 US dollars/year to 873,058 US dollars/year) [24]. Through horizontal comparison with other hospitals in the same period and vertical comparison with our own historical data, we need to insist on improving the ability of blood management [25]. Birmingham University of Alabama, USA, based on the blood transfusion benchmark test of the Medicare Severity Diagnosis Related Group (MS-DRG) categories, found that the blood consumption of the hospital was higher than that level given by the American Red Cross and strategic healthcare group. Therefore, corresponding measures were taken to reduce the mean units of RBCs transfused per discharge by 50% [17]. In Australia, predictive modeling and machine learning tools applied to preoperative data were used to predict RBCs transfused during surgery and to prospectively optimize blood ordering schedules, and this model was used to benchmark different hospitals concerning blood transfusion patterns [26].

According to our study, the reduction in surgical RBC consumption may be derived from two aspects. First, the measures adapted by our hospital to minimize blood loss played an important role, like increasing the proportion of IBS. A recent meta-analysis by Ned Kinnear proved the safety and efficacy of IBS [27]. On the other hand, the transformation of surgery type was as important. Studies have revealed that interventional surgery, such as cardiac interventional surgery, could significantly reduce the risk of bleeding and transfusion [28]. As ambulatory surgery started late in China, our hospital had taken various measures to increase the proportion of interventional surgery [29,30]. Although PBM paid less attention to the impact of day surgery on reducing RBC consumption, clinical practice has fully proven that ambulatory surgery can maximize the role of medical resources. Therefore, it might be an important way for developing countries to effectively reduce RBC consumption and improve the outcome of PBM. In addition, the strict control of transfusion guidelines could be the key point of PBM [15,16], like optimizing the patients' tolerance of anemia. Existing evidence suggests that preoperative anemia is associated with increased operative bleeding, RBC transfusion, and long-term mortality [31]. In our analysis of Hb trigger in surgical patients, preoperative anemia accounted for 57.92% and was significantly higher than that in 2010 ($p < 0.001$), and the proportion of Hb (post-surgery) < 90 g/L presented a similar trend. This indicated that the preoperative management was good in our hospital.

Overall, our study demonstrated that since 2011, by increasing intraoperative blood conservation, changing the type of surgery, and implementing stricter transfusion strategies, the upward trend of RBC consumption was arrested, and the mean units of RBCs per surgery had been maintained at a low level, the patient outcomes improved, thus saving many blood resources and activity-based costs.

There were some deficiencies in our study. First, as a retrospective study, we were faced with some missing data, such as the number of discharged patients, the ALOS, and the data of autologous blood transfusion before the implementation of PBM management, which makes the real effect of PBM lower than the current estimation. Second, the factors affecting the effect of RBC transfusion varied among institutions, some of which were related to patients, while others were related to the diagnosis and treatment process, including the relevant training system, feedback audit system, intraoperative use of hemostatic drugs and other management procedures. We admitted that other quality improvement measures implemented in the hospital during the same time-period also played an important part. The studies [32,33] from other teams in our hospital had identified the effect of tranexamic acid in reducing blood loss following surgery. We would investigate the details of certain procedures that influenced the outcomes of patients to improve our PBM program in our further research. Third, our transfusion patterns also had not been characterized on a nationwide level. Moreover, optimizing plasma and PLT consumption was not involved in our study. Although these "yellow" components are more likely to be associated with alloimmunization and allergic reactions, further study is needed to include these blood components in our PBM program.

In summary, by comparing the transfusion practice and outcomes between pre-PBM and post-PBM, we observed a good prognosis of patients and reduced blood consumption and costs. The implementation of PBM is a complex system that needs a unified design, detailed organization, and positive attendance at the national level. Our comprehensive analysis of the changes in transfusion practice pre- and post-PBM implementation processes was the basis of establishing an internal benchmark test, which was helpful to deeply explore the key points of PBM and provide the basis for the continuous implementation of PBM.

Source of Funds:

This work was supported by Sichuan Province Science and Technology Plan Project (2021YJ0454) and Discipline Excellence Development 1·3·5 Project of West China Hospital of Sichuan University (2021HXFH048).
The study was approved by the Institutional Review Board and Medical Ethics Committee of West China Hospital of Sichuan University (No. 2021/516).

Declaration of Interest:

The authors have no conflicts of interest to disclose.

References:

1. Kralievits KE, Raykar NP, Greenberg SL, Meara JG. The global blood supply: a literature review. Lancet 2015;385 Suppl 2:S28. (PMID: 26313075)

2. Yu X, Wang Z, Shen Y, et al. Population-based projections of blood supply and demand, China, 2017-2036. Bull World Health Organ 2020;98(1), 10-18. (PMID: 31902958)

3. Zhu Y, Xie D, Wang X, Qian K. Challenges and Research in Managing Blood Supply in China. Transfus Med Rev 2017;31(2): 84-8. (PMID: 28073616)

4. Shi L, Wang JX, Stevens L, Ness P, Shan H. Blood safety and availability: continuing challenges in China's blood banking system. Transfusion. (PMID: 23710600)

5. Goodnough LT, Levy JH, Murphy MF. Concepts of blood transfusion in adults. Lancet 2013;381(9880):1845-54. (PMID: 23706801)

6. Abdel-Wahab OI, Healy B, Dzik WH. Effect of fresh-frozen plasma transfusion on prothrombin time and bleeding in patients with mild coagulation abnormalities. Transfusion 2006;46(8):1279-85. (PMID: 16934060)

7. Joint Commission. Proceedings from the National Summit on Overuse. National Summit on Overuse, Oakbrook Terrace, IL, 2012. https://www.parsemus.org/wp-content/uploads/2015/06/AMA-National_Summit_Overuse.pdf

8. Hartley S, Foy R, Walwyn REA, et al. The evaluation of enhanced feedback interventions to reduce unnecessary blood transfusions (AFFINITIE): protocol for two linked cluster randomised factorial controlled trials. Implement Sci 2017;12(1):84. (PMID: 28673310)

9. 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(5):544-57. (PMID: 31305890)

10. Jairath V, Kahan BC, Gray A, et al. Restrictive versus liberal blood transfusion for acute upper gastrointestinal bleeding (TRIGGER): a pragmatic, open-label, cluster randomised feasibility trial. Lancet 2015;386(9989):137-44. (PMID: 25956718)

11. Hofmann A, Farmer S, Towler SC. Strategies to preempt and reduce the use of blood products: an Australian perspective. Curr Opin Anaesthesiol 2012;25(1):66-73. (PMID: 22157195)

12. Murphy MF, Goodnough LT. The scientific basis for patient blood management. Transfus Clin Biol 2015;22(3):90-6. (PMID: 25959997)

13. Goodnough LT, Shander A. Patient blood Anesthesiology 2012; 116(6):1367-76. (PMID: 22487863)

14. Leahy MF, Roberts H, Mukhtar SA, et al. A pragmatic approach to embedding patient blood management in a tertiary hospital. Transfusion 2014;54(4):1133-45. (PMID: 23927725)

15. 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(6):1347-58. (PMID: 28150313)

16. Isbister JP. The three-pillar matrix of patient blood management--an overview. Best Pract Res Clin Anaesthesiol 2013;27(1):69-84. (PMID: 23590917)

17. Oliver JC, Griffin RL, Hannon T, Marques MB. The success of our patient blood management program depended on an institution-wide change in transfusion practices. Transfusion 2014; 54(10 Pt 2):2617-24. (PMID: 24410741)

18. Leahy MF, Trentino KM, May C, Swain SG, Chuah H, Farmer SL. Blood use in patients receiving intensive chemotherapy for acute leukemia or hematopoietic stem cell transplantation: the impact of a health system-wide patient blood management program. Transfusion 2017;57(9):2189-96. (PMID: 28671296)

19. The Lancet. Ageing in China: a ticking bomb. Lancet 2016; 388(10056):2058. (PMID: 27968735)

20. Brown CH 4th, Savage WJ, Masear CG, et al. Odds of transfusion for older adults compared to younger adults undergoing surgery. Anesth Analg 2014;118(6):1168-78. (PMID: 24413550)

21. 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(4):753-65. (PMID: 20003061)

22. Shander A, Hofmann A, Gombotz H, Theusinger OM, Spahn DR. Estimating the cost of blood: past, present, and future directions. Best Pract Res Clin Anaesthesiol 2007;21(2):271-89. (PMID: 17650777)

23. Agrawal S, Davidson N, Walker M, et al. Assessing the total costs of blood delivery to hospital oncology and haematology patients. Curr Med Res Opin 2006;22(10):1903-9. (PMID: 17022848)

24. Thakkar RN, Lee KH, Ness PM, et al. Relative impact of a patient blood management program on utilization of all three major blood components. Transfusion 2016;56(9):2212-20. (PMID: 27383581)

25. Desai N, Schofield N, Richards T. Perioperative Patient Blood Management to Improve Outcomes. Anesth Analg 2018;127(5): 1211-20. (PMID: 29064875)

26. Hayn D, Kreiner K, Ebner H, et al. Development of Multivariable Models to Predict and Benchmark Transfusion in Elective Surgery Supporting Patient Blood Management. Appl Clin Inform 2017;8(2):617-31. (PMID: 28850152)

27. Kinnear N, O'Callaghan M, Hennessey D, et al. Intra-operative cell salvage in urological surgery: a systematic review and meta-analysis of comparative studies. BJU Int 2019;123(2):210-29. (PMID: 29726092)

28. Hemli JM, Patel NC. Robotic Cardiac Surgery. Surg Clin North Am 2020;100(2):219-36. (PMID: 32169177)

29. Bai Y, Tang Y, Deng L, et al. Management of large renal stones: laparoscopic pyelolithotomy versus percutaneous nephrolithotomy. BMC Urol 2017;17(1):75. (PMID: 28859655)

30. Regmi P, Hu HJ, Paudyal P, et al. Is laparoscopic liver resection safe for intrahepatic cholangiocarcinoma? A meta-analysis. Eur J Surg Oncol 2021;47(5):979-89. (PMID: 33339638)

31. GBD 2015 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015 [Erratum in Lancet. 2017 Jan 7;389(10064):e1]. Lancet 2016;388(10053):1545-602. (PMID: 27733282)

32. Luo ZY, Wang D, Meng WK, et al. Oral tranexamic acid is equivalent to topical tranexamic acid without drainage in primary total hip arthroplasty: A double-blind randomized clinical trial. Thromb Res 2018;167:1-5. (PMID: 29738877)

33. Xie J, Hu Q, Huang Q, Chen G, Zhou Z, Pei F. Efficacy and safety of tranexamic acid in geriatric hip fracture with hemiarthroplasty: a retrospective cohort study. BMC Musculoskelet Disord 2019 Jun 28;20(1):304. (PMID: 31248398)